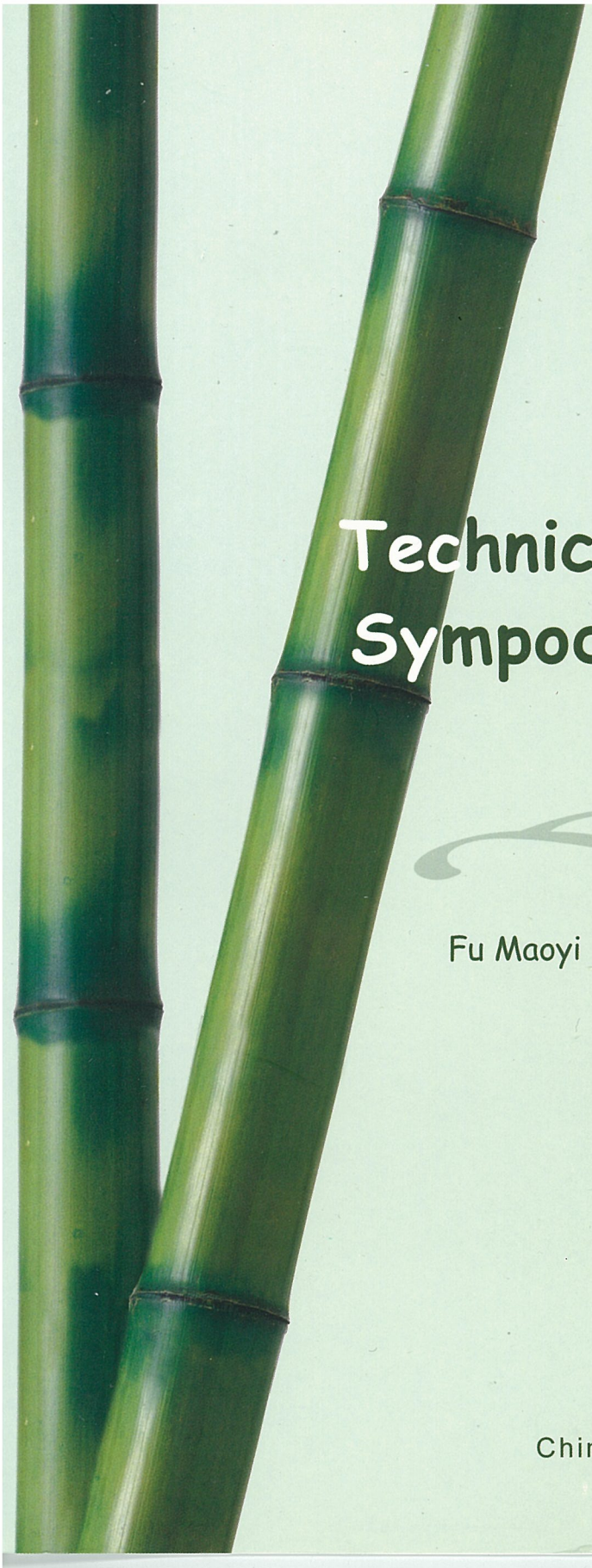

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Technical Manual on Sympodial Bamboos Cultivation

Fu Maoyi Xie Jinzhong Zhou Benzhi
Li Zhengcai Xiao Xiantan

China Forestry Publishing House

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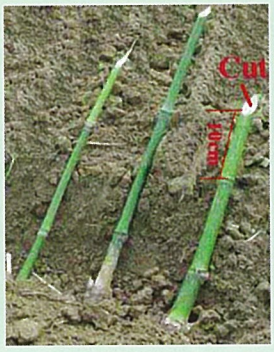

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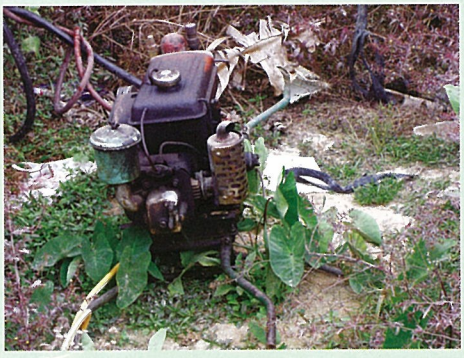

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PREFACE

Bamboo, the important part of forest resource, is characteristic for its fast growth, high productivity, extensive usage, sustainable management and high economic value. With the worsening of global environment and sharp shrinkage of tropical forests, the development of bamboo resources and its processing industry are of increasing significance in reducing wood consumption, protecting natural resource and ecological environment, promoting the sustainable development of rural economy, and helping farmers become rich in poor areas.

China, richest in bamboo resources around the world, is the origin of earth's bamboo plants and one of modern distribution areas. Bamboos are important forest resources in the south of the country, with 39 genera and over 500 species, and more than 7 million ha bamboo stands in total, among which there are over 200 species of sympodial one and more than 1 million ha bamboo stands. As *Phyllostachys heterocycla* var. *pubescens* (Mazel) Ohwi stands account for about 65% of the total forest area and therefore, plays an important role in promoting the bamboo industry in China, importance is attached by the government to the cultivation and research of monopodial bamboos, as is represented by *Phyllostachys pubescens*, in a comparatively thorough study of its managing techniques, extensive utilization and popularization of techniques. However, sympodial bamboos, compared with monopodial bamboos, are still falling behind in such aspects as its bio-ecologic characteristics, propagation and nursery methods, afforestation techniques, the sustainable management techniques, processing, and extension technique.

Though bamboo forest area expands moderately in recent years, its management and utilization has not been greatly improved, and its products with low value addition. Large areas of natural bamboo forests have meanwhile been damaged as low-value bamboo, resulting in worsening soil and water loss in mountainous areas, the deterioration of ecological environment, and the loss of biological diversity.

The manual, sponsored by ITTO, centers around the current situation of bamboo resources in China and the world, biologic basis of sympodial bamboos cultivation, sympodial bamboos nursery techniques, afforestation techniques, effective manage-

ment techniques, pests and control measures, and cultivation techniques of some major economical species of sympodial bamboos. Its purpose is to satisfy the techniques need of the sustainable development in the southern area in China and efficient utilization of sympodial bamboos resources, and eventually, to help promote a sustainable social and economic development of sympodial bamboos areas, and maintain ecological balance and ecologic diversity.

Editors
May, 2007

CONTENTS

CHAPTER 1
Distribution of Bamboo Resources

1.1 Bamboo Resources in China

China is one of the main bamboo producing areas around the world, enjoying the richest bamboo resources on the earth, the largest bamboo forest area, the most output, the longest cultivation history and high-level operation and management. There are 7 million ha of bamboo forest, which occupies about 1/4 of the total bamboo areas in the world and 3.6% of the total forest in China, its rich bamboo resources ranging from sympodial bamboos species that fit well in tropics, monopodial bamboos species that grow in subtropical areas, to amphipodial bamboos species that

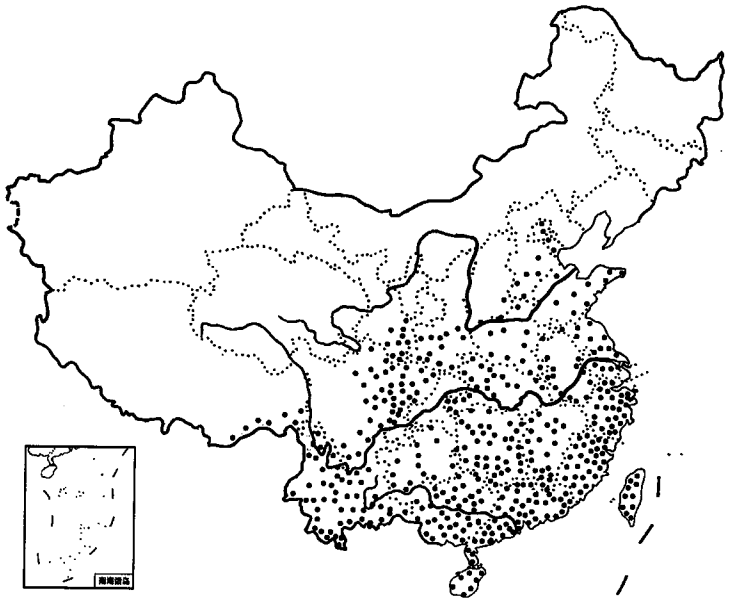

Figure 1.1 Bamboo Plant Distribution in China

grows in areas high in altitude and latitude. According to the statistics, 39 genera of bamboos with over 500 species in China are distributed mainly in Southern and central China. Almost every province has bamboos except Xinjiang, Inner Mongolia, Heilongjiang, and Jilin. Due to differences lying in climate, soil, terrain variation, and ecologic characteristics of bamboos, bamboo distribution has its distinct zones and regions that can be divided roughly into 4 regions:

1.1.1 Bamboo Region between Yellow River and Yangtze River

Such bamboo species as *Phyllostanchys* Sieb. et Zucc. ,*Pleioblastus* Nakai,*Fargesia* Franch. emend. Yi,*Arundinaria* Michaux and *Sasa* Makino et Shibata are distributed in the areas between N 30° and N 40°, with yearly average temperature ranging from 12℃ to 17℃, the average temperature of 2℃ to 4℃ in January, and yearly rainfall from 600mm to 1,200mm.

1.1.2 Bamboo Region between Yangtze River and Nanling Range

The bamboo region, with species of *Phyllostanchys* Sieb. et Zucc. ,*Pleioblastus* Nakai, *Brachystachyum* Keng, *Indosasa* McClure, *Chimonobambusa* Makino and the like, is located between N 25° and N 30°, with the yearly average temperature from 15℃ to 20℃, average temperature from 4℃ to 8℃ in January and yearly rainfall from 1,200mm to 2,000mm. It is the biggest bamboo stands and contains the richest bamboo resources in China, among which *Phyllostachys pubescens* stands reach 2.8 million ha.

1.1.3 Bamboo Region in South China

Located between N 10° and N 20°, with the yearly average temperature from 20℃ to 22℃, average temperature over 8℃ in January, and yearly rainfall from 1,200mm to 2,000mm, the bamboo region has the majority of bamboo species, such as *Acidosasa* C. D. Chu et C. S. Chao, *Bambusa* Retz. Corr. Schreber, *Dendrocalamus* Nees, *Dinochloa* Buse, *Gigantochloa* Kurz ex Monro, *Lingnania* (McClure) Chia et Fung, *Subgen. Sinicae* S. L. Chen et G. Y. Sheng, *Melocanna* Trin. , *Gigantochloa* Kurz ex Munro.

1.1.4 Bamboo Region in High Mountainous Region in Southwest China

The bamboo region lies in the mountainous area at the altitude of 1,000m to 3,000m, with the yearly average temperature from 8℃ to 12℃, average temperature from −6℃ to 0℃ in January, and yearly rainfall more than 800mm to 1,200mm. The region belongs to the virgin bamboo stands where bamboo species like *Chimonobambusa* Makino, *Fargesia* Franch. emend. Yi, *Thamnocalamus* Mu-

nro, *Yushania* Keng f. , and *Neosinocalamus* Keng f. are distributed, and it is also the distribution area of big panda and snub-nosed monkey *Rhinopithecus bieti.*

Bamboos cover a wide range of vertical distribution at the altitude from several meters to several thousand meters, varying with the change of latitude and longitude. They can be found on the Himalayas at the altitude of 3,550m, Qinling mountain range at the altitude of 2,300m, and Xingaoshan mountain at the altitude of 3,000m in Taiwan. *Fargesia spathacea* Franchet, specially produced in China with over 20 species, is distributed mostly in the mountainous areas at elevations of 1,000 – 3,500m in Central China and Southeast China. The vertical distribution of bamboos tends to be at the high altitude in the south but low in the north, and high in the west but low in the east. It also follows the tendency that they are distributed high at the altitude in the mountains but low among hills, high on the heliophilous slope while low on the heliophobous slope. Bamboo species, situated above the altitude of 1,000m, develop into auxiliary species of mountain shrubs and mountain forests, mostly characterized by short culms and low economic value. On the other hand, those with tall culms and craft value generally are distributed along the plains and hills below the altitude of 50 – 1,000m.

Bamboo cultivation has been artificially introduced nation wide for hundreds of years. A massive job of "Transplantation of bamboos from South to North" was carried out especially in 1960's and 1970's, to plant 40 thousand ha of bamboo stands along the Yellow River Basin. Besides, some bamboo species from Southeast Asia and Japan were introduced to further enrich bamboo resources in China.

1.2 Bamboo Resources in the World

Around the world, there are 22.2 million ha bamboo stands with about 150 genera and 1,225 species distributed extensively in tropical, subtropical and Warm Temperate Zone from N 46° to S 47°, the majority of which are between south temperate zone and north temperate zone. Indigenous bamboo species that have remained ever since the fourth Ice Age can be found in other continents except in European continent according to the geographical situation.

Bamboo plants on the earth can be obviously divided into 3 regions for the reason of oceans, namely Asia and Atlantic bamboo region, America bamboo region, and Africa bamboo region. Some scholars name another one, Europe and America introduction region. Different in the long period of separate growth and site condition, indigenous bamboo species with their own characteristic multiply in the regions, but it is difficult to find the identical one in different regions. However, the similar or different bamboo species belonging to two genera, *Bambusa* Retz. Corr. Schreber and *Arundinaria* Michaux, find their distribution in all three bamboo re-

gions. *Bambusa* Retz. Corr. Schreber is distributed in tropical zone and tropical area in South Asia, while *Arundinaria* Michaux in tropical zone in Central Asia, North Asia and warm temperate zone. As for species, only *Bambusa vulgaris* can be found of its extensive distribution in the tropical zone and tropical area in South Asia among all these three bamboo regions. See Figure 1.2.

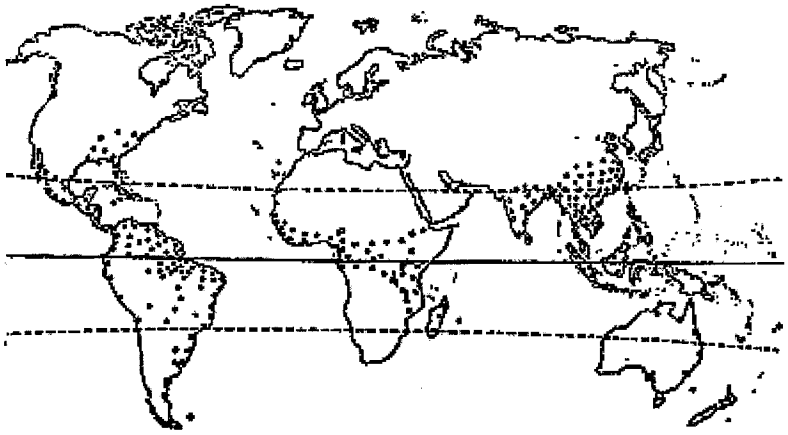

Figure 1.2 Bamboo Plant Distribution in the World

1.2.1 Asia and Pacific Bamboo Region

As the largest bamboo plant distribution area in the world, the region has rich bamboo resources and enormous bamboo forests, with its bamboo species and bamboo forest area accounting for 80% of the total in the world, from New Zealand of S 42° to the middle of Sakhalin Island in latitude, and from the Islands in Pacific in the east to the southeast of India Ocean in the west. In this region, people's basic necessities of life are closely related to bamboos. Ancient local residents made full use of bamboos to make weapons for battle, tools for farming, fishing, pigs and materials in building houses. With the development of production, bamboos were applied more extensively in all lines for the production of agriculture and industry, such as paper-making, construction, transportation, aquiculture, even for food and industrial arts. There are many new techniques of processing and utilization that were created and invented, new products that were developed and exploited in recent centuries. The massive development and utilization of bamboos in return, has profound impact on local culture and history. China is the best example because not only several thousand of Chinese history and culture was recorded on bamboo slips, but also large amount of character, painting, poems, and dancing had a strong relationship with bamboos. The same occurrence was found in Japan and Thailand. No wonder one British scientist once said that if discovery and utilization of corns help

to create Indian's culture and history, undoubtedly discovery and utilization of bamboos help to create the civilization and history of Asian people. The region therefore can be surely called bamboo home town or bamboo cultural area. There are altogether about more than 50 genera and over 900 species of bamboos, with both sympodial bamboos and monopodial bamboos, which account for about 4/5 and 1/5 of total bamboo species in the world respectively. Among these bamboos, about over 100 species have tall and upright culms, excellent in quality, with edible and delicious bamboo shoots and economic value. Main bamboo producing areas include China, India, Burma, Thailand, Cambodia, Bengal, Vietnam, Japan, Indonesia, Malaysia, Philippine, South Korea, Sri Lanka and so on, but bamboo resources are rather barren in the Oceania and island countries in the Pacific in the east of the region.

1.2.1.1 India

In India there are 19 genera of bamboos with 136 species, its bamboo stands reaching about 2.097 million ha. Bamboos there mainly belong to sympodial bamboos, and only some monopodial bamboos are distributed in the mountainous areas in the north, which can fall into 4 types.

Pure stands. More than 125 clump/ ha, with the average output of 2.52t/ha.

Mixed wood-bamboo stands. 50 – 125 clump/ha, with the output of 1.85t/ha.

Sparse bamboo stands. 25 – 50 clump/ha, with the average output of 0.17t/ha.

Scattered bamboo forest. Less than 25 clump/ha, with 5 – 30 bamboos among one clump.

1.2.1.2 Burma

There are over 90 bamboo species under extensive management, with the total bamboo stands of 2.17 million ha. It is estimated that 1.5 million ton bamboo timber can be produced every year.

1.2.1.3 Thailand

13 genera of bamboos with over 50 species are distributed in Thailand, its bamboo stands reaching around 0.51 million ha. The yearly yield of bamboo culms is 52 million averagely (with the exception of bamboos used in rural areas). There are two bamboo veneer factories in the provinces of Kanchanaburiug and Lampoon in Thailand, producing 20 thousand sheet every year. In 1936 Kanchanaburiug Papermaking Factory was established and in Prachinburi Province, there are 22 bamboo shoots processing factories. The total output of bamboo shoots arrived at 37,975t in 1984.

1.2.1.4 Bengal

About more than 30 species of bamboos with over 0.5 million ha bamboo stands are distributed in the country, among which there are 0.1 million ha of pure bamboo stands, 0.1 million ha of piecemeal bamboo stands, and mixed wood-bamboo stands 0.4 million ha. The main bamboo species include *Melocanna baccifera* (Roxb.) Kurz, *Bambusa tulda* Roxb, *Bambusa vulgaris* Schrader ex Wendl., *Bambusa arundinacea* Retz., *Gigantochloa macrosyachya* Kurz, *Teinostachyun* Munro, etc. There are two bamboo paper-making factories in the country.

1.2.1.5 Cambodia

There are 0.287 million ha of bamboo stands in Cambodia under the extensive management. Bamboos there are mainly used for rural buildings, dead stocks and handcraft products.

1.2.1.6 Vietnam

In Vietnam the total of bamboo stands reaches 1 million ha, accounting for 3.6% to 4% of the forestlands in the country. Bamboo timber is used for rural buildings, dead stocks and handcraft products.

1.2.1.7 Japan

About 13 genera of bamboos with 230 species are distributed in Japan (it was once reported to be 662 species). The total bamboo stands is 141.3 thousand ha, 97% of which is privately owned with the intensive management. The yearly yield of bamboo timber reaches 0.2 – 0.3 million ton, and bamboo shoots 0.15 million ton all over the country.

Bamboo stands managed in Japan, are aimed at transforming from "timber-oriented bamboo stands" to "bamboo-shoots-oriented bamboo stands" in the 1950s in 20th century, and from "bamboo-shoots-oriented bamboo stands" to "tourism-oriented bamboo stands" in the 1970s.

Ever since 1950s, bamboo forest area in Japan has been increasingly diminished, accompanied by the gradual reduction of the output of bamboo timbers. However, the tradition of loving bamboo and its products hasn't change a bit, hence Japan has to import large number of bamboo timbers and bamboo products from foreign countries every year.

1.2.1.8 Malaysia

There are 20,650 ha bamboo stands distributed on Malaysia Peninsula, with the annual output of 21,000 ton bamboo timbers . Bamboo is mainly used for rural buildings and dead stocks.

1.2.1.9 Philippine

Bamboo stands in Philippine reaches 7,924 ha according to a report by its Forestry Bureau in 1979. If together with the area of natural mixed bamboo stands, the actual bamboo stands arrive at 0.15 million ha, with 11 genera of 55 species of bamboos. Bamboos are applied in rural construction and handcraft products, some of them being exported every year.

1.2.2 America Bamboo Region

The region has 18 genera of bamboos with over 270 species, situated between S 47° in the south of Argentina to N 40° in the east of the United States. Of all the bamboo plants in America, only *Arundinaria* Michaux belongs to monopodial bamboos, and the other 17 genera of bamboos belong to sympodial one. There are no indigenous bamboo species except *Pseudosasa amabilis* (McClure) Keng f. and two of its subspecies in North America. In Latin America, the center of bamboo distribution is situated in Mexico, Guatemala, Costa Rica, Nicaragua, Honduras, Colombia, Venezuela, and Amazon area in Brazil between South Temperate Zone and North Temperate Zone, with abundant bamboo species decreasing gradually in numbers from north toward south until it reaches Argentina. Bamboos are mainly distributed in the east of South America and North America. The vertical distribution of bamboos ranges from some meters to 3,000 m in altitude (Chile). A large number of bamboo species have been introduced from Asia to South America and North America since 20th century.

According to the investigation conducted between 1985-1986 in Brazil, there are following main bamboo plants: 17 species of *Arundimaria* genera, 16 species of *Merotstachys* genera, 17 species of *Guadua* genera, 22 species of *Chusqua* genera, and 70 species of *Bambusa* genera. It is estimated that bamboo forest area occupies about 3%, roughly 1.02 million ha, of 340 million ha of forests along the Amazon area.

1.2.3 Africa Bamboo Region

Bamboos are distributed in small scale in that region, ranging from south of Mozambique in S 22° to east of Sudan in N 16°. An oblique and long zone of tropical rain forest and evergreen and deciduous mixed forest is formed from northwest to southeast across Africa, including the south of Senegal along west coast of Africa, Guinea, Liberia, the south of Ivory Coast, the south of Ghana, Nigeria, Cameroon, Rwanda, Burundi, Gabon, Congo, Zaire, Uganda, Kenya, Tanzania, Malawi, Mozambique, and Madras along the east coast, which constitute the center of bamboo distribution in Africa. There situates large bits of bamboo stands in the val-

ley along upper reaches of the Nile in Sudan in the north of Africa and temperate forest stand in the mountainous areas in Ethiopia. Africa continent, however, is in serious shortage of bamboo species, with only *Oxytenanthera abyssinica*, *Arundinama alpina* and several others as the indigenous bamboos species as is shown in the record. Together with the introduced ones there are only more than ten species, belonging respectively to *Bambusa simony* Carr., *Oxytenanthera* Munro, *Arundinaria* Michaux, which form large areas of natural pure bamboo stands, or become the under-layer of mixed stands accompanying other tree species. For example, there are 0.13 million ha of *Pseudosasa amabilis* (McClure) Keng f. in the mountainous area in Kenya, and 0.1 million ha of *Gigantochloa felix*(Keng) Keng f. in Ethiopia. Nevertheless, in Madagascar in East Africa, bamboo species are more abundant than those on the continent due to sufficient rainfall and warm climate.

1.2.4 Europe and North America Introduced Region

Bamboos are mostly distributed in some countries in Asia, Africa and Latin America around the world. There are no native bamboo species distributed in Europe, and only some indigenous bamboos are found in North America. Though none of local bamboos grow in European continent, more than 10 bamboo genera with over 100 species ranging in size from the *Phyllostachys heterocycla* var. *pubescens*(Mazel) Ohwi as the biggest one to *Sasa longiligulata* McClure as the smallest were introduced from Asia, Africa and Latin America to Italy, Germany, France, Holland, Britain to be exploited mainly in garden virescence, mainly because of personal likes of local residents and importance attached to beautify and protect environment. Bamboo species such as cold-resistant *Phyllostachys* Sieb. et Zucc., *Pleioblastus* Nakai, *Sasa* Makino et Shibata introduced from China and Japan are the predominant ones. In addition, Europe and West Europe in particular, introduced large amount of all sorts of bamboo seedings, bamboo products and bamboo shoot cans every year from China, Thailand and other countries, the quantity reaching several million pieces (sets) and several 100 thousand tons. Take China as an example, there are 35 bamboo species of *Phyllostachys* Sieb. et Zucc. introduced by the United States from China alone.

At present, the vast majority of bamboo stands around the world are still in desolation with severe denudation, suffering from low-level management and low output. Since 1980s, some tropical and subtropical countries attach importance to developing bamboo industry, among which China and Japan are the best examples of their long history of bamboo development and high-level management.

CHAPTER 2

Biological Basis in Sympodial Bamboos Cultivation

2.1 Characteristics and Functions

2.1.1 Nutritious Components

2.1.1.1 Stem and root

Bamboo stems consist of two parts, underground stem and above-ground stem. According to the definition in botany, underground stem is the main stem of "bamboo tree", while above-ground stem turns to be its branch.

Underground stem

Underground stem usually falls into three categories based on features of cleavage propagation and its characteristics (see Figure 2.1):

Monopodial type. The lathy underground stem grows horizontally under the ground, and is therefore called bamboo rhizome, on each node of which there is one bud arraying in turns. Some buds turn into new bamboo rhizomes, extending successively and rambling in soil. The genera with such features usually includes *Phyl-*

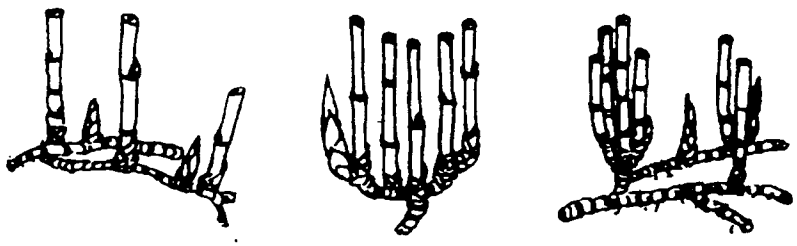

Figure 2.1 Three Types of Bamboo Rhizomes

lostachys Sieb. et Zucc. , *Acidosasa* C. D. Chu et C. S. Chao, *Brachystachyum* Keng, Ferrocalamus Hsueh et Keng f. , *Indosasa* McClure, *Metasasa* W. T. Lin, *Semiarundinaria* Makino and so on.

Sympodial type. Its underground stem is generally large, thick and short, with dense nodes and many rhizomes, namely the basal part of bamboo culms. Buds bearing on the underground stem grow out of soil, shoot and then develop into bamboo culms. New bamboo culms usually stay close to old bamboo culms, so bamboo culms are densely distributed in clumps. They are therefore named sympodial bamboos. Bamboo genera with such features includes *Bambusa* Retz. Corr. Schreber, *Ampelocalamus* S. L. Chen *et al.* , *Chimonocalamus* Hsueh et Yi, *Dendrocalamus* Nees, *Dendrocalamopsis* (Chia et H. L. Fung) Keng f. , *Gigantochloa* Kurz ex Munro, *Thyrsostachys* Gamble, *Neosinocalamus* Keng f. , etc. *Yushania* Keng f. , *Fargesia* Franch. emend. Yi Melocanna Trin, *Pseudostachyum* Munro and the like that belong to the sympodial type tend to grow horizontally under the ground for some distance before buds grow out of soil. As it displays the shape of bamboo rhizome, it is called as fake rhizome. But there is no bud on the nodes of its fake rhizome, its culm taking on the shape of monopodial type, so these 5 bamboo genera get the name of sympodial-monopodial bamboo.

Amphipodial type. Its underground stem possesses features of both of the above two types. In other words, it has bamboo rhizome that grows horizontally in long distance under the ground, and shoots from the old rhizome to grow into a new one. Meanwhile it has culms that sprout from culm base to give rise to bamboo shoots and develop into bamboos to form clumps. Mixed bamboo is thus named as bamboo stands grows in the way of monopodial type with several bamboos being opposite in clumps. *Pseudosasa* Makino ex Nakai, *Bashania* Keng f. et Yi, *Shibataea* Makino ex Nakai, *Indocalamus* Nakai, *Sasa* Makino et Shibata and the like belong to the genera characterized by underground stem of this type.

above-ground stem (bamboo culm)

Bamboo culm, the most important ingredient of bamboo plants, can be divided from top to bottom into three parts, stem, culm base, and culm stipe (see Figure 2.2).

The stem tends to be the longest part of culm. If the part below stem is under the ground or quite close to surface of soil, it is called culm base, which is composed of more than 10 nodes with buds or latent buds on each node on culm base. Just below

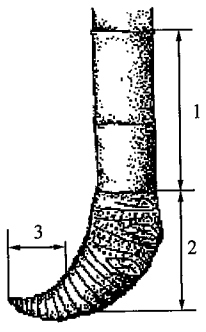

Figure 2.2 Composition of Bamboo Culms
1. real culm 2. culm base 3. culm stipe

culm base, the tortuous part closely jointing bamboo rhizome or mother culm has the name of culm stipe, which also has more than 10 nodes and internodes, but quite often there is no buds or latent buds on its nodes. The internodes are shortened to an extreme degree and its thickness vary greatly from top to bottom, so it is locally called as screws.

Bamboo culm consists of many internodes and nodes. The parts situated between two nodes are internodes, which are not the same in length, with the longest one usually in the middle, and the shortest one situated on culm stipes. Each node is composed of two annulus, the upper part of which is called culm annulus, while the lower part has the name of sheath annulus. The part between two annulus is called the inner node. Nodes of culm base give rise to growth of roots, which function to support bamboo culms and absorb water and nutrients that are kept in soil, so it gets the name of bamboo root, as is distinguished from rhizome root attached to the underground stems.

2.1.1.2 Branch

Branch, an organ attached to leaf blade, is developed from buds growing on bamboo stems. Bamboo culms can be seen as the direct branch or first level branch, while bamboo branch is regarded as the second level branch or the upper level. Bamboo branches also consist of the hollow internodes and nodes, where there are branch annulus similar to culm annulus. Some nodes at the basal part of culm tend to bulge, with their internodes shortened, to constitute branch handles and are likely to bear adventitious root as well. Accordingly, it can replace bamboo culms in cultivation for nursery and afforestation. Since different bamboo species unusually have fixed branch types, it becomes one of the important proof in bamboo identification and classification. Generally it falls into four types (see Figure 2.3).

Single branch

Ferrocalamus Hsueh et Keng f. and *Indocalamus* Nakai belong to this type, charac-

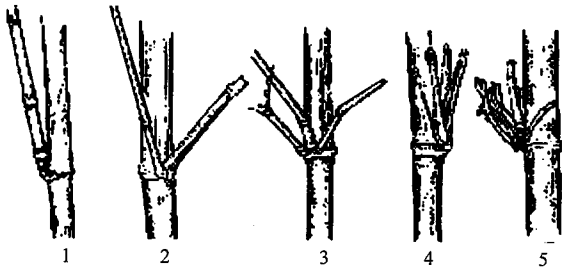

Figure 2.3 Branch Types of Bamboo Plants
1. single branch 2. double branch 3-4. triple branch 5. multibranch

terized by one branch springing from each node, sometimes the upper node having three or more than three branches.

Double branches

Phyllostachys Sieb. et Zucc. and *Metasasa* W. T. Lin are of this type, each node having two branches, thick and thin respectively. *Phyllostachys heterocycla* var. *pubescens*(Mazel) Ohwi is the typical one.

Triple branches

Qiongzhuea Hsueh et Yi, *Chimonocalamus* Hsueh et Yi, *Indosasa* McClure and *Sinobambusa* Makino ex Nakai are of this type. Each node of the type has three branches with similar thickness and thinness. Nodes up above the bamboo culms can be divided into 5 – 7 branches.

Multibranches

This type includes the majority of sympodial bamboo species, each node of which bears several branches, so it can be further divided into three subtypes on the grounds of development of main branches:

With no main branch. *Neosinocalamus* Keng f. is such an example. Its main branch doesn't develop and the lateral branches are relatively thin, so there is no obvious differentiation in between.

One main branch. Of the type, *Dendrocalamus giganteus* Munro and *Dendrocalamus latiflorus* Munro usually have moderately-developed main branches, on the other hand the main braches of *Melocalamus* Benth develop fully, which may replace bamboo culms sometimes.

Triple main branches. Take *Dendrocalamus membranaceus* Munroand some *Bambusa* Retz. Corr. Schreber for example, in addition to most of the thin sides they may as well form well-developed triple main branches.

2.1.1.3 Bamboo leaf and bamboo sheath

There are two kinds of leaf organs for bamboo plants, culm-born leaf and nutritious leaf that bears on branches. Leaves are usually situated on each node of branches, arraying in 2 rows in turns. Each leaf consists of leaf blade that has stripes, and leaf sheath which bears on the nodes of small branches covered by internodes and is often longer than internodes of small branches. There is a joint between leaf blade and leaf sheath where leaf blade falls off when it gets withered.

Culm-born leaf bearing on culms has such other names as bamboo sheath, culm sheath and shoot sheath, which is of important value in bamboo classification and functions to protect growth of bamboo nodes. When internodes stop growing,

bamboo sheath tend to form absciss layer and falls off, but some species are tardily deciduous or persistent.

Bamboo sheath consists of sheath, auricle, ligule, foliage leaf and so on (see Figure 2.4).

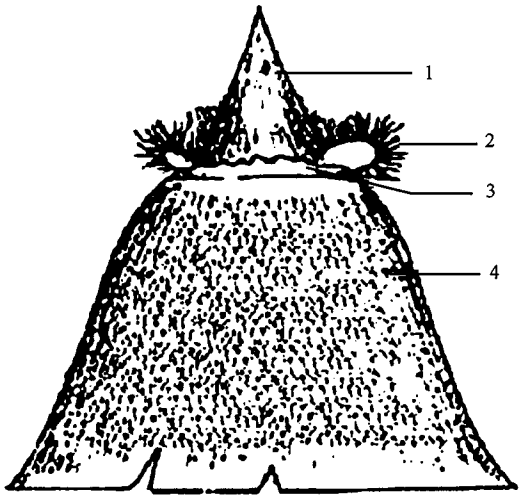

Figure 2.4 Composition of Bamboo Sheath
1. foliage leaf 2. auricle 3. ligule 4. sheath

Sheath

Covered completely by internodes of culms, the basal part of sheath is situated on sheath annulus, with its edges in separation. But there is the exception such as some species of *Chusquea* genus, some distance upward above the basal part of its outside edge closing up with the back side of the sheath. The features of sheath varies with different species, the quality of which displays thick-leathery, leathery, thick-chartaceous and chartaceous. When culm grows, some sheaths are early deciduous, some are tardily deciduous or persistent.

Auricle

Auricle usually bears on two sides of sheath apex, extending from the basal part of foliage leaf to be in connection with it as for some species. Species with auricle has considerably stable characteristics in development, shape, color of the auricle, and whether it has edge hair and grows well.

Ligule

The great majority of sheaths has ligules, but some species has no ligules or with absence or degeneration of ligules on the sheath of culm base. The color, height, width, the apex shape of ligules and whether it is covered with hair and powder changes in variation with bamboo species.

Foliage leaf

It is situated on the apex of sheath, often having no stipes, persistent or breaking off, whereas the one of *Brachystachyum densiflorum* (Rendle) Keng genus usually has stipes, even being evaginated.

2.1.2 Reproductive Organ

2.1.2.1 Flower

Flowers of bamboo plants share almost the same structure with that of the common grass family. The basic unit of bamboo flowers is called small spike. Based on observation of *Phyllostachys heterocycla* var. *pubescens* (Mazel) Ohwi flower, its small spikes are usually 25 – 27mm in length with 2 – 3 small flowers, among which apex flower is not sterile and degenerates to be acicula like instead. The internodes of rachilla is quite short, about 2mm long. Each flower has a lemma and palea respectively, equivalent to bract and small bract. The flower consists of stamen, pistil and squama which is much like perianth, usually 3 in number. There are quite often 3 or 6 stamens or just in between (such as *Pseudosasa japonica* Sieb. et Zucc. Makino, *Sasaella* genus). What contains the most in number is Oshlanda, usually 30, and 120 at most, with 3 stamens as a round in general. Each flower, under the normal circumstance, has one ovary, but some times 2 of them can be found in an abnormal flower, with one ovule included in one locule(see Figure 2.5).

2.1.2.2 Fruit and seed

Caryopsis, generally fruit of bamboo plants such as *Phyllostachys* Sieb. et and Zucc., *Dendrocalamus* Nees, has the characteristics of dryness with its part dehisced. Its pericarp is tight and small in size, and is attached to seed capsule, so it is often regarded as seed(see Figure 2.6). One ovule lies at the base of caryopsis, just the opposite to lemma. On the converse side of the ovule, there are marks with the suggestion of trough-like hila. Berry is another sort of fruit, with *Ferrocalamus strictus* Hsueh et Keng f. and *Melocanna baccifera* (Roxb.) Kurz as its example.

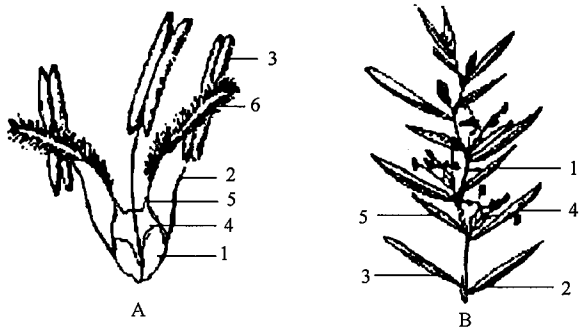

Figure 2.5 Structure of Small Flowers and Small Spikes of Bamboo Plants
(taken from the Atlas of Major Plants in China-grass family)
A. structure of small flowers: 1. lodicule 2. filament 3. anther 4. ovary 5. style 6. stigma
B. structure of small spikes: 1. rachilla 2. lower glume 3. upper glume 4. lemma 5. palea

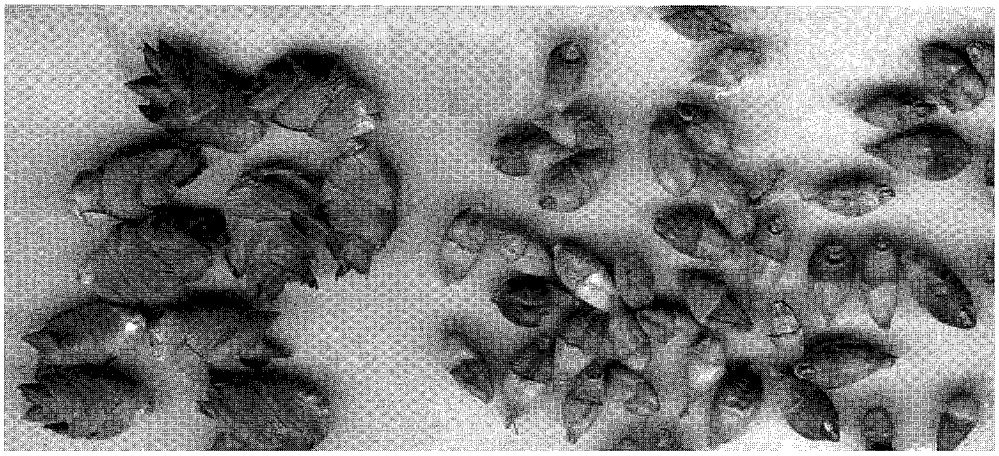

Figure 2.6 Seeds of Sympodial Bamboos

There are still another fruit of bamboo plants that looks like nuts, its pericarp relatively thick to be more than 1mm. The pericarp and seed can be completely detached. *Cephalostachyum fuchsianum* Gambleand is of such example.

2.2 Growth Characteristics

Since underground stem of sympodial bamboos is of the sympodial type, it has no bamboo rhizomes extending horizontally under the ground, but rather bamboo handles (ie. culm base and culm stipe) as the underground stem, with its internodes shortened like a pipe. It has neither root nor rhizome, and its culm stipe is small, thin, with no root but connects mother bamboo and its offspring, therefore wins the local name of "longan and chicken head". Culm stipe of smypodial bamboos is often quite long with many nodes, for example, the one of *Melocanna baccifera* (Roxb.) Kurz reaches about 1m in length, much like rhizome of monopodial bamboo. While its culm base looks thick and shortened, on which bud sprouts and root develops. On both sides of the culm base, there are several large-sized buds growing alternately, with the possibility of developing into bamboo shoots and bamboos. The underground system of sympodial bamboos is thus composed of many bamboo handles, interrelated by substance energy coming from culm base, culm stipe and bamboo root. Its fully-developed fibres root are mainly distributed 40 – 60cm in depth under soil, but no fibre can be found 120cm under the ground.

Large-sized bud, bearing on each node of the base part of culm, usually arranges alternately in two lines, much like a face- to- face distribution. The lowest pair of bud-eyes are named as the first eyes, then the second eyes, the third eyes, and so on in succession, numbers of which vary with bamboo species. For instance, *Den-*

drocalamus latiflorus Munro, *Neosinocalamus affinis* (Rendle) Keng f. and the like have 5 – 10 bud-eyes, while there are only 2 – 6 for *Bambusa multiplex* (Lour.) Raeuschel ex Schult. f. and other small-sized sympodial bamboos (Figure 2.7). Bamboo shoot, sprouted from bamboo shoot of each eye, is called in succession as first-eye-shoot, second-eye-shoot and so on. The size of bud-eye and its burgeoning power have a connection with the parts where they are situated. Bud-eye which is distributed at the middle and lower part of culm base is plump, vigorous, and burgeons earlier with more buds, characterized by the big size of shoot and high quality of grown bamboo. Conversely, those situated at the upper part, above the ground in particular, is relatively small, with less vigor, later sprouting time, and less buds.

Figure 2.7 Bamboo Handle and Its Shoot Buds Distribution

Growth rule of sympodial bamboos is similar to that of monopodial bamboo, which falls into four phases, namely initial phase, ascending phase, blooming phase and ending phase. Generally shoot buds differentiate in March and April, burgeons in early and mid May, while in late May, bamboo shoot sprouts through soil, and lasts for about 15 days in the initial stage with a moderate stocking percentage. Mid July are its blooming phase which last about 30 – 45 days and it comes to its ending phase in September (see Figure 2.8).

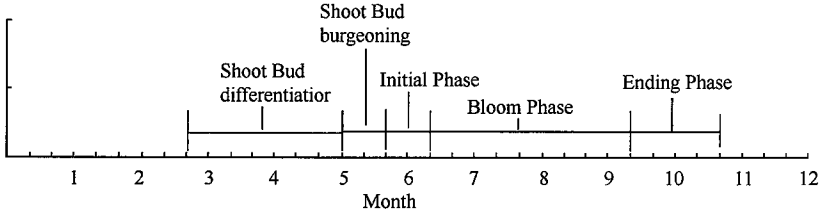

Figure 2.8 Growth Rules of Shoot Buds of Sympodial Bamboos

2.3 Growth and Environment

Growth of bamboos is significantly affected by such environmental factors as rainfall, humidity, temperature, and sunshine time, particularly the rainfall, just as the saying goes in China, "being like bamboo shoots after a spring rain". During growing period of bamboo culms, the young culm is in great need of large amount of moisture, the scarcity of which or a drought may slow down or even lead to stop of the growth of young culms.

Climate factors such as temperature, rainfall, humidity and blast volume have strong impact on growth of young bamboos. Besides, canopy density of bamboo stands, vegetation, soil, topographty, laborwork and the like play a leading role or complementary role.

CHAPTER 3

Nursery Techniques of Sympodial Bamboos

Transplanting of mother culms is a traditional way of sympodial bamboos afforestation, which is often adopted for the establishment of small-area bamboo stands. It has been met with such problems as insufficient mother culms in number, low surviving rate, and high costs and thus restricted large scale of stand establishment. Therefore, sorts of nursery techniques have been developed from 1960s, such as main branch nursery, sub-branch nursery, and nursery with buried culms for extensive use in production, and promote rapid enlargement of sympodial bamboos stands in China. After 1990s, tissue culture techniques of bamboos have been rapidly developed and applied in China, India, and Southeast Asian countries.

3.1 Nursery Site Preparation

Bamboo nursery site is favorably established on a site, which is quite close to waterhead; easy for irrigating; with convenient transportation; less than 5 degrees in slope; and fertile with loam or sandy loam soils.

For intensive soil preparation, it is recommended to plough whole site up to 20cm in depth, harrow soil into particles less than 5mm in diameter, and finally, if any, remove grasses, roots of trees, stones, etc. Seeding beds, apart from mother culms, are

Figure 3.1 Preparation of Seeding Beds

usually used for nursery. Seeding beds can be made 70 – 100cm in width and 20 – 30cm in height (see Figure 3.1). There is a drill between two seeding beds, about 20cm both in width and depth. Burned ground litter is applied in site preparation as the base fertilizer about 2,000 – 4,000kg/mu(1mu = 1/15ha) and mixed completely with the soil.

3.2 Nursery Season

Sympodial bamboos usually start to sprout new leaves from early February in most regions of China, so seedling raising can be operated from mid Feb. to late March, but mostly favored in early and mid March. It is not recommended to raise seedlings later than early April.

3.3 Nursery Techniques

3.3.1 Raising with Seeds

3.3.1.1 Preparation before seeding

Seeding can be achieved with nutritional container nursery. The basic elements, turves, perlite, and vermiculite are mixed together in the proportion of 5:1:1, sifted, put into the container with 10cm in diameter, and then watered (or a certain bactericide, Chlorthalonil 600 times solution can be used as the substitute).

3.3.1.2 Seeding

Seeds (see Figure 3.2) are sown in prepared nutritional container, followed by covering the seed with soil just up to about 1cm in depth, and watering to keep moist.

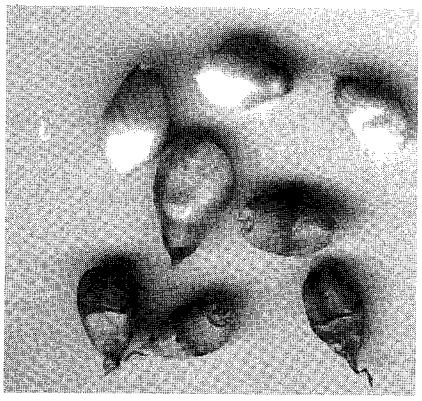

Figure 3.2 Seeds of *Dendrocalamus latiflorus* Munro

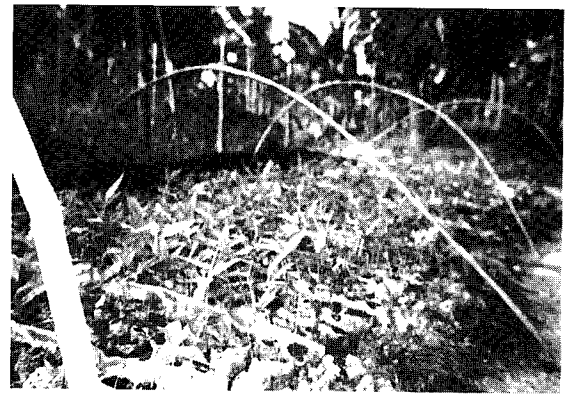

Figure 3.3 Nursery of *Dendrocalamus latiflorus* Munro with Nutritional Bowl

Seeds of *Dendrocalamus latiflorus* Munro start to sprout 5 days shortly after the planting, and finish with sprouting one and a half month later (see Figure 3.3). With removal of nutritional bowl three months after seedling, seedlings can be transplanted with soil to prepared nursery beds, and finally to the field for experiment nine months later (see Figure 3.4).

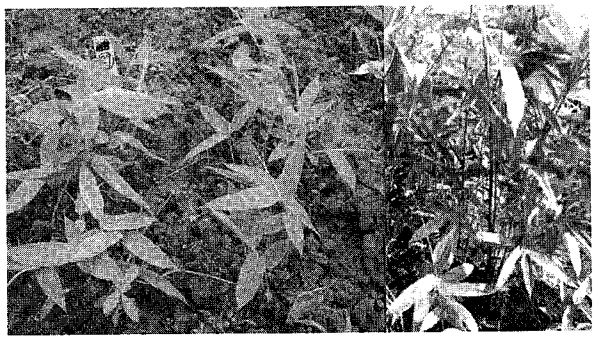

Figure 3.4 Seedlings of *Dendrocalamus latiflorus*

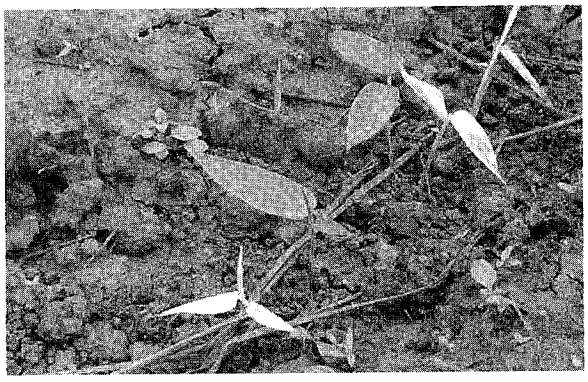

Figure 3.5 Seedlings and Albino Seedlings of *Dendrocalamus latiflorus*

Burgeoning rate of seeds that come from artificial supplementary pollination would reach 58%, the occurrence of albino seedlings accounting for 6% – 10% (see Figure 3.5), whereas albino seedling ratio of *Dendrocalamus strictus* (Roxb.) Nees with natural pollination is up to 33%. So it is evident that artificial supplementary pollination can improve markedly the quality of seeds. Seeds when after harvesting, should be sown for nursery or be used as samples as soon as possible, otherwise, the burgeoning rate of fresh *Dendrocalamus latiflorus* Munro seeds will be at a severe loss if preserved under 4℃ over one year.

3.3.1.3 Management after seeding

After seeding, seeds sprout well with proper temperature, humidity, and sunshine time; conversely, seeds are prone to decay if on inappropriate condition. The most favorable temperature is between 20℃ and 25℃. After sprouting, seeds should be watered to keep basic element moist and shaded when weather turns hot. When in the period of young seedling, they should be sprayed with 50ppm nitrogenous fertilizer and proper bactericide to be kept from pests.

3.3.2 Raising with Branch Cutting

Here branch cutting means main branch cutting, sub-branch cutting, and the technique to promote sub-branch burgeoning.

3.3.2.1 Raising with main branch and sub-branch cutting

Similar to culms in structure(see Figure 3.6), main branch and sub-branch of sympodial bamboos comprises 3 parts, i.e. branch body, branch base and branch handle. Shoot buds and root tips on the basal part of culms and branches respectively make possibility of propagation, as is fully exploited by the technique of raising with branch cutting.

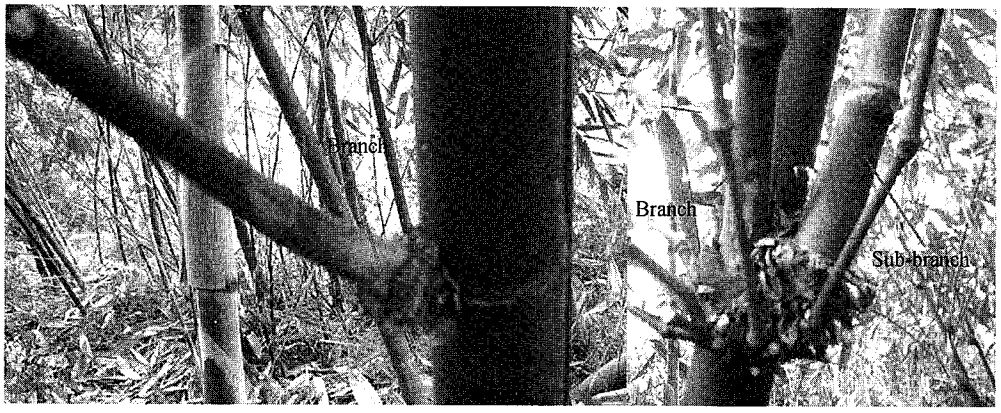

Figure 3.6 Main Branch and Sub-branch of *Dendrocalamus latiflorus* Munro

Raising stocks through both branch and cutting propagation is mostly suitable for relatively large-sized sympodial bamboos with dominant branches, such as *Dendrocalamus*, *Neosinocalamus*, and *Bambusa* spp. Main and sub-branches are used in most cases and more than 90% of them can produce new stocks.

Bed preparation. For intensive soil preparation, it is recommended to plough whole site up to 30cm in depth, and remove grasses, roots of trees and stones. Seeding beds can be made 70 – 100cm in width and 20 – 30cm in height. There is a drill between two seeding beds, about 20cm both in width and depth (see Figure 3.1). Burned ground litter is applied in site preparation as the base fertilizer about 30 – 60t/ha and mixed completely with the soil.

Main branch or sub-branch of 1 – 2 years old collected from 3-year-old mother culm is usually used for propagating (see Figure 3.7). Branch cutting, about 40 – 50cm long, is made removing the top part and leaving 2 or 3 basal nodes of the selected branch. The oblique cutting edge of the top part is in the same direction as branch base curves, keeping about 10cm in distance between the cutting edge and its node scar (see Figure 3.8). The branch is placed obliquely (30° – 45°) in seedling drill with 25 – 30cm in depth on the seeding bed, keeping its first node bud below the cutting edge up to 5 – 6cm above soil surface after soil covering (see Figure 3.9).

Figure 3.7 Branch Taking

Figure 3.8 Treatment of Branches for Propagation

The oblique cutting edge of the top part is kept upward to be available for rainwater, and thus branches will not easily get sear as a way of improving survival rate of branch cutting. Finally, the procedure ends with thatch covering above the drill and watering.

Sub-branches of sympodial bamboos are limited in quantity, because only bamboo culms of 2 – 3 years old produce sub-branches, whereas 1-year-old new bamboos generally don't produce sub-branches, unless with the occurrence of broken tip and broken branch. Accordingly, if sub-branch cutting is to be used in a large scale for propagation, labor work is likely to be used to promote sub-branch burgeoning to improve the burgeoning index of sub-branches. The exact measures

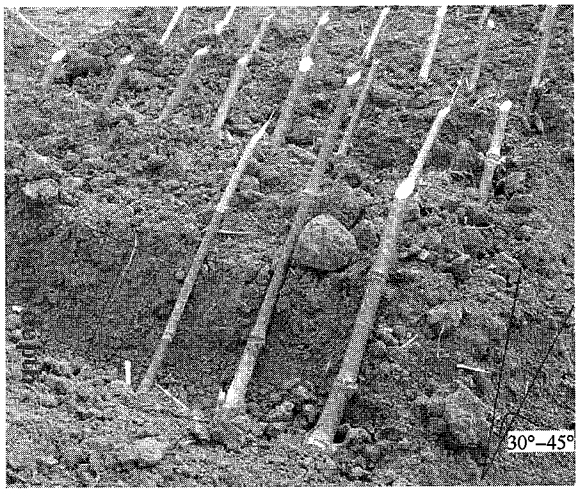

Figure 3.9 Raising with Branch Cutting

are just as follows:

In Spring when bamboos start to sprout, select 2-year-old strong culm that grows along the edge of clumps, cut bamboo tips with lopper or hook knife, cut the remaining main branch, unearth soil on two sides of bamboo handles, lacerate bud eyes of the culm with knife, and finally cover with soil.

Between February and April, newly grown bamboos that sprouted shoots the previous year are selected. The selected bamboo is dug with its handle remained, then the top part of it is cut off to keep 7 – 9 nodes of mother culm. Bud eyes on both sides of culm base are lacerated with knife. Plant the bamboo on the prepared bed with 1m × 1m in spacing. From mid April, MS nutrient solution containing appropriate concentration of mixed hormone (BA + NAA) that is determined by bamboo species is sprayed with dose of 1L/culm 5 times, such as *Dendrocalamopsis oldhami* (Munro) Keng f. with the concentration of mixed hormone of 2mgBA + 1mgNAA/L, *Bambusa multiplex* (Lour.) Raeuschel ex Schult. f. of 5 mgBA + 1mgNAA/L, *Bambusa textilis* McClure of 10mgBA + 1mgNAA/L. In order to ensure a sustainable management of sub-branch nursery garden, 2 – 3 bud eyes of mother culm base are reserved for propagation and regeneration, and 2 new and strong mother culms at proper site are reserved during shooting period (better in mid or later period) every year. In early spring the following year the top part of these new mother bamboos is cut off, only keeping 7 nodes of mother bamboo in height. And the unwanted old mother bamboos are cut off as well, to keep a balanced ratio of 1-year-old bamboo and 2-year-old bamboo 2:1 within clumps.

Propagation with branch cuttings has several advantages. There will be no or much less injury to the mother culm. Branch cuttings, much smaller than mother culm in size, are easier for storage and transportation, thus reducing costs. Moreover, if managed properly, it can be expected to have high-quality stockings with well-developed root system and naturally improve survival rate after afforestation.

3.3.2.2 Raising with branch wrapping

This technique is undertaken by wrapping soil with 3cm in thickness around the basal part of branches of sympodial bamboos, binding it up with nylon membrane and then sealing after a thorough watering. The adventitious root of the basal part of branches is used to develop root system(see Figure 3.10).

1-year-old branches are the best choice for branch wrapping, soil wrapping and binding of which are usually done around July and August. In the following February to March, the well-developed root system of branches will be cut off to be applied directly in afforestation as stockings.

The great advantage of the technique it brings is it can shorten nursery time, but it also has the disadvantage of wasting labor and time, and bringing more injury

Figure 3.10 Raising with Branch Wrapping of *Dendrocalamus hamiltonii* Nees et Arn. ex Munro

to mother culms when getting stockings.

3.3.3 Raising with Buried Culms

3.3.3.1 Raising with single-node buried culms

Culm cuttings can be taken from one or two-year-old mother culm with one node. The top part and lateral branches of a selected mother culm should be cut off. The main branch with strong base can also be used as mother culm. Mother culm about 4cm in diameter usually offers about 10 single nodes for nursery, and larger culm over 6cm in diameter may provide 15 – 20 single nodes. After transported to nursery site, a single-node cutting should be made carefully, without any injury to shoot buds on culm nodes. The cutting is placed horizontally in a prepared drill, kept at a position with shoot bud being upwards (see Figure 3.11), covered with soil at a depth of 6 – 9cm (see Figure 3.12 and Figure 3.13), and watered before covering with dry grasses above the drill to keep soil moist (see Figure 3.14).

Propagation of thin-walled bamboos by culm cuttings is usually less successful and meets with problems of easily broken cuttings, so it is difficult to be used in large scale of propagation. However, it is suitable for thick-walled species such as *Dendrocalamus latiflorus* Munro and *Dendrocalamopsis grandis.*

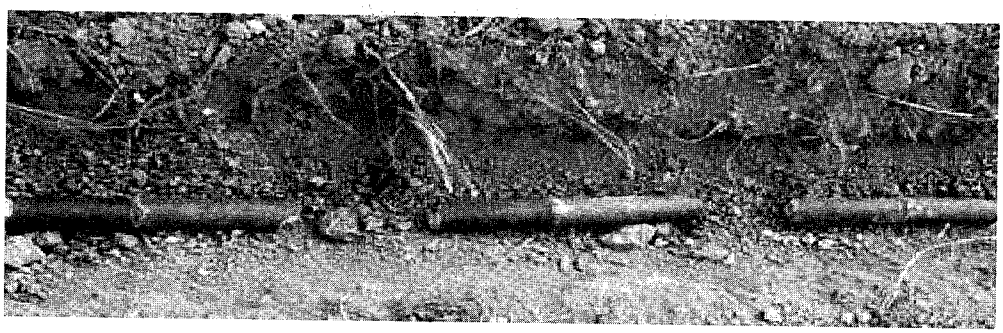

Figure 3.11 Raising with Single-node Buried Culms-position of Nodes

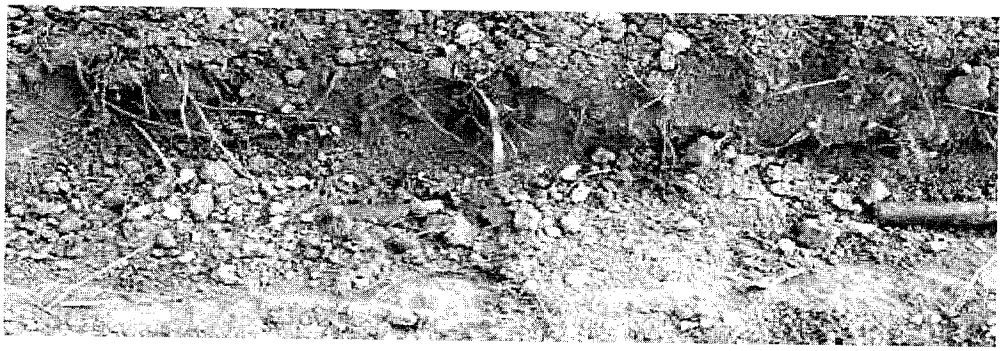

Figure 3.12 Raising with Single-node Buried Culms-covering with Soil

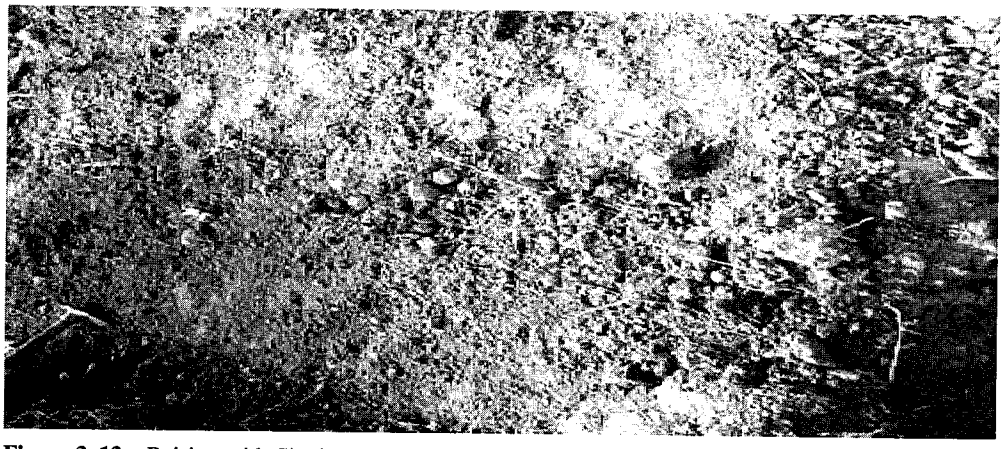

Figure 3.13 Raising with Single-node Buried Culms-after Covering with Soil

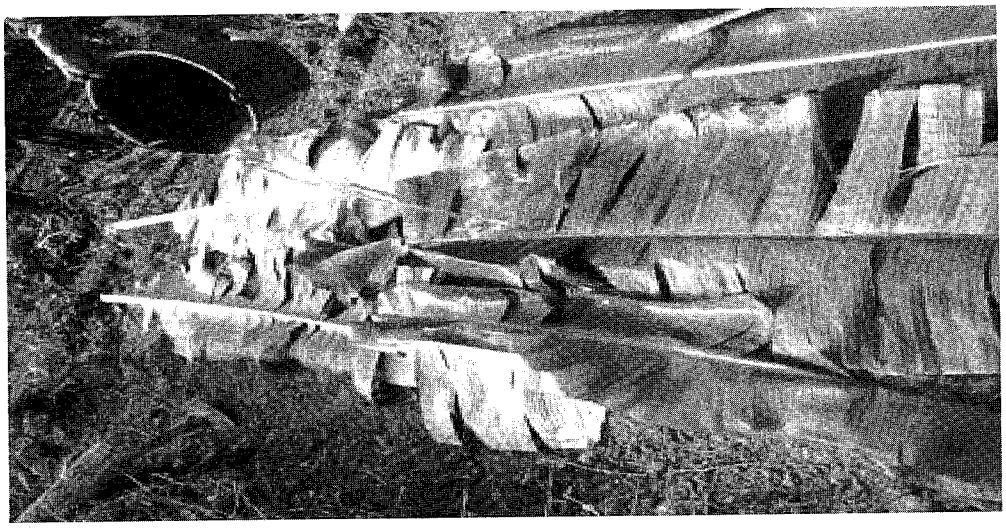

Figure 3.14 Raising with Single-node Buried Culms-watering and Shading

Although every node-bud can germinate, only around 30% of them finally survive. Differing from seed propagation, the cutting produces root system about one month after shooting and during this period, consumes nutrition reserved in the culm cutting. In this case, any unfavorable condition, such as impeded drainage and drought, will cause considerable death of cuttings.

3.3.3.2 Raising with two-node buried culms

This kind of cutting can be taken in the same procedure as single-node cutting, but it contains two culm nodes and is buried in soil with two buds toward left and right respectively (see Figure 3.15 & Figure 3.16). Propagation with 2-node cutting can achieve a higher survival of plantings than that with single-node cutting, but a little lower than with a whole culm.

Figure 3.15 Raising with Two-node Culm Cutting-position of Cutting

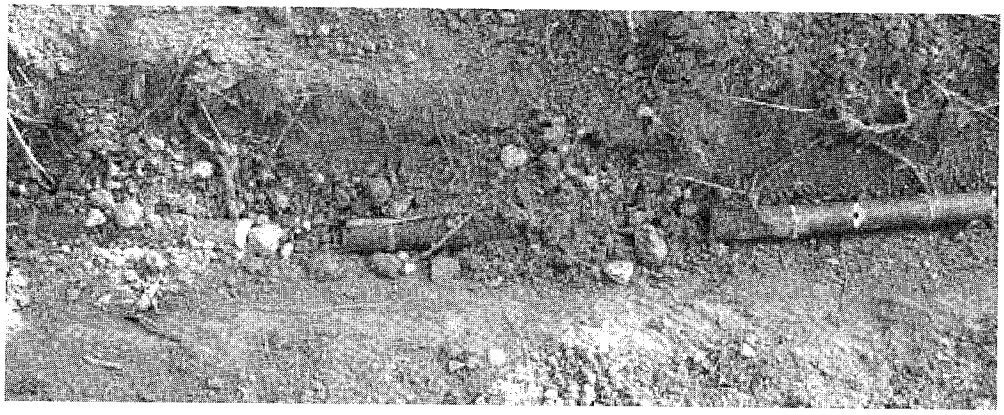

Figure 3.16 Raising with Two-node Culm Cutting-covering with Soil

3.3.3.3 Raising with Section Tear Culm Attaching the Handle

Propagating material is collected from one and two-year-old culm with the handle. Mother culm should be kept with the handle part and then treated by removal of the top and all branches(see Figure 3.17). A cross opening, being two third or three fourth of the culm diameter in depth, is made at the center of each internode with the direction opposite to the handle. The treated culm is placed in prepared drill with the handle facing downward and the openings upward to make it easier to get water (see Figure 3.18). Then it is covered with soil at the depth of 6 – 10cm(see Figure 3.19), watered and eventually covered with dry grasses to keep moist of soil.

This method of propagation usually achieves high survival of plantings and has been the best way of vegetative propagation using culm materials mainly with two reasons below. Firstly, the openings made on culms enhance node buds to sprout, on the contrary, most of node buds fail to develop if with no openings. Secondly, water and nutrients absorbed by the handle can be transported through the linkage remained to each node, and meet nutritional requirement for development before taking root, thus avoiding failure of seedlings as a result of nutrients exhaustion. With this method, each mother culm of *Bambusa chungii* McClure can produce 6 – 7 new clumps of new seedlings, but only 3 – 4 of such can be gotten for the same species

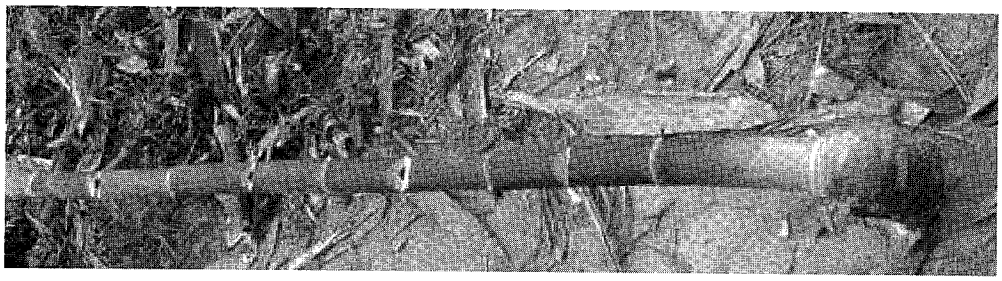

Figure 3.17 Treatment of Culms with Handles

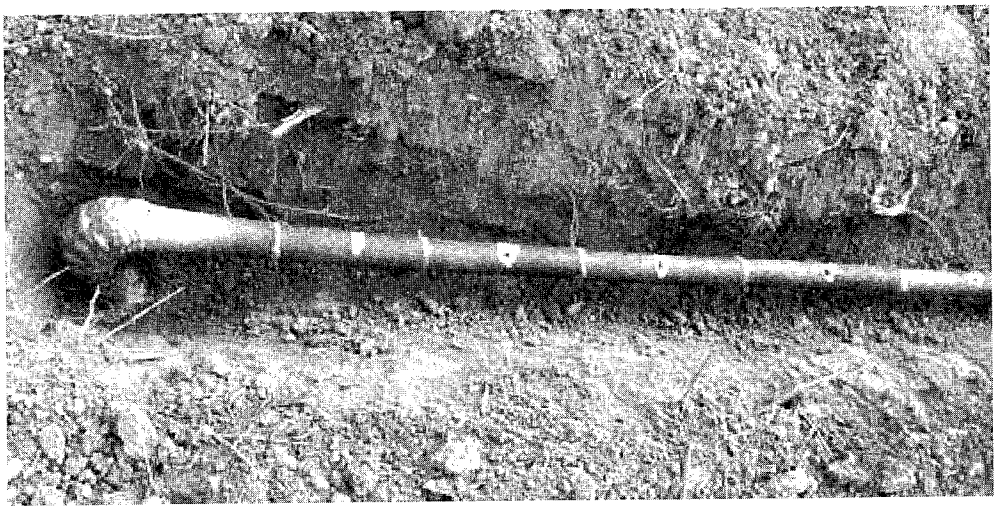

Figure 3.18 Position of Culms with Handles

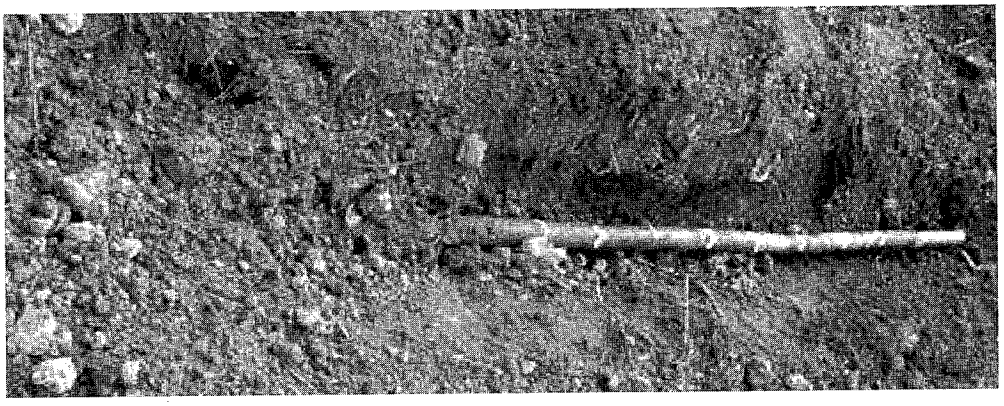

Figure 3.19 Placing the Section Tear Culm Attaching the Handle

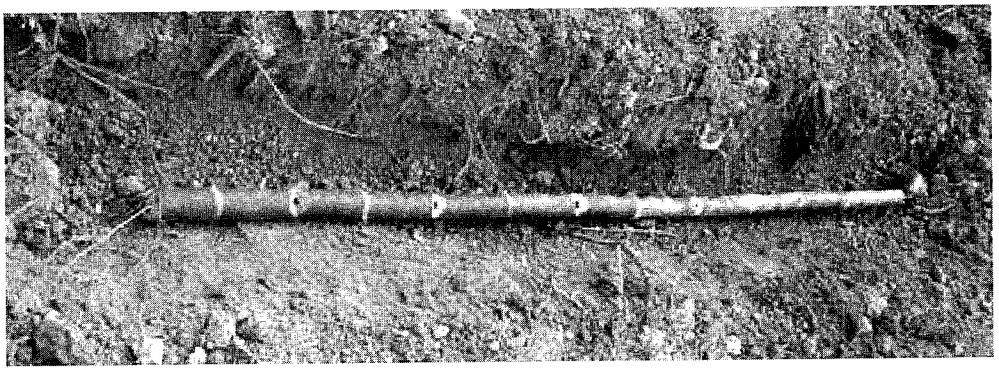

Figure 3.20 Placing the Section Tear Tulm Without the Handle

if using the above method without opening treatment and other methods.

3.3.3.4 Raising with section tear culm

Culms at the age of 1 or 2 years are used for propagation with this method, similar in procedure to the propagation using section tear culm attaching the handle. A cross opening, being two thirds or three fourths of the culm diameter in depth, is made at the center of each internode in a direction vertical to node buds of the mother culm. The treated culm is placed in prepared drill with the openings upwards (see Figure 3.20). Such method has advantages of low cost and not much labor work, but plantings produced this way are less in number, a case in point is *Bambusa chungii* McClure, each culm of which can produce 4 clumps on average. This method is more suitable for raising plantings at site near mother culm stands. When distant transportation is needed, certain measures like watering and covering with thatch or plastic sheet should be taken to prevent a declined survival of plantings due to excessive water loss of the mother culm.

3.3.4 Ground Layering

Young culms which have finished their growth in height are selected for propagation and the top part is removed to stimulate development of node buds. When buds enlarge enough, the culm is layered in a drill (see Figure 3.21) ever prepared, about 15cm both in width and depth, with base fertilizers placed and mixed with the soil in it.

Figure 3.21 Drill for Ground Layering

The layering culm is covered with 3cm soil in thickness (see Figure 3.22) and then covered with dry gras-

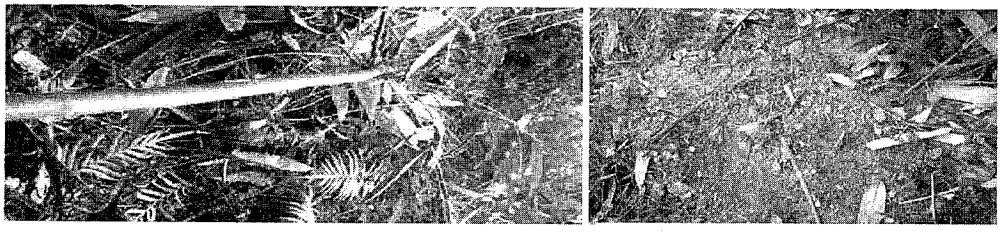

Figure 3.22 Ground Layering-covering with Soil

ses. Regular watering and avoidance of any impeded drainage in the drill are much important for a successful propagation. Layering is often done in February or March and shooting will grow in April or May, followed by root growth in July or August. The new plantings about 120cm in height are usually ready for transplanting.

3.4 Nursery Management

Management of nursery can bring forward or postpone growth phases of seedlings, so it is essential to arrange the management according to different characteristics in each phase.

Mother culm or branch, after being buried, should be shaded and watered frequently to keep moist of soil. It is important to clear weeds in time, and weeds should be cleared away after the rain. When mother culm (branch) sprouts to give rise to new leaves and shoot branches, fertilizer and water management should be reinforced and fertilizer should be conducted with mostly NPK compound fertilizer. Fertilization can be operated in low quantity, but many times. In early Autumn, fertilizer can be spread outside the root to stimulate a second shooting in autumn. Branches of sympodial bamboos generally root about 60 days after the cutting, shoot 80 days later and shoot again after autumn. Each cut seedling produces 3 – 5 shoots that year, and becomes a clump of seedlings for afforestation the following spring.

CHAPTER 4

Afforestation Techniques of Sympodial Bamboos

4.1 Site Selection

Sympodial bamboos favor warm and humid climate, great majority of which are vulnerable to cold injury if temperature falls below 0℃, except some species such as *Bambusa multiplex* (Lour.) Raeuschel ex Schult. f. as it can stand chilliness to some degree. Especially, cold waves occurring in early winter are likely to bring freezing damage to new bamboos with low lignification, and all of the aerial part of bamboos including old ones would be frozen to death if under more serious condition. The condition of air temperature, therefore, becomes a major restricting factor for sympodial bamboos introduction in a larger scale. Annual rainfall should be considered besides climate condition in selecting planting site. Those places where sympodial bamboos are fit to grow usually have more than 1,200mm of annual rainfall, mainly in growth season of bamboos. Bamboo grows well in fertile sandy loam rich in humus and alluvium with well drainage. Naturally, plantations of sympodial bamboos targeted at production and management are favorable to be established on sites such as riverbanks, wet regions along brooks and drills. As sympodial bamboos have no scattered bamboo rhizomes under the ground, if plantations of sympodial bamboos are aimed at ecological protection, it doesn't have much severe demand for the planting soil. Bamboos can be planted on the valley with uncovered rocks, but it is not suitable for afforestation on a place where there is too many stones and gravels, or heavy sticky, a place with aridity, impeded drainage, soil and mountain ranges with a bit alkalescence, and poor water supply.

4.2 Site Preparation

Different ways of soil preparation are dependent on types of planting land, conditions of terrain, topography and ecological environment. There are usually three methods as follows.

Overall land preparation is needed for a gentle terrain. First, clear away shrubs and weeds in the forest. Then plough soil deep in 30cm and clear away rocks, tree roots and stumps. This method is favorable to interplant inside stands the very year and the following year after planting, but it is labor and time consuming, with the disadvantage of large investment, high cost and restriction from terrain and economic condition.

To prevent soil and water loss, strip land preparation in horizontal level can be used in steep slope, i. e. preparing soil in strip parallel with contours. Strip width is usually 2 – 3m, decided by the standard of slope condition and whether growth of damaged vegetation in one or two years will influence the development of planted bamboos.

Lump land preparation is the most optimum for areas with uneven soil conditions and relatively fragmentized terrain. This method is a way to save labor and greatly flexible. Though with slight improvement of site condition, it can help to select areas with better soil condition to achieve higher productivity for planted bamboos.

4.3 Planting Season

Similar to nursery of asexual propagation of sympodial bamboos, spring is the optimum season for sympodial bamboos afforestation before bud eyes start to sprout and bamboo liquid starts to flow, especially for those in need of long-distant transplantation. Because on one hand, large numbers of new buds on the basal part of bamboos may have higher survival rate after afforestation if one-year-old mother bamboo is used; on the other, adequate nutrients reserved in mother bamboo or bamboo handle is favorable to the development of latent buds on the base to sprout new buds and hence new bamboos. It helps to improve surviving rate of cultivation, with the result of shooting the very year, and formation of bamboo stands in 3-4 years. If planting site is near the nursery site, it is feasible for plantation all through the year, but management after the planting should be strengthened. The key issue to make afforestation a success is to guarantee water supply, therefore in some areas with distinct dry season and rainy season, afforestation is usually made before rainy season comes to ensure a high survival rate.

4.4 Planting Methods

Afforestation of sympodial bamboos is quite often undertaken with transferred bamboos and transferred seedlings, but sometimes directly with branch cutting and buried nodes.

4.4.1 Afforestation with Transferred Mother Culms

Traditionally afforestation with transferred mother culms are mostly used. Selected among healthily growing bamboo clumps, mother culms should be 1 – 2 years old and strong enough with thriving leaves and with no pests, bud eyes on the culm base of which are round and rich, and fibres of which are usually well-developed. This sort of mother culms are characterized by intensive shooting, easy survival after plantation, and fast afforestation. The moderate size of mother bamboos should be regarded as well, the optimum of large size species usually 4 – 8cm in diameter breast height, and medium size one 2 – 4cm in diameter breast height. If mother culm is too small, it will grow poorly to affect its survival; conversely, if too large, it is not convenient to be dug, transplanted, and planted, so not a good choice as mother culm.

Digging up mother culms: 1or 2-year-old strong culms, which are usually situated at the edge of bamboo clumps, with the culm base deep under the ground, and well-developed bud eyes and root system. After selecting mother culms of good quality, dig up soil 25 – 30cm far from the culm handle of the mother culm first, then move from far to near to start deep digging (see Figure 4.1) on condition that bud eyes should not be injured, and fibre and rootlet of the culm handle should be reserved if possible. Then find the joint which connects culm stipe of mother culms and old culms near the side close to old bamboos, cut it off with a sharp chisel or knife, and then dig up mother culms together with the culm handle and soil. Small sized bamboos can be dug up with 3 – 5 culms in clumps due to tightly tangled root systems.

Due attention should be paid to the separation between mother culm and the old one when digging, if not, culm base of mother culm is at the risk of being mangled, thus affecting it survival rate. Then top part of the culm can be cut off, leaving 5 – 7 nodes (see Figure 4.2) to make easy for transportation. The cutting edge should be cut in the shape of horse ear and if wrapped by plastic sheet, it can reduce evaporation from the cutting (see Figure 4.3). If with low rate of sprouting branches, mother culm can be kept with 2 – 3 tangled branches. If it can not be planted in time, it should be put in a shady and cool place against wind, and be watered properly. When distant transportation is needed, certain measures should be taken

like keeping the culm handle moist, protecting bud eyes, and keeping old soil from falling down.

Planting of mother culms is achieved first by digging up holes with 30 – 50cm in depth (see Figure 4.4). Width of the hole is dependent on the size of culm handle of mother culm and the amount of old soil, usually 450 – 600 clumps/ha for species of large and medium size such as *Dendrocalamus latiflorus* Munro, *D. oldhami* (Munro) Keng f., *Bambusa pervariabilis* McClure, *B. chungii* McClure, and *Neosinocalamus affinis* (Rendle) Keng f., and 750 – 900 clump/ha for species of such small-sized species as *Bambusa multiplex* (Lour.) Raeuschel ex Schult. f. and *B. multiplex* cv. Fernleaf. Before planting, fill the hole with thin soil at the bottom, if possible, applying some mild humus farmyard manure with 15 – 25kg/hole,

Figure 4.1 Selection and Digging up of Mother Culms

Figure 4.2 Removing the Top Part of the Mother Culms

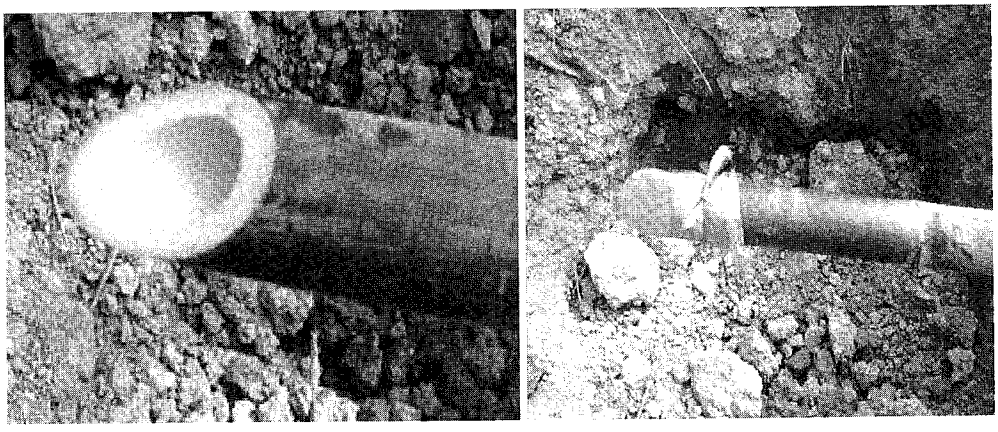

Figure 4.3 The Cutting Edge of Mother Culm and Its Wrapping Treatment

or superphosphate with 0.25kg/hole (see Figure 4.5), mix the surface soil, then place mother culm obliquely in the hole with the cutting edge of the top part kept upward (see Figure 4.6) to be available for rainwater to keep it from drying out. In order to ensure an extended root system, it is essential to fill soil with layers, having root system of the culm handle stay tightly to soil, press the soil, water enough, and finally add soil on to the base part with 2 – 3cm in depth (see Figure 4.7 & Figure 4.8) to make it look like steamed bread as a token of protection of rhizome from rotten by water logging.

Figure 4.4 Planting Hole of the Mother Bamboo

Figure 4.5 Base Fertilizer Application

Figure 4.6 Plantation of Mother Culms

Figure 4.7 Plantation of Mother Culmscovering with Soil

Figure 4.8 Afforestation with Transferred Mother Culms

4.4.2 Afforestation with Transferred Seedlings

Nursery site is often established to cultivate large numbers of seedlings to meet the need of large area afforestation. This method has such advantages as high survival rate, low cost, convenient transportation, and being favorable for long-distant introduction and cultivation.

New bamboos, more than 0.5 cm in ground diameter cultivated in the nursery site, are selected for afforestation (see Figure 4.9). After being dug up in clumps, seedlings are treated in nursery by cutting off most branches with several basal nodes left, and then divided into smaller clumps each containing 2 - 3 culms. After root-soaking in thick mud of soil or with old soil, they are wrapped with the handle part to be sent to planting site.

Figure 4.9 Seedlings for Afforestation

Planting density and method are quite similar to the afforesta-

tion with transferred mother culms. One thing that should be concerned is ignoring or being reluctant to cut branches off when digging up seedlings in the nursery site. It has the potential risk that branches evaporate too much after cultivation and if there is not enough water supply from root system, the seedlings may die for excessive water loss. Therefore, it is essential to cut more than 2/3 of branches to ensure high survival of seedlings after the transplantation.

4.4.3 Afforestation with Buried Internodes or Branch Cutting

The method of buried internodes or branch cutting can be adopted to make for sympodial bamboos stands directly in the area with good planting condition and favorable management. Planting season is selected the same to raising with buried internodes or branch cutting. The method, without the procedure of seedling transplantation, helps to save cost to a great extent and speed up afforestation, but might as well lead to the problem of inconvenient management and low surviving rate. Accordingly, to improve surviving rate, two branches should be placed in each hole, and measures like moisture management and shading should be strengthened before branches produce roots.

4.4.4 Density of First Planting

Density of first planting of sympodial bamboos is dependent on species' biological characteristics. For those large-sized species, it is favorable to use sparse density of planting, for example, the optimum density of *Dendrocalamus latiflorus* Munro is 250 – 400 clump/ha, 204 clump/ha on the hillside, and generally 368 clump/ha on average with 70kg/clump as average output. A suitable planting density for *Dendrocalamus giganteus* Munro, *Dendrocalamus hamiltonii* Nees et Arn ex Munro is 220 culm/ha. Dense planting is quite often used with regards to medium and small sized species, such as the cultivation of *Dendrocalamopsis oldhami* (Munro) Keng f. with 250 – 600 clump/ha. Sometimes larger density of planting is used to reach 825 clump/ha as the highest and 456 clump/ha on average. The average shoot yield of *D. oldhami* (Munro) Keng f. is 19 kg/clump.

CHAPTER 5

Seedling Cultivation Techniques of Sympodial Bamboos

The phase between the beginning of afforestation and close canopy is called seedling phase, which usually lasts for 2 – 4 years (see Figure 5.1) and dependent on density of first planting, different species, environmental condition and nursery measures. Its main features are as follows: the planted mother culm takes time to adapt and recover to produce roots due to the injury of its underground root system and weakening of water fertilizer absorption after the digging, transporting, and transferring to the new environment. Meanwhile the land for planting is covered with nothing, its soil condition varying greatly with changes of temperature, rainfall, direct sunshine time, and moisture in particular. In rainy season, it may likely cause water logging if the land is not well-drained, while ground evaporates intensely in the season with sunny days and little rain. On the other hand, sparsely located culms and adequate sunshine as a result of new afforestation, is prone to growth of weeds and shrubs, which compete against bamboo

Figure 5.1 2-year-old Seedlings of Sympodial Bamboos

stands for moisture and nutrient.

According to the main features in this phase, corresponding technique measures should be taken to center around survival of bamboos and a fast regeneration and propagation to increase bamboo culms and stimulate the canopy in order to improve survival rate and speed up afforestation. They are water management, intercropping, weeding and soil loosening, fertilization, keeping shoots and protecting bamboos, and so on.

5.1 Water Management

Water condition of forest land soil is an essential factor in influencing survival rate of bamboo afforestation. Newly planted mother culms and seedlings, after the digging, transporting, and cultivation, usually suffer from injury of root system, together with a weakening of water absorption and respiration. If there is not enough water in soil, the root system will suffer from water absorption and fail to meet the need of branch transpiration, thus resulting in drying out of seedlings for water loss. The root system will go rotten for the abnormal respiration metabolism with air shortage in soil if the land is not well-drained. Only under the condition of moist soil with no water logging, can the root system of both mother culms and seedlings obtain adequate moisture and enough air supply to be favorable to water absorption and growth recovery. Hence it is important to strengthen water management the first year after afforestation in addition to enough watering when mother culms are planted. If in the sunny days with little rain, the newly planted mother culm is likely to lose water, with its leaves drying and falling, because of its difficulty in water absorption resulted from injury of root system. Therefore, timely irrigation should be achieved to provide water supply for refreshment of mother culms when soil turns to be dry, but leaves of bamboos have not yet rolled up for water loss. After watering, stalks and weeds can be covered on soil to reduce water evaporation of the land, at the same time restrict weeds from growing. Conversely, in sunny days with no rain, if there is not a good drainage, it is likely that moisture is kept in interspace of soil, so the root system of culms tend to rot because it can't have normal respiration metabolism for lack of air in soil. Therefore, in rainy seasons, canals should be dug and water should be drained in low-lying place and gentle terrain with high-level underground water to protect forest land from water logging and bamboo root systems from rotting.

Irrigation. Horizontal ditches can be dug at a flat place or the terrain with gentle slope as they are convenient for irrigation (see Figure 5.2). But for those hilly mountainous areas difficult to get water, water should be carried on shoulder and then be irrigated in culms. The amount of water for irrigation is dependent on mois-

Figure 5.2 Bamboo Stand Irrigation

ture of soil that is close to the root system of mother culms or seedlings. After irrigating, surface soil should be dug and softened, or added with 1 – 2cm thin soil, to reduce evaporation. For irrigating in growth season, a few human manure and urine can be added to stimulate seedling development of and improve drought-resistant capacity of bamboos.

Moreover, ditches should be made to drain water in the forest land with high-level underground water.

In order to reduce evaporation of stand land and rank growth of weeds, it is favorable to cover ground around mother culms or seedlings with 3 – 5cm straws, wheat stalks or weeds to improve surviving rate and promote growth of new culms.

5.2 Intercropping

Intercropping can be undertaken 2 years before afforestation, as it takes full advantage of soil productivity and light energy to increase short-term income of bamboo stands, and may as well be helpful in replacing bamboo stands with farming to stimulate in advance of bamboo regeneration and the canopy closure.

Plants with high economic returns such as watermelon, beans and medicinal materials is favored for young stands with better soil condition. At the first year, due to big spacing in the stand, cassava and watermelon can be intercropped since their vines will cover the ground to help reduce evaporation of soil and benefit greatly to make a moist and ventilative soil condition. Moreover, vines left in the stand after the reaping helps to increase the content of soil organic matterial in the stands if mixed with soil to make it fertilized. In the stands with poor soil fertility, plants like beans and green manure is fit for intercropping, as nitrogen fixation from bean crops can raise soil fertility of the stand. In short, the choice of intercrops should be

aimed at favoring bamboo stands, therefore it is not suitable to select plants of grass family of the same species that compete with bamboos for nutrients, and such crops as sesame and marihuana that consume soil. Meanwhile, attentions should be paid not to injure the root system and shoot buds of bamboos, and still intercropping space should be decreased each year following a gradual canopy closure of bamboo stands.

5.3 Weeding and Soil-loosening

Bamboos are usually sparsely distributed in new bamboo stands with sufficient sunlight, so it is likely to give rise to weeds and shrubs, which have the potential to impede bamboos from growing and result in the occurrence of pest diseases if not cleared timely. It is therefore of importance for newly-established bamboo stands to be cleared with weeds and loosened with soil twice or three times before the canopy closure. Firstly it should be done in June when it rains often and hence with fast growing weeds and shrubs, weeds should be cleared together with soil loosening for the reason that weeds are apt to get rotten. The second time is around August and September when the growth of weeds comes almost to an end, but the seeds have not yet grown up, so stand land becomes clean enough after the clearing to reduce the growing of weeds the following year. The measure of soil-loosening in this season can improve sanitation environment of stands and clean up the place where pests live on and live through winter to reduce pests harm in the next year. February the following year, when weather turns to be warmer and weeds starts to grow, is the third time of such measure to be taken to exterminate weeds in its sprouting phase to benefit bamboo growth.

This measure can cover the whole area of bamboo stands on the gentle terrain, but for stands with larger slopes, it can be done within the range of 0.5 – 1m around the clumps. Along with clump expansion, the range should expand year after year. Be careful not to injure bamboo roots, culm handles and shoot buds.

5.4 Fertilizing

Fertilizing helps to stimulate the maturity of young culms ahead of time. For the newly-established bamboo stands, all sorts of fertilizers can be used, slow-release organic fertilizer such as barnyard manure, bone dust, farmyard manure, and pond mud, which are the optimum for fertilization in autumn and winter to increase fertility and maintain soil temperature, and good for shoot buds on new culms to spend winter. On the other hand, quick-release fertilizer (such as carbamide and ammonia), decomposed cake fertilizer, human manure and urine, and the like should be

Figure 5.3 Fertilizing of Sympodial Bamboos Stands

fertilized in spring and summer to meet timely the need of bamboo growth, thus avoiding fertilizer loss.

The method of fertilizing. It can be achieved by digging up ditches or holes around the bamboo clumps, and covering with soil afterwards (see Figure 5.3). If quick-release NPK compound fertilizer is used, the new stand can be fertilized with 0.5 – 1kg/clump; while with slow-release organic fertilizer, it is 22.5 – 37.5t/ha for barnyard manure or farmyard manure, and 37.5 – 60t/ha for pond mud.

Along with soil-loosening, fertilizing should be achieved with a suitable fertilization time and the quantity of fertilizer that are decided by stands fertility, fertilization capacity and growth characteristics of different species.

5.5 Keeping Shoots and Protecting Bamboos

With the main target at keeping new culms, the number of bamboos in the bamboo stands is recommended to be increased to stimulate a fast canopy. Strict protective measures should be taken during the shooting stage to forbid animals from intruding. After the shooting, if there are too many shoots on the same mother culm, they will usually develop into degraded shoot and fail to become bamboo culms due to insufficient water and nutrient supply. Therefore, some shoots should be dug as early as possible to leave two or three strong ones to grow into bamboos. Quite often, each culm will keep only 2 – 3 shoots for bamboos according to the size of species, leaving 2 – 3 shoots for each culm the following year with removal of the remaining ones. The same is true in the third year. This way of shoot thinning improves quality of the remaining bamboos, and additionally can increase the income from bamboo shoots.

5.6 Pest and Disease Control

Pest and disease control should be concerned, especially shoot-feeder and leaf-feeder for their bigger harm to the new bamboo stands.

CHAPTER 6

Efficient Cultivation Techniques of Sympodial Bamboos Stands

6.1 Efficient Cultivation Techniques of Bamboo Shoot Stands

6.1.1 Soil and Fertilizer Management

Intercropping is favored 1 – 2 years after the establishment of sympodial bamboo stands to help cultivate bamboo stands. While in the third year, with expansion of bamboo stands, stand canopy is gradually in closure and some bamboo shoot stands turn out to have distinct shoot yield. Strengthening management of bamboo stands at the right moment is the key to increase the output of both bamboo shoots and bamboo timbers. Compared with monopodial bamboo stands, soil and fertilizer management of sympodial bamboos has its unique technical measures, such as raking to dry in the sun, earthing up, fertilizing, irrigating, cultivation and weeding, centering on features of shoot buds' sprouting, unearthing, and growing into bamboos.

6.1.1.1 Raking to dry in the sun

Each spring soil cover around culm handles should be removed to expose bamboo head and shoot head to sunlight, a way using the stimulation of light and heat to promote the burgeoning of shoot buds and therefore, achieving the purpose of early shoot sprouting and shooting increase. The optimum time of the measure is from late March to April, 20th, achieved by digging up soil around the clumps from the outside to the inside in circles, removing the massy root system, cutting off fibre that twists shoot buds to protect them from being bound, and exposing if possible all the shoot eyes to wind and sunlight (see Figure 6.1).

6.1.1.2 Fertilizing

It is generally considered right to fertilize sympodial bamboo stands three times the whole year. It is first done after raking to dry in the sun around the root to stimulate shooting, applying human manure or rotten compost around the dug-up clumps and covering with soil afterwards, the amount of fertilizer varying on different conditions, usually 15kg/clump of rotten compost and 25kg/clump of rubbish manure.

Figure 6.1 Raking to Dry in the Sun of Bamboo Clumps

Mid May is the suitable time for a second fertilizing to supplement nutrient shortage in the process of shoot-bud differentiation and expansion. Quick-release NPK compound fertilizer is usually selected with the ration of N: P: K to 5:4:3, which is more effective if added with calcium silicate. Each clump can be applied with 0.6kg carbamide, 1.0kg superphosphate and 0.4kg gallium-nitride. The way of fertilizing can be referred to see Figure 5.3.

The application is done a third time in combination with shoot handles fertilizing after shoot harvesting. Shoot holes left by shoot-cutting take on the state of mucilage due to the active secretion of bamboo juice from the cut in summer, so it is apt to get rotten to affect the normal growth of neighboring shoot buds. In that case, earthing is done after bamboo juice on the cut freezes and displays a bit dryness. Before earthing, diluted carbamide is applied in combination with the fertilization of shoot holes, to stimulate sprouting of more shoot eyes. Due to long shooting stage of sympodial bamboos, a timely nutrient supplement in summer when it grows vigorously will for one thing, make it fully possible for more sprouting of shoot eyes and improve the output as a result; and for another provides the opportunity for new shoot heads to develop "The second time shooting".

6.1.1.3 Shoot cultivating

Some shoot eyes of bamboo clumps, after the treatment of raking to dry in the sun, start to expand and turn blue to form little shoots. It is thus the right time to earth up to cover shoot buds for the sake of enabling sprouting shoots to grow in the dark soil

to cultivate bamboo shoots with flavor, tender flesh and strong shape. The majority of sympodial bamboos contain a certain substance of bitterness, which is regarded as taxiphyllin according to the appraisal of bitter substance in *Dendrocalamus latiflorus* Munro by Wu chunmei in Taiwan, China. The compound is likely to produce such substances as HCN after the heating, which does no good to the eating of *Dendrocalamus latiflorus* Munro shoots. Moreover, the influence on the bitterness of shoots as is brought by the unearthing and exposure to sunlight is so tremendous that the content of taxiphyllin in shoots reaches twice as much as those unearthed. Soil on opening ground among bamboo clumps is covered around the root of clumps with 10cm in thickness higher than the former bamboo handles (see Figure 6.2).

In cultivation for smypodial bamboos shoot stands, covering technique can be adopted in the way of covering soil with sugarcane leaves or weeds cut at the edge of stands (straws are not a good choice). If there are sufficient covering in shooting season, shoots tend to turn ivory in color, with good flavor and less fibre, and hence higher quality and price com-pared with those without covering. Still, covering material tends to improve soil fertility after decomposition.

Figure 6.2 Soil Cultivating of Bamboo Clumps

6.1.1.4 Irrigating

A good effect can be achieved on bamboo shoot stands by irrigating once every week or every two weeks in dry season to bring forward shooting and increase output (see Figure 6.3). When in the period of shoot harvesting, soil should be watered timely to keep moist if there is no rain for long, so as to ensure high yield of bamboo shoots and vigorous development of the retained bamboos.

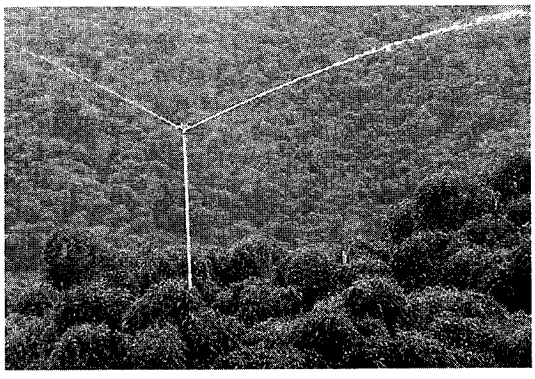

Figure 6.3 Irrigating of Bamboo Stands

6.1.1.5 Intertilling and weeding

Intertilling and weeding are usually done together with cultivating and producing measures such as raking to dry in the sun, earthing up and shoot digging. When earthing up, soil loosening and weeding can be done at

the same time.

Intertilling is achieved in some bamboo regions together with the cutting of old bamboos. Old bamboo handles are dug up and soil in the bamboo stand is ploughed thoroughly 20cm in depth in enhancing soil efflorescence and improving soil ventilation.

Bush cutting in bamboo stands is done once or twice every year for sympodial bamboo shoot stands to clear away shrubs and rattan. It is first achieved in early May before shooting and again in early October to cut down weeds and shrubs in the stands and then lay them horizontally on stand ground for decomposition to be used as fertilizer.

6.1.2 Structure Adjustment

The structure of sympodial bamboos stands is mainly bamboo density structure and age structure. While bamboo density includes interclump density (number of clumps within the unit area) and innerclump density (number of main bamboos retained in each clump).

6.1.2.1 Interclump density

Interclump density of sympodial bamboos is often dependant on the density of first planting in afforestation. Though it can be adjusted somewhat in long period operation, the principle of guaranteeing photosynthesis and nutrient supply as is required by its growth should be followed. Please see the details in section 4.4.4.

6.1.2.2 Innerclump density

Innerclump density of sympodial bamboos, in other words the number of retained mother culms, is defined by the biologic characteristics of species. With regards to sympodial species in large size, shoot-used bamboo species in particular, mother culms with relatively low quantity is usually adopted, for example, it is suitable for *Dendrocalamus latiflorus* Munro, *Dendrocalamus giganteus* Munro, *Dendrocalamus hamiltonii* Nees et Arn ex Munro, *Dendrocalamopsis beecheyana* var. *pubescens* (P. F. Li) Keng f. , *Dendrocalamopsis beecheyana* (Munro) Keng f. and the like to keep 4 – 6 mother culms in each clump. However, things are different for mid size and small size species, with more mother culms kept instead. 6 – 12 mother culms are retained each clump for shoot-used bamboo species such as *Dendrocalamopsis oldhami* (Munro) Keng f. , while it is 12 – 20 culm/clump for *Bambusa pervariabilis* McClure, *Bambusa chungii* McClure, *Neosinocalamus affinis* (Rendle) Keng f. , *Bambusa textilis* McClure, and other timber-used species.

6.1.2.3 Age structure of mother culms

1 or 2-year-old sympodial bamboos, which are usually in the young phase characterized by the tender tissue, well-developed bud-eyes on the handle part and intensive germinating power, are the hope of bamboo stand regeneration. While 3 or 4-year-old bamboo is in a mature phase and most of its bud-eyes on the handle part have produced shoots and developed into bamboos. The remaining shoot eyes have no shooting capacity, however its exuberant branches can shelter those 1-year-old mother culms with thriving shoots from wind and function to sustain as well. Generally, all of 4-year-old old culms and part of 3-year-old ones are therefore cut down by the way of retaining and meanwhile cutting down mother culms every year to keep a reasonable structure of stands.

The proportion of age structure of sympodial bamboo stands is determined by its management mode and goals, for example, 1-year-old culms and 2-year-old culms of *Dendrocalamus latiflorus* Munro, *Dendrocalamopsis oldhami* (Munro) Keng f., *Dendrocalamus hamiltonii* Nees et Arn ex Munro and other shoot stands are usually done in the proportion of 2∶1 or 3∶1, and the proportion of 1-year-old culms, 2-year-old culms and 3-year-old culms is 2∶2∶1 for timber stands such as *Bambusa pervariabilis* McClure, *Bambusa chungii* McClure, *Neosinocalamus affinis* (Rendle) Keng f., *Bambusa textilis* McClure.

6.1.3 Technique of Shoot Harvesting and Culm Retaining

Sympodial bamboos are similar to monopodial ones in shooting. Due to undernourishment, or harm from disease and pest, some shoots unearthed can not develop into bamboos and thus get the name of "degenerated shoot". As is recorded that the degenerating rate of shoots reaches 74% because 271 shoots cannot develop into bamboos among 366 shoots produced from 8 clumps of *Chimonbambusa pachystachys* Hsueh et Yi, therefore it should be handled reasonably in the operation of both bamboo timber stands and shoot stands. Particularly when managing sympodial bamboo shoot stands, how to make use of tiller of bamboo head and shoot head, mastering the tillering season, exploiting different tillering capacity of basic eyes and end eyes, and harvesting shoot keeping mother culms in time become the key issues of sustaining a high and stable yield of the stands.

Increase of shoot yield is regarded as the primary goal of sympodial bamboos shoot stands, so it differs from timber stands in shoot harvesting. The technique is achieved by keeping 3 – 4culm/clump of shoots with medium size that are evenly distributed in the outer circle of clumps to develop into new mother culms, and removing all the remaining part based on the shooting period of different species. Bamboo shoot stands with the soil cultivation can be harvested if its shoots grow out of soil up to 5-10cm. In shoot harvesting, soil is dug up to remove that around

shoot buds to expose shoots and then shoots are cut off with shoot knives. Remember to retain the handle part of shoots and ensure a smooth cutting, moreover the unsprouted shoot buds bearing on the culm handle of mother culms should be protected. Quite often shoot handles remained after shoot harvesting both in early phase and medium phase are capable of producing shoots again, and thus is given the name of "The second time shooting". In a well-operated shoot stand it can be seen twice or three times generally, with 5 or 6 times at best. Reasonable shoot harvesting technique therefore can stimulate the occurrence rate of "The second time shooting" and increase shoot yield.

6.2 Managing Techniques of Sympodial Timber Sands (Pulp Stands)

6.2.1 Soil and Fertilizer Management

6.2.1.1 Bush cutting

The advantage that bush cutting brings is to reduce the competition for water and nutrient between bamboo stands against weeds and shrubs, the decomposition of which helps to improve stands' fertility. So the yield of new bamboos can increase by 20% – 30% after bush cutting. Meanwhile it can on one hand eliminate interhost and habitat of pests, and on the other, those flammable weeds and shrubs to reduce occurrence of disease and insect pest and fire as well.

Bush cutting is done once or twice each year to clear away shrubs and rattans in the stand. If weed cutting is attempted twice, the very time from May to June and from August to September are the good choice to cut down weeds and shrubs and then have them spread horizontally on the ground to decay for fertilizing. If it is attempted only once, the best season is in July with high temperature and humidity, so weeds are tender enough to decay with high fertility and it might as well save labor work. If it is done too early, weeds haven't fully grown up to provide high fertility and tend to sprout in mass after bush cutting. On the contrary, weeds are too old to get rotten easily and seeds of which are mature enough for sprouting the following year to lead to more weeds if it is done too late. Still some attention should be paid to cut off bamboos that are slender, malformed, blown down by winds and those with tops off and with serious damage from disease and insect pest. Those mixed tree species unfavorable to the growth of bamboos in the stands should be eliminated as well year after year.

6.2.1.2 Soil loosening, handle removing and intertilling

Every 3 or 5 years, sympodial timber bamboo stands is recommended to plough and

loosen soil once and land clearance once in winter time, following the principle of "digging shallow near clumps and handles, but deep far from them". In other words, when digging near bamboo clumps and handles, it should be shallow with 6 – 10cm in depth for land clearance and 15 – 20cm for soil loosening; while far away from clumps and handles, it is better to be deep with 12 – 15cm in depth for land clearance and 20 – 30cm for soil loosening. Additionally, brush roots, old bamboo handles and old bamboo rhizomes should be removed. Big rocks in the soil should also be cleared to secure those strong bamboo handles, bamboo rhizomes and shoot buds from being damaged. Those newly cut bamboo handles should be protected because buds bearing on the culm base will give the rise to shoots and later develop into bamboos. Intertilling is suggested to be in combination with the removal of old bamboos. Old bamboo handles are dug up and soil is cultivated thoroughly 20cm in depth with the benefit of stimulating soil efflorescence, improving soil ventilation and so on. In the process of soil loosening, caution should be made to cover bamboo handles with soil to avoid the exposure of shoot buds and lessen water evaporation in soil. The stands with big slopes is suggested to be changed into terrace in soil cultivating due to its great advantage to soil and water conservation.

6.2.1.3 Fertilizing

With increasingly improved management level of sympodial bamboo stands, fertilizing has already become an important technical measure to cultivate fast-growing and high-yielding stands. Those organic fertilizers such as barnyard manure, weeds and shrubs, pig and cattle manure, pond mud, and green manure not only increase nutrient in soil, but also improve physical quality of soil. A good result is achieved when applied with NPK and other quick-release fertilizers in the growing season. According to the study, if *Bambusa chungii* McClure pulp stands with its clump structure of 1 – 3 years old and over 10 culms retained for each clump, is fertilized with N: P: K of 5: 1: 1 in proportion and 250g each clump in August, it can reach the highest yield. As for *Bambusa distegia* (Keng et Keng f.) Chia et H. L. Fung pulp stands, it will have the best effect when each ha is applied with 69kg carbamide, 9.7kg superphosphate and 39.3kg potassium chloride around March and April, and June and July respectively each year. While for *Neosinocalamus affinis* (Rendle) Keng f. stands, the fertilization of carbamide and potassium chloride should be done in June, and phosphatic manure should be fertilized in October. If NPK is applied with N: P: K of 1.5: 1: 1 in proportion, a highest yield and better economic benefit can be achieved, and moreover there are higher yield with fertilizer quantity of 0.98 – 1.21kg/clump.

6.2.1.4 Irrigating

A good effect can be seen by irrigating sympodial bamboo stands (see Figure 6.3). Irrigating once every week or every other week in the dry season if possible enables early shooting and yield improvement. When it comes to shooting time, stands should be watered timely to keep soil moist to secure a vigorous growth of those retained new bamboos if there is no rain for a long time.

6.2.2 Structure Adjustment of Sympodial Bamboos Timber Stands

Much like the structure of sympodial bamboos shoot stands, the structure of sympodial bamboos timber stands also consists of three parts, the density of first planting, the number of culms of retained bamboos, and the age structure of the retained ones.

6.2.2.1 Density of first planting

A reasonable density of first planting is an important condition to ensure the output level of timber stands for the reason that stand density within certain scale and leaf area index have a very distinct correlation with the stand yield. In that case, the density of planting is determined by size of culms and soil condition. Take *Neosinocalamus affinis* (Rendle) Keng f. and *Dendrocalamus membranaceus* Munro for example, row spacing of the planted culms can be 4m×4m or 4m×3m in the place with deep layers of ground and high fertility of soil; on the contrary, 3m×3m or 2.5m×2.5m might be the right choice for those ordinary soil conditions.

6.2.2.2 Number of retained mother culms

As is mentioned above, a reasonable density is the basis to increase production, so it is recommended to retain 12 – 14 culms for each clump. However sparse density and younger mother culms are adopted according to different managements in different places. If there are only 6 – 10 shoot eyes for each mother culm, the less the retained bamboos are in number, the lower output it brings following the rule that only 50% of shoot eyes are able to shoot and become bamboos. The retained shoot handle of such species as *Dendrocalamopsis beecheyana* (Munro) Keng f. shoot doesn't contain shooting power, but rather, it's shooting has to depend on shoot eyes on the basal part of the mother culm, so certain culms should be kept of sympodial bamboos.

6.2.2.3 Age structure of bamboo stands

Generally 1 or 2-year-old smypodial bamboos are in young and mature phase, its tissues being tender and bud-eyes on the handle part having strong germinating power and good development. They are therefore the hope of regeneration of sympodial

bamboos stands. For those 3 or 4-year-old bamboos in their mature phase, most bud-eyes on the handle part have shot and developed into bamboos. The retained shoot eyes basically contain no shooting capacity, whereas its exuberant branches can shelter those 1-year-old mother culms with thriving shoots from wind and function to sustain as well. Consequently, all the 4-year-old old culms and part of 3-year-old ones are cut down, and age structure of 1-year-old bamboo, 2-year-old bamboo and 3-year-old bamboo is in the proportion of 4:4:2.

6.2.3 Other Managerial Techniques of Sympodial Bamboos Timber Stands

6.2.3.1 Shoot protection and bamboo cultivation

During the time of shoot unearthing, grazing should be prohibited and livestock not allowed to enter bamboo stands. Meanwhile, shoots that are unearthed in the prophase and midphase should be retained while those unearthed in the anaphase should be removed.

6.2.3.2 Disease and insect pest control

Timely prevention is to be carried out if disease and insect pest are found in bamboo stands. Please refer to the section of "the prevention of disease and insect pest of bamboos" for measures in detail.

CHAPTER 7

Prevention and Control of Diseases and Insect Pests

Bamboo is closely related to other life forms in Nature during its growth. Throughout the entire process of its growth, insects and microorganisms live on bamboo, feeding on whatever part of bamboo to maintain their own survival. Though some of the insects and microorganisms have beneficial effect on human beings, most only consume bamboo or bring diseases to bamboo, affecting the latter's growth negatively, even resulting in withering, devastation or desolation of vast plots of bamboo stands.

7.1 Main Diseases of Sympodial Bamboos

Infection and encroachment brought about by microorganisms affect normal growth of bamboo, destroy bamboo tissues, and even kill bamboo stands. The most commonly seen microorganisms are bacteria, fungi and viruses. According to investigation, there are more than 400 types of microorganisms that are parasitic and saprophytic on the bamboo. But there is not yet thorough research carried out with regard to these microorganisms. Some of the microorganisms are helpful, such as *Shiraia bambusicola* P. Henn. and bamboo fungus; Some of them are harmful, like what are usually called bamboo germ. 20 types of disease are commonly seen, of which less than 10 types are likely to cause severe loss.

7.1.1 Bamboo Culm Rust

Bamboo culm rust whose systematic name is *Stereostraum corticioides* (Berk. et Br.) Magnus, also called bamboo mattress sickness, occurs in Shanxi, Henan, Shandong, Jiangsu, Anhui, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Sichuan and Guizhou Provinces in China; potential victims include

all the genera of *Phyllostachys* Sieb. et Zucc. and *Bambusa* Retz. Corr. Schreber, and other species like *Brachystachyum densiflorum* (Rendle) Keng. When these bamboos are infected, the surface layer of infected culms turns black and brittle, which greatly decreases the value of bamboos; in severe cases, the result is that bamboo growth declines, fewer bamboo shoots up, those bamboos with shorter diameter wither, and eventually, the entire bamboo stands declines.

7.1.1.1 Symptoms

Bamboo culm rust usually occurs in the middle and lower part (more often) of bamboo culms. In severe cases, the disease will spread to the upper part and twig of culm, and the bare bamboo rhizome. At the end of July and August every year, fading speckles appear on newly infected part of culms in the shape of ligules or shuttle; grayish white particles emerge little by little under the coat and around old speckles, after the end of October, infected cuticle ruptures. The fine particles called winter spore cluster turn tan and expand gradually, earth tan in color and blanket shaped. During the middle and late part of April in the following year, winter spores inflate by absorbing water, fall off, unveiling a smoke purple brown at first and assuming tan latter. In May, there comes out ferruginous blanket-shaped powder. That is the summer spore. After the summer spore disperses, the infected part appears dark brown.

7.1.1.2 Causes

The cause of bamboo culm rust disease is hypodermic hard layer rust germ—stereo stratum corticioides (Berk. et Br.) Magnus, a subdivision of fungus basidiomycetes under the outline of the winter spore, rust germ item. In searching for the cause of bamboo culm rust disease, so far, only the winter spore clusters and the summer spore clusters, instead of the basidium of productive spore, are seen on the infected part of bamboo culm. Winter spore clusters are round or oval, 1 – 2cm wide with a rust spot 0.5 – 1.0 mm thick. When the plant disease is serious, winter spore clusters crowdedly and may link into a piece in the shape of blanket, which is over 10cm in length. The winter spore is oval, double-celled, with diaphragm either lightly crinkled or not, having a slender handle of 200 – 400 μm, faint yellow, 19 – 32 μm × 25 – 45 μm big whose wall is 3.0 – 3.5 μm thick, smooth, and colorless. Summer spore is sphere-like or oval, single-celled, 15 – 20 μm × 19 – 27 μm big, whose wall is 2.5 – 3.0μm thick, slightly smooth, having a small spinule like strumae, colorless or faint yellow.

7.1.1.3 Occurrence rules

Germina lives through the winter in the form of hypha or in winter spore of infected

yellow spot of bamboo stalk. And hypha can live on living tissues of its host for many years. In Jiangsu China, between June and August, spots that change color appear on the surface of bamboo tissue around old sick spots on bamboo stalk and then develop into strips or arris of spots that become yellow at last; from the end of September to November, immature winter spore emerges and expands until January when the temperature begins to drop. After February, winter spore develops again, until March when a layer of fresh yellow leather tray-like matter develops on the yellow spot. That is winter spore for pathogen, also called bamboo mattress disease, which disappears in early April.

In mid and late April when it is overcast and sunny, winter spore clusters expand by absorbing rain water, turn up and fall off until May. In late April a picul of winter spore mature, starting to disperse, but it is not yet reported that such amount of winter spore containing germ infect bamboo. In the middle and last ten days of April, after the winter spore falls off, in the original sick spot, summer spore starts to turn up, mostly at May. The summer spore clusters assume powder nature, blanket shape, and is ferruginous. Between the end of April and late June, summer spore disperses, on sunny and windy days, especially after rain. When it is overcast, fewer spores disperse. During the period when summer spore are released, the surface of infected bamboo stalk is covered with a rust yellow layer of summer spore on sunny days after the shower. At the same time, summer spore on the bamboo stalk may be washed down to bamboo root, which shows that rainwater may pass on sickness, moreover insect on bamboo including ladybug also may disseminate disease. In late May comes the prime season, when summer spore are released, statistics obtained from sticking spore with glass shows that summer spore captured abuts surface is more than 10 times those that are captured on stalks 1.2m. That is why the near ground bamboo stalk is easier to catch the illness and has more sick spots than those far away from the ground. Winter spore and summer spore may be produced successively in turn. release time of summer spore (infectious period) tally with the bamboo shoots vegetal period(sheath shedding, ramification, leaf unfolding) to, but bamboo culm rust mainly refers to disease of old injured bamboo and the disease of new bamboo that year infected with summer spore. The latent period lasts for over 7 months, or even 19 months, displaying symptom the following year after November, forming winter spore cluster. Prolonged illness spot also gradually develops into winter spore cluster, which survives winter in this way. Chronically prolonged illness spot mostly divides into 2 distinct circles: the inner layer is dead spot that is vandyke brown, no longer produces pathogen, the outer layer is yellow and changes color, which is living pathogen that may produce winter spore cluster and summer spore clusters.

The three stages of infectious winter spore clusters, the summer spore clusters

and yellow spots are rather distinct. Yellow spots include original yellow spot and developed yellow spot. Original yellow spots refers to those spots on the surface of the stalks of new or old bamboo that year that is inflicted by summer spores and that is nurtured by original yellow spot; developed yellow spots refers to yellow spots which emerge out of latent hypha around old infected spots on bamboo stalks that expand and spread, and they can become infectious only after producing winter spore and summer spore.

7.1.2 Balansia Take

Balansia take, with systematic name of *Balansia take* (Miya-ke) Hara = *Aciculosporium take* Miyake; *Phaeosphaeri bambusae* Miyake et Hara, also named broom sickness, may be divided into leaf-originated disease and branch-originated one. Leaf-originated *Balansia take* is a newly discovered plant disease, known to occur in China's Jiangsu, Zhejiang Province which endangers *Phyllostachys glauca* McClure and *Phyllostachys bambusoides* Sieb. et Zucc. that belong to *Phyllostachys* Sieb. et Zucc. As a result of the disease, new leaves and new tip of infected bamboo wither, bamboo stand turns scorch, crippling the growth of side shoot, hence forming clusters of twigs. In severe cases, the damage is more serious than branch-originated bamboo disease.

Branch-originated balansia take occurs in China's Shanxi, Henan, Anhui, Jiangsu, Zhejiang, Jiangxi, Hunan, Hubei and it also occurs in Japan, and endangers various bamboos such as species of *Phyllostachys* Sieb. et Zucc. and part of species that belongs to *Brachystachyum* Keng, *Bambusa* Reta. corr. Schreber, *Sinocalamus* McClure, especially *Phyllostachys glauca* McClure, *Phyllostachys sulphurea* cv. Viridis and *Phyllostachys heterocycla* var. *pubescens* (Mazel) Ohwi. Side ramifications grow thickly in infected bamboos, droop in cluster, grow weakly, and bamboo shoots decrease. In severe cases, the entire bamboo withers. In China's Shaoxing's Lanting and Bamboo Garden in Anji, bamboos are infected in high ratio, causing severe damage. Clusters of infected ramifies join each other, pushing down the bamboo branch and bamboo tip, hence devaluing bamboos.

7.1.2.1 Symptoms

Leaf – originated balansia take

At the initial stage, bar-like liquid stain appears on the face of new bamboo leaf. Most Infected spots centers around midrib of the leaf while some of them develop from the edge of leaf, turning jasmine first, then become tan and scorch, at last the whole leaf withers. A small part of infected spots develop slowly or stop growing. The edge of infected spots has deeper color. During the later stage, ridged dark

brown spots appear on infected upper and lower epidermis of bamboo leaves, mostly on the upper epidermis of the leaf. At last infected leaf turns taupe and sheds off. leaf – originated bamboo disease come on with new leaf and new tip affected successively. When new leaf is infected, withers and sheds, new bamboo tips will follow suit, which causes abnormal bourgeoning of the side sprout of the twig at the lower segment. The bourgeoned twig will be affected in the latter part of the year. leaf – originated bamboo disease assumes clear symptoms on bamboo. At the initial stage, bamboo leaves do not shrink. Years later, with twigs piling up, bamboo leaves gradually become smaller.

Branch-originated balansia take

Every spring bamboo sprouts come out. In late May and at the beginning of June, when 2 – 4 young leaves grow, vigorous and healthy new branches stop growing. But the new branch, which has got sick, continues to grow until August, whose new section appears slender with long internodes (on average 19 internodes, each about 36cm on average), and has sagging vine and scaled bamboo leaves. At the beginning of September, newly infected vine continues to grow once more until November. The length of vine ranges from 10 cm to over 130 cm. On the tip of some exceptional sick new bamboo branches appears pseudostroma. On the tip of infected vine-like branches, there appears a section of withered one, on which new sprout will come out at the beginning of March for the second and third times. And In May again, the 3rd and 4 ramification occurs, the fourth and fifth ramification in September and October. After 2 years growth and ramification, sick branches form a cluster of new small twigs that assumes a broom shape or nest shape.

7.1.2.2 Causes

Leaf-originated bamboo disease is caused by *Phaeosphaeri bambusae* Miyake et Hara. Ascus-fungus carpophore does not appear on sick leaves until March. Between June and July, ascus spore matures and disperses in ascus-fungus from sick leaves. After August, very few seeds in vivo remain in the ascus spore. Dust-color germ ascus seats are whole or partly buried in sick organs, dun, containing a number or a single false pouch shell, spherical or oblong, with a major axis of 195 – 270 μm long and a minor axis of 145 – 190 μm long; with round orifice on it. On the base of false pouch shell grows a row of ascus with double-decked membrane. The ascus is club-shaped or tubular, whose major axis is 68.4 – 91 mm long and minor axis is 19.5 – 32.6 μm long; In the ascus, there exist 8 ascus spores, spindle-shaped, slightly curving, faint yellow, having 3 septa, slightly crinkled. And the ascus spore has a major axis of 28.5 – 32.3 μm long and a minor axis 8.5 – 11.2 μm long.

Branch-originated balansia take is caused by *Balansia take* (Miya-ke) Hara

that belongs to the ascus fungus subdivision, nuclear fungus outline, spherical shell fungus item. M-shaped granule grown on the tip of sick bamboo branch is pseudostroma, 6.6 – 10.4 mm long, 1.4 – 2.5 mm wide, which is asexual carpophore of disease germ. The mature pseudostroma has an irregular cavity room (spore divider) and a massive of conidium. Conidium is colorless, long and slender, 34.4 – 62.1 μm in body length, 1.0 – 1.8 mm in width. In June, on the side of pseudostroma grows wart-shaped tuber that is small gray brown. When it is crinkled, the big base is pad-shaped stroma, which indicates the natural stage of disease germ. Underneath the surface layer of the stroma is bottle-shaped perithecium laid out in fan-shape, whose minor axis is 69 – 193 mm and major axis is 276 – 538 μm; Ascus is tall and slender, clavate, 198.2 – 348.8 μm in body length, 6.9 – 10.4 μm wide. The upper wall is round and thicker, having a longitudinal trace; Ascus spore is linear, 117.3 – 265.6 μm long, 1.0 – 1.8 μm wide, tall and slender and colorless. When ascus spore sprouts, many germ tubes stretch out on both sides. It is reported that in the tissue of branches infected with MLO, whose pathogenesis is yet to be studied.

7.1.2.3 Occurrence rules

Leaf-originated balansia take

Generally few new bamboo tops can be taken bad on new bamboo, but those from old sick ramifies become sick for successive years. In China's Nanjing, from the end of April to the beginning of May, when sick bamboo produce 3 pieces of tender leaves which bud, plant disease occurs at once; When all the 3 pieces of tender leaves unfold to over 600% in size, plant disease increases obviously. Afterwards disease occurring rate of new tree top dramatically rises; from Mid-May to the beginning of June, when the ten-day period average temperature exceeds 20℃, new bamboo top gradually stops growing, tender leaf stops sprouting and the disease develops more slowly; after Mid-July plant disease stops developing at all and sick leaf falls off gradually. Only a few sick leaves linger on the bamboo top. In October, if new branches grow on bamboo top of fall, a small number of tender leaves also still can be taken bad.

Branch-originated balansia take

Disease germ survives winter in sick bamboo leaves. The cause of infection is the conidium originated from spring branch that overwinters. The first infection is due to invasion of germ to the cut of tender leaves. When sprouting, infected branch is in no way different from healthy and vigorous branch. However, in May and June, vigorous and healthy new branches stop growing after sending out 2 to 4 pieces of new leafs; but infected branches still continues to grow until August, and newly

grown section is thin and viny. At the beginning of September, newly infected vine continues to grow once more until November. The top of some of new sick ramifications may grow white pseudostroma that is M-shaped. New sprout will come out at the beginning of the following March for the second and third time. In the last days of March, a small number of ramifies produce pseudostroma. And in early May over 80% of ramifying produce pseudostroma. When relative humidity is high, horn of conidium effuse from the pseudostroma, and the spore scatter with the rain—big rain and strong wind can contribute to the scattering. In Nanjing, China, spore starts to disseminate in late April. And the period from early May to middle June is the prime season for dissemination; the spore travels not far—no more than 10m. After that, the branch withers and ramifies again for a third and fourth time. Then in June, new pseudostromas appear again, and ramify for the 4th and 5th time, only 10% of which may produce pseudostroma.

The top end of infected ramifications that survives the winter start to expand in late March and in May reveal white granular false mesh—spore disseminate abundantly at the beginning of May and then the mesh wither, fall off and produce new small branch again. At the end of March, part of small ramification produces false mesh in the top-end. The false mesh grows again in September and October, 3 times a year altogether and is most abundant the first time. From late May to July, on some of the pseudostroma, the dust-color mesh forms from leaf sheath crack, causing the surface of pseudostroma to bulge—some resembling a pad, some strumae-like—that is the natural stage of germ, with perithecium buried in a row in the mesh surface layer. A suitable temperature condinium and ascus spore to sprout is approximately 25℃ and the humidity 90% or over. When old sick branch is cut off, no disease has seen to continue to be taken bad.

7.1.3 *Sarocladium oryzae* Sawada W. Gams et D. Hawks

Sarocladium oryzae Sawada W. Gams et D. Hawks was firstly reported by Rahman and Zethner in 1971 in Bangladesh, and researched in 1982. This sickness only occurs in Bangladesh, harming many kinds of bamboos. Those bamboos susceptible to *Sarocladium oryzae* Sawada W. Gams et D. Hawks, according to degree of harm, is listed in the following order: *Bambusa vulgaris* Schrader ex Wendl. and the *Bambusa vulgaris* cv. Wamin (new bamboo stand suffering damage seriously with the rate for single-cluster bamboo to be killed of as high as 40% -75%); Next is *Bambusa flexuosa* Munro (new bamboo suffers medium damage with the damage rate of a single-cluster harmed reaching rate 25% -75%). Additionally, there is *Bambusa tulda* Roxb. (lixin new filial bamboo), which mildly suffers injury with a damage rate for a single cluster of 25% -50%. Plant disease is most serious to *Bambusa vulgaris* Schrader ex Wendl., and can cause bamboo cluster to die. It is also repor-

ted that if decayed bamboo is harmed, a bamboo stand may destroy on a large scale.

7.1.3.1 Symptoms

Infected bamboo shoots first appear on internodes 50 – 60cm away from the tip. The upper tissue of the infected bamboo is not observable as it is covered with shoot sheath. Its infection is deduced by abnormal death of the shoot sheath. Bamboo shoots all may suffer invasion in the growth process. From June to November, when bamboo shoots is 1 – 4m tall, it is taken bad heavily. Sometimes bamboos over 8m tall are also susceptible. New bamboos that even slightly wither (no withered twig or strips are seen then) can stop growing, but plant disease cannot infect strong new bamboos that have grown tall. At the later stage of infection, the bamboo shoots may develop into crownless bamboo, with withered remnant of varying degree on the top; underneath the withered tip is withered strip spot. Shoot sheath Removed, black sick spot can be seen on the stalk; when necrosis sickness spot expands to a certain degree, tissues above sick spots wither to death, preventing plant disease from spreading. They form linear sick speckles while the infected tissue dies. Virtually in all circumstances, sick spot coexist with pests' holes and eaten tunnels. The black spot spread upward and downward, in which pests play a very vital role in spreading and disseminating the disease into and between stalks.

7.1.3.2 Separations of disease germs

From May to August, if infected bamboo shoots with decayed spots and bamboo leaves infected for 7 to 90 days are picked as samples for separation, *Sarocladium oryzae* and Sawada W. Gams et D Hawks can be obtained, with a separation discovery rate of 61% and 81% respectively. Samples from infected bamboos that bear withered bamboo shoot tips, sick spots and insect holes show a separation discovery rate of 100%. Samples from main item bamboo and small twigs and shoot sheath of *Bambusa vulgaris* Schrader ex Wendl. and *Bambusa flexuosa* Munro, show that the separation rate is the highest in *Sarocladium oryzae*, which displays typical symptoms of *Sarocladium oryzae* after the inoculation and from which disease germ can be derived from the inoculated tissue. Through cultivation of the infected tissue, disease germ of *Sarocladium oryzae* assumes a high frequency of occurrence. Other separator includes *Fusarium moniliformae* Sheld and *Staehybotris bisbvi* (Sriniv.), but they do not show symptoms of *Sarocladium oryzae.*

7.2 Major Insect Pests of Sympodial Bamboos

There are many kinds of insects that feed on bamboo. While the majority of them

do not cause serious damage or affect the normal growth of bamboo, some insects may do some harm to it. It is estimated that there are more than 100 kinds of insects like that. And dozens of insects like this may result in serious damage, and even causes massive areas of bamboos stands to die, which poses a potential heavy loss in bamboo production.

7.2.1 *Cyrtotrachelus buqueti* Guer.

Cyrtotrachelus buqueti Guer. , also named the horizontal awl elephantinsect, distributes in China's Fujian, Guangdong, Guangxi, Sichuan, Guizhou, Yunnan Provinces. It endangers *Bambusa pervariabilis* McClure, *Bambusa chungii* McClure, *Dendrocalamopsis oldhami* (Munro) Keng f. and *Bambusa textilis* McClure, especially those thick bamboo shoots over 2cm in diameter. The damage rate is 10% – 25% generally. Together with the *Cyrtotrachelus longimanus*, *Cyrtotrachelus buqueti* Guer. harms bamboo stand, whose bamboo shoots can be killed at a rate as high as above 90%.

7.2.1.1 Morphological characteristics

Adult. Female adult is 26 – 38mm long while male adult is 25 – 39mm long, orange yellow or vandyke brown in color. The head is hemispheroid, black; the tubular proboscis stretches out from the forehead, black. For female adult, the proboscis is 9.4 – 15.5mm, slightly smooth. On both of its sides is a shallow rut. For male adult, it is 8.5 – 12.5mm with clear rut, on the back of whose edge are dentations, 7 – 8 pieces for each side. The geniculate antenna is born with a crescent moon shaped ditch in the rear of the proboscis. The notum of the front thorax is like a round bulge; at the center of the back edge is an arrow-like black spot; the elytron is yellow or vandyke brown; outer edge is round and corner of the stern has a sharp tuber on it. When the two wings fold, a 90-degree angle dentation forms. The femur and tibia of the foreleg are longer than that of the middle and hind legs. The female adult's femur is longer or equal to the tibia, on which the inside brown hair is sparse and short; the male adult's foreleg is long and big, whose femur is shorter than the tibia. The brown hair underneath the tibia is long and thick.

Egg. It is oblong, having a major axis of 4.0 – 5.2mm long, slightly tine at the top end, round at the lower end, milk white when born, glossy, changes gradually into fresh yellow. The surface is smooth and free from streak.

Larva. Newly hatched larva is 5mm long, milk white all over; Old mature larva is 46 – 55mm, deep yellow in color, a tan head, a big black mandible. The front thorax notum is somewhat ossified, with a scutum on it which has a vandyke brown spot like the glyph "eight". The body is full of creased trough and does not have any streak.

Pupa. It is 35 – 50mm in length, milk white when born, changes gradually into dust yellow. The back edge of the front thorax notum has brown arrow-shaped lines. The pupa is hard, covered with scrapes of bamboo leaves, weed and soil particles.

7.2.1.2 Biological characteristics

The cyrtotrachelus longimanus lives for 1 generation in China's Guangdong Province per year. Adult survives winter in pupa room under soil and unearths in mid-June the next year. The last ten days of August is the prime season. Adult appears in bamboo stand in early October. The egg stage is from last ten days of in June to mid-October. The larva is active from mid or late June to mid-October. Larva eats in bamboo shoots, and matures in 11 – 16 days, pupates from mid-July to late October, emerges between the beginning of August and early November and survives winter in the earth pupa.

Adult. In mid-June, when daily average temperature reaches above 27 – 28℃, an adult starts to unearth. The best time to unearth is 6 – 9am and 16 – 19pm in the day. Newly unearthed adult is sluggish and does not move at noon, on rainy days and in the evening. It hides at the back of bamboo leaves, or under fallen leaves or in weeds instead. And an adult becomes most active after it lets up and moves about at 8 – 12 am and 15 – 18 pm. An Adult is good at soaring, which enables it to seek for bamboo shoots for nutrition and seek mates for coupling and spawn. Adult are capable of showing fake death, when frightened or vibrated, it will crash to ground with abdomen upward, and immediately turns over to crawl or flies away; Also a small portion of adult may flutter when falling.

Right after unearthing, the adult can climb onto bamboo shoots, pecking at bamboo shoots to supplement nutrition with head downward, and can mate in 2 days. Often the male adult flies over to rest by female adult, and couple with the latter after several probes. Very often, one female adult can attract many male adults to come and compete for coupling. The coupling may occur for several times. At that time, the female keeps eating. After coupling the female adult spawns right away. When spawning, the female has to fly around to seek for thicker bamboo shoots over 2cm in diameter, and crawl from the lower part of the bamboo to the upper part to stay on, if no bamboo shoot is found to have been spawned on, the female adult turns around to peck for a whole in order to lay egg. An egg pit is 2 – 3 mm deep inside bamboo and 6mm long, 3mm wide. Seen from outside, the pit is round with scrapes of bamboo shoots fiber are exposed. After the pit is completed, the adult withdraws its beck, turns round and stretches its tail into the pit, thus the egg is produced. At most, three eggs may be produced on bamboo shoots. Spawning season may last 15 – 20 days. Each adult spawns 35 – 40 grains, the adult lives

a life of 40 – 70 days. And the ratio of life span between a female adult and a male adult's is 1∶1.

Larva. 1 – 3 days after an adult spawns on bamboo shoots, bluish gray liquid may be seen flowing from the egg pit, from which black liquid comes out 3 – 4 days later. And another 3 – 4 days later, 2 tiny red spots appear on the top end of the egg, indicating the egg is to be hatched. Newly hatched larva moves upward for food after breaking out of the shell, eating only a little, though; larvae of 2 durations move upward in side way, then horizontally; larva of 3 durations eat more, again moves in side way upward for food and leave behind a "z" shaped path until it reaches the top of the bamboo. Then the bamboo shoots stop growing, and the larva turn round for food again, eating up the upper half of bamboo shoots. One larva may eat 20 – 30cm of bamboo shoots in its entire lifetime. As a result the damaged bamboo shoots stops growing and dies prematurely. Larva of 5 durations, the old mature larva, eats bamboo from inside the bamboo shoots, and in one morning bites out a round hole of about 8cm in diameter, then builds a slanting landslide underneath the round hole with bamboo shoot fiber. Then in the morning the larva wriggles to the edge of the round hole and rolls out to the ground. The larva wriggles along the slope in the ground, moving rapidly, seeks a site with loose soil, excavates with the big mandible, digs up the soil, continues to drill downward to the point 20 – 30cm deep, and crawls onto the ground again to drag in some weeds, bamboo leaves or tree leaf into the hole to mix with the clay. Thus the room is completed. The site of earth room ranges from 9cm to 63cm below the ground, with inside diameter 45 – 65mm long. At entrances on the ground piles up a circle of fine soil. The larva in the earth room pupated after 8 – 11 days; after another 11 – 15 days turns into an adult again to survive winter.

7.2.2 *Cyrtotrachelus longimamus* Fabricius

Cyrtotrachelus longimamus Fabricius, with other name, called as bamboo shoot straight cone elephant and popular name bamboo shoot tail range, is distributed in Zhejiang (Wenzhou, Zhoushan), Fujian, Hunan, Guangdong, Guangxi, Sichuan, Guizhou (area) in China and India. It harms bamboo shoots of less than 2cm in diameter such as *Bambusa textilis* McClure, *Dendrocalamopsis oldhami* (Munro) Keng f., and *Phyllostachys heteroclada* Oliver. An adult *Cyrtotrachelus longimamus* Fabricius pecks bamboo shoot from outside while a larva eats bamboo shoots from inside. As a result, plenty of dead shoots, which caused by insects, appear and those bamboo shoots that at last grow into bamboos become abnormal or crownless. Often over 30% of bamboo shoots are harmed, of which over 90% are severely damaged. This insect often works with *Cyrtotrachelus buqueti* Guer. successively to aggravate the damage on bamboo stands. On the 50,000 ha of bamboo stands in

Zhaoqing district of China's Guangdong Province, 50,000 tons of bamboos are lost as a result of such damage every year.

7.2.2.1 Morphological characteristics

Adult. Female Adult is 20 – 30 mm long, male 22 – 34 mm long. Newly emerged adult has fresh yellow color and turns into orange yellow, tan or Vandyke brown after breaking out from the soil. Its head is hemispheroid-shaped, black. A tubular proboscis stretches out from the hemisphere forehead, 9 – 11 mm long, smooth. Flageolet of male adult is slightly short with a rut on the back that has a row of dentate bulge on either side. On the back edge of the nota in the front thorax is an irregular round black spot. The outer line of the elytrum is arc-shaped; the anal tip is obtuse, does not have sharp spine. When two wings fold its center is sunken. The femora and tibia of foreleg are as long as middle and hind feet.

Egg. It is oblong with a major axis of 3.0 – 4.0 mm long and a minor axis of 1.2 – 1.3 mm. When initially hatched, an egg is milk white, and then changes gradually for milk yellow. Before hatched it is pale brown, glossy, with a smooth earth streak on the shell.

Larva. Newly hatched larva is long 4mm, milk white in body color, fawn in head shell, having an indistinct metamere; Old mature larva is 38 – 48mm long with a deep yellow body, henna head, black mouth apparatus. The front nota is ossified, bearing a yellow spot, in which there is no Vandyke brown caret-shaped grain; on the body there are lots of wrinkle troughs and inconspicuous grey back lines which are streakless.

Pupa. A pupa is 35 – 45mm long. When initially pupated, it is milk white, later changes gradually for tan. The back edge center of front thorax has an irregular round shallow chloasma; the valve in the front thorax is big and black. The oblong 53 – 67mm long pupa is made of bamboo shoots fiber and soil.

7.2.2.2 Biological characteristics

In China each generation of *Cyrtotrachelus longimamus* Fabricius lives for 1 year, survives winter as an adult in pupa room under earth. For insect state In Zhejiang, Guangdong, Guangxi (area). The starting time for adult to unearth is 10 days earlier in Guangdong compared with Guangxi, 30 – 40 day earlier compared with Zhejiang, but the finishing time is basically the same of 3 provinces (area). That is, late September. Thus other initial period of the insect's biological stage, are all based on that of adult, put off correspondingly. So it is with the finish time.

Adult. In Zhejiang Province in China, during the middle and late period of June, and during the middle and late part of May in Guangdong, over wintering adult comes to the ground when the average daily temperature reaches 24 – 25℃.

Most adult come out of the soil when daily temperature reaches 27 – 28℃. The period of 6 – 9am, and 16 – 19pm, is the peak time for adult to come out. They usually hide themselves and remain still after that. 24 hours later they will move about. Adult starts moving about early in the morning when dew dries, usually at 6 – 7am. The earliest ones starts at 6 – 7am, most of the adults becoming active in the period between 8 – 10am or 14 – 17pm, and retiring at 20pm. During the noon, night and rainy days they tend to perch on the back of bamboo leaves, or on the ground. Adults are good at flying, yet they only fly abuzz short distance in the bamboo stand in search of bamboo shoots for nutrition or laying eggs. Adult has apparent death when disturbed; it will fall to the ground and hide them in the grass or start up. Apparent death is not so obvious at noon. After two days' nourishment, an adult is ready to mate. After 2 days supplement of nutrition an adult can couple. When female adult couples it keeps taking food on bamboo shoots with head downward. Both female and male adult might couple for many times. A female adult can spawn right after coupling. First the adult flies to the 1 and 2cm-thick bamboo shoot where no spawn has ever been produced. There it pecks out a micropyle at the bamboo shoot 10 – 30cm away from the top, then turn round and goes upward, spawns 1 grain of egg, leaving neat shoot sheath textile fiber outside the micropyle. A female adult spawns 25 – 30 grains of eggs and lives for 50 – 90days.

Larva. An egg is hatched in China's Zhejiang Province in 4 – 5 days, in Guangdong Province in 3 – 4 days. Before hatched, an egg assumes tan color, egg shell split longitudinally, then larva comes out. Newly hatched larva has little activity, but can eat bamboo shoots 3 hours and a half later with it tiny intestines; The larva first eats upward, after 3 – 4 days their appetite increases. It does not turn round downward until it has arrived at the top of bamboo shoots. At that time it will move to 20 – 25cm below the hole where an egg is laid. The larva eats up 25 – 35cm of bamboo shoot leaving excrement in intestines, which often causes where larva eats filled with excrement. The larva lasts for 5 durations, that is, 12 – 15 days in Guangdong, 26 – 29 days in Zhejiang. When a larva is old and mature, the top of damaged bamboo shoot withers to yellow, and the eaten section turns soft. The old mature larva often moves upward along where it has eaten late at night in bamboo shoots, and crawls to the place 13 – 20cm away from the top of bamboo shoot. Then it bites the top of the bamboo shoot off and discard it, leaving a neat margin there, and building up intestines with bits of bamboo shoot and excrement. Next it turns around downward for about 7cm, again cutting off this section of bamboo shoots, and falls to the ground with the section that is called "the bamboo shoots tube" or "the bamboo shoot tail"; some larva falls to the ground clinging to the top of bamboo shoot that is cut off previously then eat out the upper section of the bamboo shoot and stays in the lower section of the "tube". The larva may crawl

on the ground with the "tube" on its back and go into the ground where it is a suitable. And if it is daytime, it will stay in the "tube" and will not bury the bamboo shoot until it is dark. When entering the ground, the larva loosens the soil with the upper mandible, and pushes the soil toward the entrance to a certain depth, then drills horizontally. The path and depth vary with soil texture, which range from 12cm to 45cm and mostly 25cm. When the larva builds pupa room, it has to return to the entrance several times to drag in some "tube" fibers to mix with soil, and after approximately 10 – 12 days, again ecdysis and pupate, and after another 12 – 15 days become adult to survive winter.

7.2.3 *Hieroglyphus tonkinensis* I. Bol

Hieroglyphus tonkinensis I. Bol belongs to Acrididae of orthoptera and is distributed in areas like Zhejiang, Fujian, Taiwan, Jiangxi, Hunan, Hubei, Guangdong, Guangxi and Guizhou in China. It harms *Sinobambusa tootsik* (Sieb.) Makino, *Bambusa eutuldoides* McClure, *Bambusa multiple* cv. Fernleaf, *Bambusa textilis* McClure, *Bambusa chungii* McClure, *Phyllostachys sulphurea* cv. Viridis, *Phyllostachys heterocycla* var. *pubescens* (Mazel) Ohwi, the *Phyllostachys heteroclada* Oliver, *Phyllostachys glauca* McClure, *Dendrocalamopsis oldhami* (Munro) Keng f., sugar cane, paddy rice and Chinese fan-palm. It was discovered most lately to be one of the major harmful insects to endanger bamboos. Especially bamboo stands around houses, at the foot of a hill, on banks of rivers and streams are killed heavily. When it occurs in Fujian, the insect population reaches 200 heads per square meter in density while, in Zhejiang, following the disaster of yellow-spined bamboo locust, this insect aggravated the harm, leaving large expanses of bamboo stand withered.

7.2.3.1 Morphological characteristics

Adult. A male adult is 32 – 38mm long, female adult 41 – 42mm long. Its body is yellowish dark green; its forehead and the two sides of its head are yellow. The compound eyes are oval, big and tan. The antenna is 18 – 23mm long with a faint yellow base, 2 – 4 sections of which are white and 10 sections blue-black on the tip. The central backboard of front thorax is concave, saddle-shaped with 4 deep black horizontal lines. The first line is not connected at the back and the 2nd line only exists at the back without extension. The wing extends beyond the abdomen with a hilly green base and a smoke brown tip. The hinder femur is faint yellow. Near the greenish tibia is a black loop. And there are 2 rows of thrusts on the outer flank of the tibia, of which 9 are outer lines and 8 are inner lines that are slightly short.

Egg. An egg is oblong and slightly curved with a major axis 4.5 – 5.5mm long and a minor axis of 1.0 – 1.2mm long. At birth an egg is yellow white, later its

color turns deep. The oogonium is oval, slightly curved, with an obtuse bigger and round lower tip. And the upper tip is covered with honeycomb-like stuff. The oogonium has a major axis of 10 – 26mm long and a minor axis of 5.0 – 7.5mm long, including the honeycomb-like stuff of 4.0 – 9.0mm.

Nymph. A nymph lives for 7 durations. For the details of a nymph's body length, antenna length, pitch number and wing bud length. Old mature nymph is blue-green.

7.2.3.2 Biological characteristics

In China, there is one generation of *Hieroglyphus tonkinensis* I. Bol per year which survives winter as a egg and is hatched from mid-April to the beginning of May in China's Guangdong Province and in the last ten days of May in Zhejiang Province. Nymphae live for 7 durations. Their eclosion occurs on and off between the end of June and the beginning of August. The prime seasons arrives in the middle and last ten days of July. Coupling occurs from the beginning of July to early October. In Guangdong Province coupling takes place at the end of July, and in Zhejiang Province the beginning of August is the peak time of coupling. From the beginning of July to mid-September, an adult spawns to survive winter.

Adult. Emergence may occur in the day or at night, mostly in the afternoon. Generally, male adult's emergence occurs 3 – 5 days earlier than the female and the activity lasts even for one month. At that time, the nymph tightly holds to bamboo branch with its 6 legs and a 20 – 40 minutes later ecdysis takes place, which draw a close to the process. The reproductive organ of newly emerged adult is not fully developed and there for the adult must take a large amount of bamboo leaves to supplement nutrition. It eats quite fiercely, often soaring to seek bamboo leaves and it also has cybotaxis. The adult is ready for coupling after 15 – 30 days intake of supplement nutrition. The coupling often occurs in the daytime. Both female and male adults are capable of copulating many times, at least 3 – 5 times, sometimes 12 – 15 times; each time it lasts 3 – 6 hours, the longer one may reach 40 hours. After coupling the male adult eats little and gradually approaches its death; a female adult still need to eat a massive amount of bamboo leaves before starting to spawn about 10 day later. When spawning, the female adult first digs the soil with its ovipositor, next secretes foaming stuff, then produces 15 – 35 grains of spawns in the froth, finally secretes the foaming mucilage to seal the hole and forms the oogonium. Each time process lasts for 1.5 – 4 hour. Each adult produce 2 – 8 oogoniums, which is buried 2 – 5cm under the ground and the female adult dies soon after it finishes spawning.

Nymphae. In Guangdong, in April overwintering oogonium gradually becomes loose after absorbing water. When average daily temperature reaches above

24℃, the egg grains start to expand, the surface turning smooth and soon are hatched, which usually takes place during 14 – 19 pm in sunny days, and fewer eggs are hatches on overcast and rainy days. Identical egg block may hatch simultaneously, but sometimes some eggs are delayed for 3 – 5 days. It takes 4 – 12 minutes to hatch. Newly hatched nymph stays still for 10 – 30 minutes after it comes onto the ground and can move about once the body color deepens. The hatching rate is 90% – 98%. Initially hatched nymph does not eat at the same day but nibbles at the edge of bamboo leaves leaving them edged approximately 30 hours later. Nymph of 2 durations is able to eat up the entire or large part of the bamboo leaf, until only the main nerve is left. Initially hatched nymph has weak mobility and often crawls to the neighboring grass families. The nymph of 1 – 2 durations swarms on the sprigs of bamboo for food, often with 10 to 100 heads weighing down the sprig; 3 durations later the nymph gains strengthens, gradually disperses to search for food, often gathering in a dozen, and jumps up onto bamboo or big ramifications for food. The nymph's appetite improves with age and can eat old leaves at last. One nymph can consume 450 – 550 square cm of bamboo leaves in its cycle. And at the last period the nymph take as much as 32% – 38% of what it may take in the entire cycle. The nymph mostly takes food during 8 – 11 pm or 16 – 20pm, and does not eat anything at noon or on rainy days.

7.2.4 Green Slug-caterpillars

Green slug-caterpillar, whose systematic name is *Parasa bicolor* (Walker), belongs to slug-caterpillar branch of lepidoptera and is distributed in Anhui, Jiangsu, Zhejiang, Fujian, Taiwan, Jiangxi, Hunan, Sichuan, Guangxi, Yunnan (area) in China; Sri Lanka, India, Burma, the Sikkim and Indonesia as well. This insect is harmful to *Phyllostachys heterocycla* var. *pubescens* (Mazel) Ohwi, *Phyllostachys sulphurea* cv. Viridis, *Phyllostachys glauca* McClure, *Pleioblastus amarus* (Keng) Keng f., *Sinobambusa tootsik* (Sieb.) Makino, *Bambusa pervariabilis* McClure, *Bambusa textilis* McClure, *Phyllostachys bambusoides* f. lacrima-deae Keng f. et Wen, *Bambusa rutila* McClure, *Phyllostachys bambusoides* Sieb. et Zucc., *Phyllostachys heteroclada* Oliver and tea. Larvae of green slug-caterpillar in massive number feed on bamboo leaves and in severe cases may cause bamboo to wither and reduce bamboo shoots of the following year and quality of new bamboo.

7.2.4.1 Morphological characteristics

An adult is 13 – 19mm long. Its wing is 30 – 44mm long when fully opened. The vertex, prothorax and the back are green and the belly is brown yellow. Female adult has a threadlike antenna while male adult's antenna is ctenoid with 1/4 of threadlike tip. It has black ommateum, brown yellow lower labial palp, green fore-

wing and tan hair on outer and margin anterior border. There are 2 rows of little brown spots on the outer borderline and minor outer wing. While the two spots on the outer wing are bigger, those 4 – 6 spots on the minor borderline are smaller. The hinder wing is brown yellow.

Egg. It is oval, flat, and 1.5mm long in major axis. When hatched, it is light yellow, gradually turning ivory-white and slightly transparent. Eggs are laid out in scale-work, covered with transparent membrane.

Larva. Old grown larva is 26 – 32mm long and yellowish green in color. It has bluish gray and slightly purple ridge that is a little bit broad. On each puncture on the back is semicircular dark green spot, inlaid in the back line, altogether 8 pairs. The minor back line is cyan; on each puncture is a black spot respectively. Above the minor back line and valve line is a row of punctures respectively. No puncture on the front thorax knurl, which actually has shrunk under the central thorax with the head. The punctures on central thorax and back thorax and the first, seventh and eighth abdominal segments are especially long. The eighth and ninth abdominal segments each have a pair of black fabric spherical hair clump. Outside each hair clump grows a brown red puncture.

Pupa. A pupa is 12 – 16mm long, milk white in color when hatched which gradually changes for yellowish brown color. The hinder tarsus reveals anterior wing bud with three pairs of valve on the abdomen. The back is covered with broad bands composed of many brown spinules hook. The tip of the abdomen is round and obtuse. The pupa is oblong, major axis 15 – 21 mm. There are two layers of pupas, the dust-color out layer loose, the top assuming a truncation shape, with one even lid of 6mm in diameter that has a round hole in the middle. The inner layer is sol, hard, and crisp, brown in color. Above the space between the inner and outer layer exists a big crevice.

7.2.4.2 Biological characteristics

In Jiangsu Province and Zhejiang Province in China, one generation of pupa exists for 1 year, and in Guangdong Province in China there are 3 generations per year. A mature larvae overwinters in pupa 2 – 3cm below surface soil. In Zhejiang Province it pupates in early or mid May; at the beginning of June green slug-caterpillars first appear and the middle period in mid June, is the prime season of laying eggs; between the mid-June and late August, larvae endanger bamboo. In mid-August old mature larva leaves the bamboo and dig into the earth to spin pupas and overwinter. In Guangdong Province each generation appears respectively from mid-April to late May, from the end of June to late July, from the beginning of September to early October. The period when larva eat bamboo leaves is from late May to mid-June, from the beginning of July to the late August, from the beginning of September to

early November respectively.

Adult. In Guangdong Province green slug-caterpillars pupates between late March and early April, in Zhejiang Province between late April and beginning of May and a pupa turns into insect 23 – 29 days later. Pupa's emergence begins at 16 pm and ends at 23 pm, at 18 – 23 reaches the peak when 60% or so pupas emergence. In the daytime, the adult stays still, while at night it moves about and is most active at dusk and before daybreak; adult has photoaxis, more males fly toward light than females do. Between 19 – 23 pm and 21 – 22 pm such activity reaches the peak. After emergence that very evening or late the next day, the adult may couple, which occurs mostly between 23pm to 4 am, and lasts for about 2 hours. Male and female Adult couples only once a lifetime. After the coupling male adult dies soon, female adult lays eggs at the same day or the next day. The eggs assumes a scale-shape in single line or in two rows and is produced by either side of the costa at the back of the bamboo leaves, with each egg block containing 16 – 36 grains of eggs, occasionally 5 – 6 grains, at most over 100 grains. Every female adult produces 8 – 12 blocks of eggs that is altogether 120 – 340 grains. Right After that, the female adult dies after living for a span of 4 – 8 days.

Larva. The incubation period of larva lasts for 8 – 10 days in Zhejiang Province and 5 – 7 days in Guangdong Province. At first newly hatched larva stays close by egg shells in swarms; soon it is able to feed on the lower epidermis of bamboo leaves, causing them to wither and forming blocks of white membrane. Larvae of 2 durations gathers round the original egg clump or scatters into 2 – 3 groups searching for food, preferring leaves of new bamboos. Larvae older than 2 – 3 durations are able to feed on the entire leaf. Usually a dozen larvae juxtapose on the back of bamboo leave, with heads on the tip of leaves nibbling at the same time. It will move backward while eating and the bamboo leaves are at last left with even margins. Larvae older than 3 durations often form single-file line in a dozen with head and tail docking, crawling and moving on the bamboo stalk and branch. After the larvae pass by, a silver-white glistening mucilage trace is left and does not shed long after it dries. Larva period lasts for 8 durations, which is 33 – 37 days in Guangdong, and 40 – 60 days in Zhejiang.

7.2.4.3 Natural enemies

Double-colored green slug-caterpillars do not have many natural enemies. During egg stage adult and larvaeprey upon them, with a rate not very high though. During lava period, Green slug-caterpillars prey on them; also slug-caterpillar cab ichneumon is autoecious in them with a percentage of 4%.

7.3 Prevention and Control of Insect Pests of Sympodial Bamboos

As mentioned above, many plant diseases and insect pests endanger the normal growth of bamboo, even result in deterioration and death of large expanses of bamboo stands, causing huge economic loss and ecological environmental destruction, which arouses people's special concern. Research on bamboo disease has made remarkable progress and achieved notable success, which has laid a good foundation for further prevention and control both in terms of strategy and method.

7.3.1 Prevention and Control Strategies

At first, when a certain plant disease or insect pest endangers bamboo stands, people tend to hold the manner of adopting single means of prevention and control. In that way, the effect was perhaps obvious at that time, but that could not fundamentally stop disease from occurring and spreading once again. People learned lesson from multitudinous failures and defeats and realized that it was essential to first establish a scientific prevention and control strategy, then formulate prevention and control means which conforms to development law to achieve the desired effect. Bamboo plant disease prevention and control strategy can be summarized as the following main points.

7.3.1.1 Priority on prevention

Once bamboo disease and insect pest occur, it is difficult to control. Not only does it consume manpower, physical resource and financial resource, but also, as transportation is inconvenient in mountainous areas, which are densely forested, it is extremely difficult to deal with bamboo disease and the effect is not often ideal. Therefore, prevention work is especially important. It is necessary to set up the guiding ideology that prevention outweighs control and special attention should be paid to the following aspects.

Quarantine

Circulation of bamboo, bamboo product, bamboo shoots and nursery stocks carry with it plant disease and insect pests to where environmental condition is suitable for plant diseases to occur. Therefore, it is vital to strengthen quarantine in the circulation process of bamboo, bamboo product, bamboo shoots and nursery stocks.

Precaution

Occurrence and development of plant disease undergo a process of change from in-

fancy to maturity, from quantity to quality. Dynamically monitoring plant disease, establishing early warning system, formulating prevention and control system are an important measure in controlling plant disease's large-scale occurrence and an important factor in determining whether further action is needed to deal with the disease.

Prevention

Occurrence and spread of bamboo disease need certain environmental condition. A change of some element in the environmental condition often can suppress some plant disease or insect pests from occurring. Practice has proved that, bamboo stands with good sanitary condition and less pest carrier are less likely to subject to pest disasters.

7.3.1.2 Comprehensive prevention and control

Occurrence and spread of a certain disease, is related not only to the plant disease and insect pest themselves, but also to the environmental condition. Not any single way or method can yield ideal effect. It is advisable to take comprehensive prevention and control measures based on development law of plant disease. Such measures include: bamboo stand management, physical prevention and control, biological prevention and control, medical prevention and control. Comprehensive prevention and control may reduce occurrence and probability developing into plague of plant disease, thus the method is superior and can better achieve prevention and control effect.

7.3.1.3 Ecotype prevention and control

Ecotype prevention and control refers to improving immunity of bamboo stand ecosystem to the occurrence, spread and plague of plant diseases under the guidance of forest ecological principle and through adjustment. In the bamboo stand ecosystem all elements are closely linked. These relations are either advantageous or disadvantageous to bamboo growth. But in most cases, these elements are at a state of equilibrium that enables bamboo to grow healthily free from harm. Artificial adjustment is adjusting relations between each living organism so that it can keep a dynamic balance. Some accidental external factors including inappropriate human activities often can destroy this kind of balance. For example, when preventing and controlling some kind of insect pests by inappropriately using drugs, some natural enemies of pests may also be killed. Once this kind of harmful pests come on again, without any natural enemy to keep them off, it will inevitably spread and expand and eventually develop into a plague. Ecotype prevention and control also have another meaning, that is, trying to avoid adverse effect brought about by disease and pest

prevention and control onto bamboo products and ecological environment. For example, using improper agricultural chemicals to control insect may leave inadequate amount of residual of agricultural chemicals in bamboo shoots, which will affect food security, at the same time pollute the environment. Therefore, ecotype prevention and control is also environment friendly.

7.3.2 Methods of Disease Prevention and Control

During the past years, with accumulation of experience, people have continually been improving their understanding and strategy of plant disease prevention and control, and invented plenty of effective methods correspondingly. The methods can be classified as: prevention and control by managing; stands prevention; physical prevention and control; biological prevention and control and medical prevention and control.

7.3.2.1 Prevention and control by management of bamboo stands

It means preventing and reducing plant disease occurrences through managing the bamboo stands to realize prevention and control of diseases. It mainly includes:

Eliminating disease-carrying insect carrier

Promptly eliminating sick bamboo, sick ramifications of bamboo, infected bamboo and bamboo shoots, may help reduce the occurrence, aggravation and spread of plant disease. At present the best way to prevent and control cluster branch disease is to promptly wipe out and destroy infected ramifies. Prompt elimination of infected bamboo shoots may help reduce density of harmful insects during bamboo period, thus reduce the damage.

Weeding

By removing weeds in bamboo stands, some interhosts for larvae pests will be cut off; the removed weeds can be stacked to produce composts and kill eggs. This method may reduce the harm to bamboo shoots by above 40%.

Sanitation in the bamboo stand

By controlling the density of bamboo stand density to maintain good ventilation and illumination in the bamboo stands, occurrence of plant disease like bamboo culm rust may decrease.

Protecting natural enemies

The natural enemy plays an important role in preventing the emergence and spread of pest disease. For example, bamboo locust has many natural enemies, such as

thrush, swallow, happy cuckoo, crow, red-mouth blue peacock, bamboo partridge - birds; ground beetle, insect-eating stinkbug, insect-eating horsefly, ant and so on which preys on locust nymph; praying mantis and wasp that prey on insect locust nymph as well as spider that preys on locust nymph—preying insect; black egg bee that is parasite to locust egg, musca to locust nymph, musca to adult—parasitic insect; Grass-hugging fungus living on bamboo locus—parasitic fungus. Protecting natural enemies of plant pests involves maintaining suitable environmental condition for natural enemies on the one hand, reducing harm from agricultural chemicals on the other hand.

Winter hoeing. In the winter hoe soil shallowly. This may destroy the environment where harmful insects survive winter and kill harmful insects or ovum.

7.3.2.2 Physical prevention and control

Physical prevention and control is defined against medical method. It usually includes the following.

Luring and killing pests by light, then kill them

Luring and killing insect by using light since some pests are fond of light. For example, before insects such as bamboo cicada, bamboo locus, bamboo shoots noctuid, bamboo boat moth become insect after emergence, installs black light lamp in the forest to lure and kill insect. It is very effective.

Manual capture

The adult cyrtotrachelus longimanus insect which is very large, bright colored and capable of playing dead, is easy to catch and suitable for manual capture.

Scraping infected spot

To bamboo stand lightly infected with bamboo culm rust, use a knife to peel off winter spores on the bamboo stalks effectively.

Luring and killing pests with strong smell

Adult bamboo shoots Musca have the strong fondness of stench smell. Put Things like fish internal organs and rotten bamboo mixed with pesticide in the forest. This method is quite useful.

7.3.2.3 Biological prevention and control

Prevention and control of pests by fungus and insects. For example, release redeye richogramma, during the ovulation period of green slug-caterpillars, 1,200,000 heads per hectare to control green slug-caterpillars of the same year. Using blue in-

sect fungus, Su Yunjin bacillus liquid which has a spore content of above 10 billion per gram to spray on green slug-caterpillars, can reach an effect of above 90%.

7.3.2.4 Medical prevention and control

Medical prevention and control always have been the main method in preventing bamboo disease, which cannot be replaced by any other prevailing means. When plant disease massively occurs, medical prevention takes effect in controlling epidemic situation within a short time.

The following should be noted about this point:

Selection of medicine

First, Drugs should be selected pertinently. Select the most effective drug for each specific pest or disease; second, the drug selected should have the minimum negative effect on the environment, food safety and protection of natural enemies (see Figure 7.1).

Figure 7.1 Pesticide

Adequate timing and amount

Choosing the best time to apply drug can achieve twice the effect with half the effort: with moderate amount, the best effect can be achieved, no drug wasted, less pollution incurred.

Figure 7.2 Smearing Pesticide

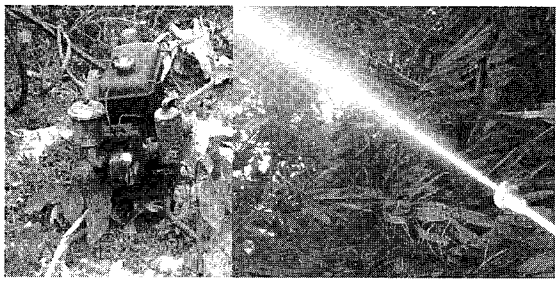

Figure 7.3 Spraying Pesticide

Proper method

Different pests do harm to different parts of bamboo in different ways. Therefore, different methods should be adopted in treating bamboo disease. For example, to leaf-eating insects like bamboo cicada and bamboo locus, medical spraying and smoking can be applied, but to insects which do harm to bamboo shoots or bamboo culms such as elephant insect, it is better to use cavity injection or stalk painting than spraying(see Figure 7.2 & Figure 7.3).

CHAPTER 8

Techniques of Major Economical Sympodial Bamboos Species

8.1 *Dendrocalamus latiflorus* Munro

Systematic name: *Dendrocalamus latiflorus* Munro
Large-sized sympodial bamboos species; culms 15-25m tall, 8-25cm in diameter, internodes 30-50cm long, culm wall 1-3cm thick. Young culms covered with white powder on the surface, a ring of brown hair annulus below each node. Sheaths thick-leathery, early deciduous, apex round on each shoulder, sheath tip rather narrow, sparsely covered with easily deciduous brown bristly hairs abaxially; auricles delicate, linear evaginating, sparse; ligules 2-4mm tall, dentelated; foliage leaf ovate-lanceolate, evaginating, covered with pale brown bristly hairs on the belly. More branches on each node, primary one usually solitary. Leaf blade large sized, 18 – 30cm long, 4 – 8cm wide. Shooting period 7 – 9 months.

Its shoots are big in size with thick flesh and taper like. It tastes crisp, tender, and slightly bitter and the shoot texture tastes a bit crude. It is edible directly after rinsing, and can be processed into bamboo strips of good quality or sore shoot, soy sauce shoot, canned shoot, etc after ferment. Culms are strong and solid, which are the suitable sources of pulp papermaking or farm tools, construction materials, daily necessities, crafts and the like. Its wide leaf is suitable for waterproof appliances such as bamboo hat and boat mat or for packing, and it can also be used to wrap food. The leaf is large sized and elegant, therefore it is regarded as good ornamental bamboo.

Dendrocalamus latiflorus Munro is extensively distributed and cultivated in Burma, Thailand, Philippines and southern Provinces in China. There are large areas of intensively cultivated bamboo stands in Fujian, Guangdong, Taiwan and other Provinces, mostly in mountain foots, valleys, river beaches or around villages un-

der the altitude of 600m.

8.1.1 Nursery Techniques

The nursery techniques of *Dendrocalamus latiflorus* Munro mainly consist of raising with seeds, raising with buried culms, with buried nodes, and raising with main branch and sub-branch cutting, etc.

8.1.2 Afforestation Techniques

8.1.2.1 Site selection

Dendrocalamus latiflorus Munro favors warm and moist climate and is not cold-resistant. Its requirement of annual average temperature is about 19.6℃ to 21.8℃, with 40.9℃ as the highest and 4.5℃ the lowest, and annual rainfall is 1,400 – 1,800mm. It is optimum for *Dendrocalamus latiflorus* Munro to be planted on sandy dam soil and alluvium that is well-drained and slightly rich in humus along road sides, river banks, brooks or space beside buildings. It can also be cultivated on the hillside under the altitude of 600m as long as soil layer is deep and fertile. But if with barren soil, it should be fertilized in a proper way.

8.1.2.2 Afforestation methods

Its afforestation is divided into afforestation with transferred bamboos and transferred seedlings. Traditionally the former method is adopted with the selection of mother bamboos among vigorous *Dendrocalamus latiflorus* Munro clumps after 5 – 7 years of planting. There are a few or no leaves bearing on the tip, and sheaths persistent on the base culms. 4 – 6 shoot buds are situated on each side, surrounded by many slight lateral roots, small roots with branches bearing on, which is regarded as the best mother culm. If the shoot bud on each side is too small, with few lateral roots, or with short rootlet, it is usually of no good quality to result in low surviving rate and no shooting for a long time after the planting. In order to save the labor work, the selected mother culm is not favored to be neither too big nor too small in diameter as it will cause either inconvenience in transportation or poor growing capacity. Therefore mother culm with 5 – 8cm in DHB is the optimum. The period from vernal equinox to grain rain is the right time to dig up and plant *Dendrocalamus latiflorus* Munro. It is best to be dug and planted before sprouting of lateral buds. The top part of the culm can be cut off, leaving 1.5 – 2.5m in height to make it easy for transportation. The cutting edge should be cut in the shape of horse ear. As for *Dendrocalamus latiflorus* Munro planting, a hole is first dug with 30 – 50cm in depth, its width depending on the handle part of mother culm and the carried old soil. Then mother culms should be kept upward obliquely. 450 – 600 holes are needed for each hectare in planting.

8.1.3 Nursery of Young Stands

Within 7 – 10 days after the planting, *Dendrocalamus latiflorus* Munro should be irrigated once every 3 or 4 days if there is drought in spring. Thin fertilizer is recommended to be applied every half month since it starts to sprout buds and spread leaves, however autumn is not the right season for fertilizing. Be aware to clear weeds and loosen soil at ordinary times. About 50% of mother culms tend to give rise to new shoots in April and May in the same year after planting, the remaining part will shoot the following year. If it doesn't shoot the second year, it means shoot buds on the mother culm is damaged, in this way, old mother culm is suggested to be removed in spring during the third year to be replaced by new ones.

8.1.4 Management of Mature Stands

8.1.4.1 Shoot digging and retaining for regeneration

The average shooting period can be divided into initial phase, blooming phase and ending phase, starting from May to October, and some may even shoot in November. During the initial phase between May and June, shooting accounts for about 26% of total. The initial-phase shoot is usually sprouted from some shoot buds (the first eye, the second eye, or the third eye) bearing at the bottom of culm base, so it is situated deep under the ground with strong growing power. On the other hand, the ending-phase shoot, developed from shoot bud which is close to the end, is situated shallow under the ground with poor growing capacity. Strong shoots with the suitable location in the blooming period is selected to be retained as the mother culm in reproduction.

Each mother culm usually has 4 – 6 years in life span, but it reaches its strongest shooting capacity within 1 – 3 years. Its shoots can be dug every year, and the removed shoot head make it possible to give rise to new shoot buds. 4 – 6 years later the increasing shoot buds bearing on the shoot head and its basal part lead to the result that mother culm is burdened with increasingly heavier nourishment. If it does not increase in number, the bamboo stand faces the problem of declining, therefore newly bamboo individuals should be retained once for regeneration every 4 – 6 years.

8.1.4.2 Unearthing

Shoot buds on the handle part of mother culms are unearthed by hoes from outside to inside around the bamboo clumps to be exposed to sun on mid and late February each year. It is a way to improve soil temperature and stimulate sprouting or shoot buds, convenient for fertilizing.

8.1.4.3 Fertilizing

Along with the high yield of shoots from D. latiflorus Munro, it consumes a great amount of nutrients, hence it should be fertilized twice or three times every year. The fertilizing is first carried out in combination with earthing 10 days after the unearthing. It is therefore called spring fertilization which may include human ordure and urine, barnyard manure, rubbish fertilizer, pond mud, decomposed cake fertilizer, etc. Each clump is applied with 25 – 50kg human ordure and urine, or 5 – 10kg decayed cake fertilizer, or 150 – 200kg pond mud and rubbish fertilizer. The second and third fertilizing are conducted during the initial phase and blooming phase of shooting, each clump with 10 – 15kg human ordure and urine, or about 0.5kg carbamide and vitriol amine. The fertilizers, diluted with water, are watered into drills that are made near the clumps. Attention should be given to keep tender shoot from touching the fertilizer water, which is too heavy in concentration to result in its death.

8.1.4.4 Earthing and hole sealing

The shoot sheath of *Dendrocalamus latiflorus* Munro, before unearthing, takes on olive brown with delicate and delicious shoot flesh. But after unearthing, its sheath turns into green when exposed to sunlight and its flesh becomes old that it tastes bitter. Accordingly, its shoot should be earthed before the unearthing to sustain taste and quality. Soil is covered 12 – 16cm in thickness above the deep-grown shoot, but for those shallow-grown shoots, it is about 30cm. After that, broken basins or pots are used to cover soil, and then followed by damp soil to fill in. Earthing is necessary to deal with the shoot holes after shoot digging. Those shoot holes left by shoot digging after April-May or September can be filled in immediately for hole sealing, those dug around June and August, however are suggested to seal the hole after the cutting dries up a bit every 3 – 5 days in sunny days and 5 – 7 days in cloudy days. If hole sealing is not properly dealt with in proper time, the cutting is prone to decay and thus affect normal development of shoot buds.

8.2 *Dendrocalamus oldhami*(Munro)Keng f.

Systematic name: *Dendrocalamopsis oldhami*(Wen) Keng f. ex W. T. Lin

Fine sympodial bamboo shoot species. culms 6 – 12m tall, 3 – 9cm in diameter, internodes 20 – 35cm long, culm wall 4 – 12mm thick. Young culms are covered with white wax powder, smooth and glabrous. Sheaths leather hard and fragile, deciduous, yellow green when young, covered with brown thin hair on the surface, glabrescent with luster, subtruncate at apex; auricles tiny, of similar size, elliptical or closely circular, sheath tip slender, ligules about 1mm tall, truncate, foliage leaf e-

rect in triangle or long triangle, approximately as wide as the sheath apex at base, glabrous beneath, crude in the belly.

Bamboo shoot is the main target for *Dendrocalamus oldhami* (Munro) Keng f. planting. Since it displays in the shape of horse shoe, it is called "horse's hoof shoot" or "white jade shoot". Its shoot flesh is white, thick, delicious, crisp and suitable for fresh eating and hence is regarded as one of the favorite food in summer. Its shoots can also be used for producing cans. Its culms are good material for furniture, dead stock, weaving products and paper-making with good quality. The bamboo timber in the middle layer is a good choice for Chinese medicine because of its heat-clearing efficacy.

Dendrocalamus oldhami(Munro)Keng f. favors warm and moist environment, slightly better in cold resisting than *Dendrocalamus latiflorus* Munro. It can also bear saline and alkaline with low grade. Though it is apt to break against strong wind, it has strong regenerating capacity and certain wind-resistant capacity as well. Accordingly, it is favored to grow in coastal areas with suitable climate, where there the annual average temperature is 18 – 21℃, the average temperature in the coldest month over 7.5℃, and annual rainfall over 1,500mm. In addition to its endurance of low temperature of –5.5℃ for a short period and slight endurance of moisture, it has a relatively strong adaptability against soil and therefore capable to grow on alluvium, gravel, mountain yellow soil, and light saline-alkaline soil, and moreover able to bear short-period flooding (1 –2 days) on alluvial beachs.

The species is extensively distributed and cultivated on banks along brooks and rivers, alluvial plains, low hills, the foot of mountains, valleys and around villages in Fujian, Tianwan, Guangdong, Hainan, Guangxi, South Zhejiang Province, etc in China, being pure stands or mixed with *Dendrocalamus latiflorus* Munromainly by cultivation. Fujian and Taiwan are the most distribution of *Dendrocalamus oldhami* (Munro) Keng f. which covers about 25 thousand ha, particularly in Fu'an in Fujian Province where a 50km-long *Dendrocalamus oldhami* (Munro) Keng f. corridor is situated along the Sai River, and is therefore titled with "the hometown of *Dendrocalamus oldhami* (Munro) Keng f."

8.2.1 Nursery Techniques

The nursery techniques of *Dendrocalamus oldhami* (Munro) Keng f. mainly consist of raising with seeds, raising with buried culms, with buried nodes, and raising with main branch and sub-branch cutting, etc.

8.2.2 Afforestation Techniques

8.2.2.1 Site selection and preparation

The suitable planting site of *Dendrocalamus oldhami* (Munro) Keng f. ranges from

low mountains, hills, valleys, flat ground, the two sides of brooks and rivers, to places around villages and houses, usually no higher than 300m in altitude. Acid or slightly acid soil is preferred with thick soil layer, good condition of water fertilizer, high-quality humus, and loose texture. Weeds and land should be cleared for the site preparation, which requires for strip and plot land preparation. Its spacing is 3m × 4m in culms and holes are dug in triangle with 100cm × 100cm × 40cm in specification, with its surface soil and under soil being placed separately.

8.2.2.2 Selection of mother culms

Afforestation with transferred bamboos in individual plants has the advantage of high surviving rate, strong shooting capacity and fast maturity. Culms that is born in the very year, strong without disease and insect pest, grows on the edge of clumps, and its stems are deep in soil are selected as seedlings. Besides, fat bamboo eyes with at least 2 – 3 pairs of bud eyes are required, and its root system should be advanced. When digging, soil is dug up from far to near, digging deep gradually to keep from injuring bud eyes on the basal part and the root as well. The joint connecting stems and mother culms is cut by sharp knife to make the section flat. It should not be pulled in force in case that the bamboo handle is mangled. Mother culms, after the digging, need to be shaded to prevent from wind and sunlight. Meanwhile culm top should be cut obliquely at 2m length, its oblique cutting edge being kept upward to be available for rainwater. The surviving rate is likely to be improved if mother culms are wrapped with soil.

8.2.2.3 Planting

Surface soil is applied with base fertilizer one week before afforestation, each hole with 50kg farmyard manure or 30kg, and then mixed evenly with surface soil. Mother culm is better dug up and planted at the same day and same place. Attention is given to keep it moist in case of long-distance transportation, generally no longer than 3 days. And it should be placed obliquely in the hole in forward direction, bud eyes on its stems facing two sides and stem being in bevel of 45° – 60° against ground. At the same time, the cutting should be kept upward and its root system extended to have a close contact with soil. More attention is given to leave no opening at the lower part of the root system. After all the above are done, soil is suggested to be stepped to make it tight in layers and cover with soil with 10cm in thickness. Then it is covered with straws to keep moist and it requires watering if there is no rain for several days.

8.2.3 Nursery of Young Stands

New culms should be watered once every 3 or 4 days after planting when facing

spring drought, and it is likely to take roots and give rise to branches and leaves one month later. During the third year they can produce shoots. During afforestation the very year, it is cultivated twice. The first time is made in July, together with weed clearing and earthing, to apply the fertilizer during the shooting period with 1% carbamide and water solution, each mu with 3kg carbamide. When in September, the second cultivation is made to apply bamboo fertilizer, digging channels around the bamboo handle with 5 Liang carbamide and 2 Liang compound fertilizer for each clump. In the following year, cultivation is done three times. Again together with weed clearing and earthing, 0.5kg carbamide is applied for each clump in May and July, and 1kg compound fertilizer or 50kg farmyard manure for each clump in September. Fertilizers are applied evenly in the channel to avoid touching shoot bud in case of its shrinkage, and is then followed by soil covering. If the shooting period happen to have no rains, young bamboos will grow slowly, so irrigation should be made quite often to promote the growth. Those places with good site condition may intercrop watermelon, legume and the like to increase income and replace intercropping for cultivation as well.

8.2.4 Management of Mature Stands

Cultivation of mature stands needs to be done three times each year.

8.2.4.1 The first time

In March when temperature begins to rise around vernal equinox, soil is dug to expose bamboo base. To be exact, surface soil and soil around bamboo clumps is dug up to remove fine roots on the surface of bamboo, and expose bamboo handle to sunshine for one month. Afterwards, together with earthing, pre-shooting fertilizer is applied around clump, namely carbamide, carbonic acid ammonium, compound fertilizer, human manure, farmyard manure, etc. 1 – 2kg fertilizer or 50 kg organic fertilizer is suggested to be applied for each clump in order to provide nutrients for shooting, stimulate the burgeoning of shoot eyes, and ultimately improve shoot-quantity.

Raking to dry in the sun is the key measure to cultivate shoot-used bamboo because it helps to increase soil temperature, enhance burgeoning of shoot buds, and can also prevent root groups from tangling with each other. In addition to these, it restricts branches and leaves from growing too vigorously to some degree, and therefore make for shooting nutrients accumulation and improve shooting capacity. As for the raking to dry in the sun bamboo handle, earthing should be done to keep shoot turning to green when exposed to light and thus become bitter in taste. Usually soil is covered onto the base of a clump in depth of 20 – 25cm, thinner for shoots that are deep under the ground, but thicker for those shallower under the ground.

8.2.4.2 The second cultivation

Shooting-period fertilizer is made during late July. After the first shooting peak, *Dendrocalamus oldhami* (Munro) Keng f. generally gives rise to relatively less shoots for one week during mid and late July when it is the right time to apply quick-release fertilizer, human manure and so on, each clump 2 – 3kg carbamide or 50 kg dense human manure to stimulate the burgeoning of shoot buds to promote the shoot yield. Fertilizer is applied in the dug circle canal, together with weed clearing and soil loosening, and avoid touching shoot bud directly if possible, and then is followed by soil covering.

8.2.4.3 The third cultivation

In November and December, old culms of more than 4 years old is cut. Its handle part is removed, while retaining part of 2 and 3-year-old bamboos, and all of the 1-year-old bamboos. 12 – 15 mother culms, healthy and without disease and insect pest, are selected and kept in even distribution for each clump. The right proportion of 1-year-old bamboo, 2-year-old bamboo and 3-year-old bamboo is 7:2:1. Meanwhile, weeding, soil loosening, fertilizing and earthing should be thoroughly made. Each clump is applied with 50 – 100 kg farmyard manure and 5 – 10kg decayed cake fertilizer to help stimulating shooting and keeping warm. Circle canal is dug 20cm far away from the clump to apply fertilizer evenly in the canal and then followed with covering soil.

8.3 *Bambusa textilis* McClure

Systematic name: *Bambusa textilis* McClure

Fine mid-sized sympodial timber bamboo. Culms 6 – 12m tall, 2 – 6cm in diameter, internodes 40 – 70cm long, culm wall thin, 2 – 5mm thick. Culms erect, curved and droopy at the end tip, culm node smooth, young culms covered with white powder and pale colored bristly hairs. Sheaths thick-leathery, hard, fragile and bright, deciduous, slightly protruding at the apex displaying unsymmetrical wide arc, glabrous beneath or covered with dark brown pubes that are deciduous-prone; aurecles narrow, oblong, equivalent in size, twists and turns on the edge; ligules 1 – 2mm tall, its edge and covered with short ciliate; foliage leaf long triangular, orovate-triangular, erect, heart-shaped contract on the base, glabrous beneath, crude on the belly, more branches on each node with similar size, the central one slightly thicker and taller. Blades lanceolate, 9 – 25cm long, 1.0 – 2.5cm wide.

Bambusa textilis McClure is characterized by its straight and erect timber,

smooth nodes, and tender, tough timber quality. It also has good tension, not likely to crack after drying, and good durability in use, so its bamboo skin is of good quality and regarded as the outstanding one among timber bamboos. It proves to be good material not only for architecture, furniture, crafts, toys, dead stock, rope, but also for the processing of toothpick, bamboo chopstick, and papermaking as well. In addition, the tall and erect feature of the plant and its green and elegant appearance make it possible for landscape plants in courtyard.

It is mainly produced in the southeastern area of China, suitable for the terrain where there the annual average temperature is 20 – 22℃, the average coldest temperature over 8℃, and annual rainfall over between 1,200 – 1,800mm. It can be found on the alluvial plains, low hills and banks along brooks and rivers that are lower than 500m in altitude. Loosen and fertile loamy soil or sandy loam with good drainage is preferred, its pH value ranging from 5.0 – 6.5. *Bambusa textilis* McClure, featured by its extensive use, fast growth and easy propagation, is deeply favored by people and therefore sustains a rapid development. Bamboo Corridor along the banks of Suijiang River in Guangning County, Guangdong, China is such a famous example because the corridor covers about 60 thousand ha in concentration, accounting for approximately half of the total area of *Bambusa textilis* McClure. "Zhengjiang Bamboo Skin" produced there is exported to China Hongkong, China Macau, and southeast Asian countries. It is a main distributing center of producing, processing and marketing of *Bambusa textilis* McClure in China.

Ever since 1970s, attempts have been made to introduce *Bambusa textilis* McClure to go across Yangtze River, even to Henan Province in Yellow River drainage basin, but meet with the difficulty of its failure in living through winter. There are some successful experiences, however. At present, the distribution of *Bambusa textilis* McClure has extended to areas of Hunan, Jiangxi and the middle of Zhejiang Province, the adaptability of which has been improved to be suitable for 17.3℃ annual average temperature, 6℃ average temperature in coldest month and can bear the extremely low temperature of –6℃. The annual yield of *Bambusa textilis* McClure timber reaches 3.75 – 22.50ton/ha with the highest yearly yield of 37.5ton/ha.

8.3.1 Nursery Techniques

The nursery techniques of *Bambusa textilis* McClure mainly consist of the raising with buried culms, buried nodes, buried handles, and branch cutting, and the like. Of these techniques, the most extensively used in production is the raising with buried nodes for which 2-year-old bamboos are preferred. It is proved that those with double-node cuttings reaches 90% in surviving rate, while the surviving rate of single-node cuttings is merely 60%. If counted in the number of cuttings, double-node

cuttings keeps higher survival rate than the singe-node one; however, it is vise versa when the number of nodes is counted. Node cuttings are sawed to keep about 10cm in length above the node, and 20-25cm in length under the node. But if for the double-node cuttings, it can be cut relatively short on condition that it doesn't affect the length of the succeeding node cutting. Both of the edge should be cut in the shape of horse ear in the opposite direction, to avoid injuring its green surface or damaging bamboo tube. The technique needs to be applied before bud eyes start to sprout and bamboo juice begins to flow when the culm reaches an abundant accumulation of nutrients. It is best done from mid February to mid March if sympodial bamboos are distributed in southern area, but in northern area especially in mountainous areas it can be postponed until mid March and even early April. In order to keep bamboo nodes from drying out to affect its survival, the best way is to chop the bamboo and then successively followed by cutting and burying, or place the node cuttings and original item of mother culms in the flowing water or bury inside wet sand to keep them moist. Generally better effect is achieved by the way of burying in original item or many node cuttings than those of single-node cuttings, the surviving rate of the former is once or twice higher. In case of long-distance transportation, mother culms should be covered with wet straw and watered often, and prevented from exposing to wind and sunshine. When they reaches the planting site, they should first be buried in wet sand or dipped in flowing water for 1 or 2 days, and then made the cutting for nursery after mother culms absorb water fully and the bud eyes begin to expand.

If possible, nodes are treated with growth hormone before the burying to help stimulate node cuttings to take roots. According to the experiments, single-node cuttings of *Bambusa textilis* McClure reaches the survival rate of 80% 12 hours after the treatment of 100ppm naphthalin acetic acid, its survival rate falling down to 60% 12 hours after the treatment of 10ppm heteroauxing, and only around 30% if without any treatment.

8.3.2 Afforestation Techniques

There are two techniques of *Bambusa textilis* McClure afforestation, the one with transferred bamboos and with seedlings.

8.3.2.1 Afforestation with transferred bamboos

The selection of mother culms

The best mother culms for the afforestation should be not only strong, with vigorously growing branches and leaves and with no disease and insect pest, but also bud eyes on the culm base is fat and solid, and 1 or 2-year-old culms bear developed fibres. Accordingly, such culms are strong in shooting power, easily survive after

planting, and grow fast into stands. Those over 2 years old is not preferred as mother culm because bud eyes on the culm base has partly given rise to shoots, and most of the remaining bud eyes tend to be aging to lose sprouting capacity and its root system starts to decline as well. Attention should also be given to choose those with the right size neither too big nor too small. *Bambusa textilis* McClure is of the middle-sized species, so those with 2 – 3cm in DHB is favored. If it is too small, the culm tend to grow poorly and thus affect its survival, while it is not the right choice for mother culm if DHB is too big because its big size will lead to inconvenience in digging, transportation and planting.

Digging of mother culm

1 or 2 – year – old vigorous bamboo culms usually bears on the edge of bamboo clumps, its culm base being deep in soil and its bud eyes and root system developing well, so they are the likely choice for mother culms. Soil is dug up 25 – 30cm away from the mother culm, from far to near, and dug deeper gradually to keep from injuring bud eyes on the culm base, but keep rootlets and fibres of the bamboo handle as much as possible. Situated close to one side of the old culm, the joint connecting culm stipe of the mother culm and culm base of the old culm should be found and the culm stipe of mother culm should be cut at the end of it with sharp chisel and hoe with force and them dug up with handle and soil. When cutting, the damage of bamboo handle should be avoided by all means, otherwise it may be apt to decay otherwise to have low survival. After mother culm is dug, the upper part of the culm is cut only to retain that with 1.5 – 2.0m in length. In principle 2 – 3 branches should be kept and the shape of horse ear is cut in the same direction from the middle of internodes and the hook of culm stipe. By this way, it can reduce evaporation and thus reduce water loss of mother culms and make it convenient for transportation and planting. If it can not be planted timely, it should be placed in the shade with the prevention from wind, and watered properly. In case of long-distant transportation, wet straw is needed to wrap the bamboo handle and keep bud eyes from being injured.

Afforestation season

It is optimum for *Bambusa textilis* McClure to be afforestated from mid February to late autumn when it is convenient for mother culms to be dug, transported and planted as well, thus leading to a high surviving rate. It gives rise to shoots the very year after planting and develops into stands within 3 or 4 years. During the rain season when it is humid and hot, the surviving rate of *Bambusa textilis* McClure will not be low if it is dug up, then planted at the very place with the technique of raising with buried culms, and ultimately followed by reinforcement of after-planting

nursery.

Planting density

The density of *Bambusa textilis* McClure afforestation should depend on its topography and soil condition. Usually those places along banks of brooks and rivers, alluvial zone on the plain, and where with loose and fertile soil are selected to make the density varying from 4m × 4m to 4m × 5m in row spacing. In those hilly areas with poor soil condition, however, the row spacing is better made in density from 3m × 4m to 4m × 4m.

Thorough site preparation

Thorough site preparation is the key issue in improving survival rate and making possible a rapid development into stands. An overall preparation is needed at places with flat topography or without much slope, but as for hilly country, flat strip preparation is suggested to make the strip 1 – 2m in width, 1 row for each strip, or 7 – 8m in width but 2 rows for each. Terrace is better made for this way of cultivation to make it available for water storage, soil conservation and convenient operation. With the two methods of site preparation as is mentioned above, holes are first to be dug with 50cm × 50cm × 40cm or 80cm × 80cm × 40cm in specification, and then followed by planting. If possible, 15 – 25kg farmyard manure is suggested to be applied for each hole and mixed with surface soil to be base fertilizer. Hole planting is only adopted when there is insufficiency of manpower.

Planting methods

Afforestation of *Bambusa textilis* McClure with transferred bamboos usually consist of individual plant and co-planting of mother culm and its offspring. As for the former method, one individual mother culm is planted for each planting site, but for the latter, it is in the way of clumps. The method of individual planting is favored to place mother culm oblique with bud eyes bearing on the two sides of the culm base in horizontal position. On the condition of abundant seedlings and sufficient workforce, the later method is often adopted. Clumps of mother-offspring culms is dug up with the root, usually one mother culm with two offspring or two with three and four offspring, to be cut of its upper part of the culm over 1. 5 to 2. 0m in height. And 2 and 3 branches are kept for each culm. Erect planting is suggested because the highest survival rate can be reached. In addition to this, it starts to shoot early in considerable numbers, grows very fast, and tends to become stands within 1. 5 and 2. 5 years under the circumstances of deep, fertile soil, and careful nursery.

8.3.2.2 Afforestation of seedlings

Bambusa textilis McClure's culm and branch bears latent bud, so proper measures can be done to stimulate its bourgeoning, take root and developed into an independent new culm under the suitable circumstances.

1-year-old seedlings with 0.5 – 1.5cm in ground diameter are usually adopted for afforestation. Before the afforestation, seedlings are made to cut part of the branches and leaves to reduce evaporation after the planting. In terms of long-distance transportation, the tip of the seedlings should be cut, only keeping the base culm with 3 and 4 buds. Then seedlings are dug up in clumps in avoidance with injuring shoot buds by all means and as much as old soil is perfered to wrap it. If there are too many culms, it can be divided into smaller clumps, each having 2 – 3 or 3 – 4 culms. After root-soaking and wrapping, they will be transferred to land site for afforestation.

8.3.3 Nursery of Young Stands

Intercropping is suggested for the newly established stand 1 – 3 years after afforestation due to its sparsely distributed bamboos. It not only helps to increase the income, but also replace intercropping for cultivation as well to promote the growth of new culms. Overall preparation can be made among the rowing space of clumps where there is smooth topography, and favorable soil quality. On the contrary, for hills and mountainous region with much slope, flat strip preparation is the optimum choice. For the intercrops, legume is the best choice such as peanut, soybean, black bean, mung bean, red bean, horsebean, and pea. Additionally, potatoes can be intercropped such as sweet potato, big potato and yam. And mountainous green soy bean, rattlebox, clover and the like are chosen for intercropping green manure. Priority should be given to stands nursery for the interplanting. And be aware that bamboo handle and shoot buds are not injured during site preparation, cultivation and harvesting. Along with the expansion of clumps of *Bambusa textilis* McClure, interplanting area is better shrunk year after year until it is finally stopped. If without interplanting, the newly established stand should be weeded and soil should be loosened in time to keep weeds and shrubs from rapid growth to compete with stands for water and nutrient, and thus hinder bamboo development. Therefore, before the canopy closure of new culms, weeding and soil-loosening are done twice each year, from May to June and from August to September respectively. If it is done only once, the optimum time is from July to August. Bamboo handle and shoot buds should be avoided being injured.

In order to promote the newly established bamboo stands to turn mature ahead of time, all sorts of fertilizers, mainly organic fertilizers such as barnyard manure, farmyard manure, and pond mud, are best suggested to be applied in autumn and

winter. Those quick release fertilizers such as human manure, ammonium sulfate and carbamide should be applied in spring and summer to meet timely the need of bamboo growth and avoid loss of fertilizer. As for slow-release fertilizer, they can be applied in the canal and hole near the clumps, i. e. , barnyard or farmyard manure with 22.5 – 37.5t/ha, or pond mud with 37.5 – 60t/ha. But quick-release fertilizer is better to be applied after soil-loosening, 0.15 – 0.25kg chemical fertilizers or 1.5 – 2.5kg human manure being appropriate for each clump of new culms each time.

8.3.4 Nursery of Mature Stands

8.3.4.1 Shoot protection

In terms of shooting period of *Bambusa textilis* McClure, May-June is its initial phase, July-August being the blooming phase and September-October ending phase. The shooting amount of the former two phases accounts for over 80% of total the whole year. Shoots ever produced in these two phases are usually thick and strong, and with good quality, hence should be retained as much as possible. In contrast, those bamboosshooting during the ending phase are small in number and usually thin and weak, with poor quality in bamboo formation, which is prone to freeze injury in winter in the northern part of China mainly because the growth period tends to be short, and young culm has not turned tough yet. Shoots that are both thin and weak may be cut for eating in order to reduce nutrient consumption in clumps. The culm base of shoots should be kept when cutting, to produce shoots and grow into bamboos under the suitable circumstance.

8.3.4.2 Forest land digging and soil loosening

Bambusa textilis McClure bamboo stand is to be dug each summer and cultivated each winter. The digging is usually made 6 – 10cm in depth, and loosening 15 – 20cm in depth, but for the space quite distant to clumps, the depth is 12 – 15cm for digging and 20 – 30cm for loosening respectively. Meanwhile, bamboo handle should be covered with soil to protect shoot buds from exposure and thus reduce evaporation. In terms of stands with much slope, the stand can be built into terrace which is favorable for stands growth, and water and soil conservation.

8.3.4.3 Stand fertilizing

Much like the fertilization of young stands, the mature stands is mainly applied with organic fertilizers, quick-release fertilizers being subsidiary, but there is not limitation in number. In introductory area where bamboo is transferred from south to north, quick-release fertilizers are not suggested before and after frost in case that bamboo produces too many delicate shoots in late autumn to live through the winter.

8.3.4.4 Regeneration of old and remnant bamboo stands

After cutting and utilization for a long time, clumps of *Bambusa textilis* McClure stand are filled with old and remnant bamboo heads. If the handle root is forced to grow out of ground, bamboos tend to be sparse year after year. Even if there grows new ones each year, it is not easy for the rhizome to go deep into ground and to absorb nutrient and water when squeezed among old bamboo heads. Accordingly, bamboos turn to be increasingly thinner and stand yield reduces too. And stands will become old, remnant and ruined if old bamboo heads are not removed for long. Therefore, the following measures should be taken to handle such stands:

Remnant bamboo cutting and old handle digging

Around May, all the thin and small remnant bamboos among clumps in bad growth condition are cut, its old and dead bamboo head being removed. Soil around clumps is loosened afterward to keep 8 – 10 culms of 1-year-old bamboo with good growth for each clump, 5 – 6 culms for 2-year-old bamboo and 3 – 4 culms for 3-year-old bamboo respectively. These 15 – 20 culms in total provide bases for clump regeneration.

Land loosening and green grass covering

After the first step, an overall soil loosing should be made once with 13 – 20cm in depth. Weed is then cut to cover the handle part of clumps to prevent water from evaporation, and additionally used as fertilizer after the decay, thus being favorable for the retained strong bamboo handle to produce shoots and grow into bamboos.

Shooting direction control and directive cultivation

Phototropism of *Bambusa textilis* McClure is adopted for shooting circulation within a certain range of clumps to make possible of a reasonable distribution of clumps and culms and make the best of stand space. Two ways are undertaken to control shooting direction to make a continuous regeneration of bamboo stands. For one, bamboo is prevented from shooting in an unfavorable direction by cutting; for the other, bamboos are induced to shoot in a favorable direction by the way of soil loosening and fertilizing.

Reasonable cutting

Reasonable cutting is a critical measure to guarantee rapid growth and fertility of *Bambusa textilis* McClure stands. The principle should be followed to cut the weak, the old, the densely distributed one, and the inside, but keep the strong, the young, the sparse and the outside. 1-year-old bamboos should be all kept due to the

strongest bourgeoning capacity. Those of 2 years old might be kept as well since they grow vigorously and accumulate rich nutrient. As for the 3-year-old bamboos, they are to be kept partly for each clump because their growing capacity tends to weaken gradually and the tissues tend to be mature enough to support new culms. Those 4-year-old bamboos tend to be decline and cunsume too much nutrients, so they should be removed all. The cutting of *Bambusa textilis* McClure is better done in late winter and from January to March in early spring.

8.4 *Bambusa chungii* McClure

Systematic name: *Bambusa chungii* McClure

Culms 3 – 10m tall, 4. 5 – 6. 0cm in diameter, internodes thin-walled, covered thickly with white powder, 30 – 50cm long or longer; a ring of deciduous conversed brown bristly hairs remained on the sheath annulus after unsheathing, more branches fascicled with similar thickness. Sheaths covered with white powder and black bristly hairs, especially in the middle of the basal part; auricles narrow and round, margin ciliate; ligules only 1 – 1. 5mm tall, margin dentate or covered with rather short cilia; foliage leaf evaginating, ovate-lanceolate, belly densely covered with short bristly hairs, shortly pubescent toward base beneath. Blades linear- lanceolate or oblong-lanceolate, varying quite a lot in size, 7 – 21 cm long, 1 – 3. 5 mm wide, shortly pubescent on the surface.

Its culm is good-quality raw material for weaving, timber exploitation and paper-making. Still bamboo core and bamboo marrow are available for medical use with the effect of heat and also for eye disease. Besides bamboo shavings can be made into cool tea. The species is regarded as good ornamental bamboo in the courtyard due to white powder covering the culm and its elegance and beauty in the shape of clumps.

Bambusa chungii McClure is named in memory of Professor Zhong rongguang, the ex-president of Lingnan University of Guangzhou.

It is distributed in Fujian, Guangdong, Guangxi and other places, with the cultivation in the south of Zhejiang, Sichuan and Hunan.

8.4.1 Nursery Techniques

Nursery techniques of *Bambusa chungii* McClure mainly consist of raising with buried culms, buried nodes, buried handles and raising with branches, etc.

8.4.2 Afforestation Techniques

8.4.2.1 Site selection

The great majority of *Bambusa chungii* McClure are distributed in plains and hilly

areas, auuvial terrain along two sides of brooks and rivers in particular. Deep and thick soil layer which is loose and fertile are the key factors for extensive distribution and good growth of sympodial bamboos. Mountain foot of hills or slope field that are less than 300 – 400m in altitude make possibility of establishing sympodial bamboo stands after ploughing and site preparation on condition that the upper layer of soil is deep and thick enough. However, soil that is dry and barren, with too many stones and gravels, or too heavy is not the optimum for the base of afforestation since sympodial bamboos will not grow well on such site condition.

8.4.2.2 Afforestation season

Afforestation with transferred culms is best undertaken during the dormancy period of *Bambusa chungii* McClure between January and March, due to the convenience for digging, transportation and transplanting of mother culms, and high survival rate as well. Mother culm produces shoots the very year, and develop into stands within 3 or 4 years. In places with distinct drought season and rainy season, afforestation is best done before rainy season comes to take advantage of humid and hot weather in the rainy season. Mother culms are dug up and immediately followed by planting. In addition, if after-planting management is strengthened, the surviving rate will not be too low. But the technique requirement is relatively high, therefore it is not suitable for large-area planting.

8.4.2.3 Afforestation methods

Selection and protection of mother culms

Those 1-year-old culms with low branches or low latent buds, strong and with no disease and insect pest are usually selected as mother culms. Bud eyes on the culm base is fat and solid, and the 1 or 2-year-old culms bear developed fibres. Such culms are characterized by the strong shooting capacity, apt to easy survival after the planting, and develop fast into mature stands, therefore they are the best ones for afforestation with transferred sympodial bamboos. For the digging, soil is first dug up around the periphery that is 25 – 30cm away from the mother culm, from far to near, and dug deeper gradually to avoid injuring bud eyes on the culm base, but keep rootlets and fibres of the bamboo handle as much as possible. Situated close to one side of the old culm, the joint connecting culm stipe of the mother culm and culm base of the old culm is then found and the culm stipe of mother culm is cut by sharp chisel and hoe with force and then dug up with handle and soil. Afterwards, 3 – 4 branches are kept for the culms with lower branches by cutting obliquely through internodes of 1.5 – 2m in height up the culm, its cutting edge showing the shape of horse ear. If these mother culms can not be planted timely, they should be placed in the shade for prevention from wind, and watered properly. In case of

long-distance transportation, wet straw is needed to wrap the bamboo handle and keep bud eyes from being injured and soil from falling off.

Planting

Transplanting of mother culms with attached handles is realized by the way with buried culms and the way of erection and intersection usually 1.5m × 4.0m in row spacing for individual culm, and 1.0m × 0.5m × 0.5m for the hole. Before planting, minute soil is first filled at the bottom of hole. If possible, some rotten and mixed barnyard manure, 15 – 25kg for each hole, can be applied and mixed with surface soil. After that, mother culm is planted obliquely in the hole, its horse-ear-like cutting edge kept upward to make it available for rain water. Or slurry is irrigated to keep the culm from drying up. When placing position of mother culm is adjusted, soil is filled in layers to make a close contact between root system of bamboo handle and soil, pressed tightly, and followed by watering. After all these are done, soil is covered over 3cm in depth above the base part of mother culm in the shape of steamed bread, to protect rhizome from decaying due to drained water.

8.4.3 Nursery of Young Stands

8.4.3.1 Interplanting of bamboos and crops

The interplanting is undertaken 1 and 3 years after afforestation, substituting cultivation for nursery. This measure not only helps to increase earning of farmers, but stimulates the growth of new bamboos. Legume (horsebean, pea, soy, and mung bean, etc.), green manure and cole are best chosen for the intercrops.

8.4.3.2 Weeding and soil loosening

Before the canopy closure of new culms, weeding and soil loosening are suggested to be done once or twice each year, around May to June, and August to September respectively. If it is done only once, the best time is around July and August. For bamboo stands on the gentle terrain, an overall action is suggested; but for those with much slope, it can be realized around bamboo clumps with the range of 0.5 – 1m in distance. Along with expansion of clumps, weeding and soil loosening should be expanded gradually. Be aware that shoot buds on the bamboo handle and bamboo shoots should not be injured.

8.4.3.3 Irrigating, draining and fertilizing

After digging, transportation and planting, the root system of newly planted mother culms and seedlings is injured and its water absorbing capacity declines as well. So if there is insufficiency of moisture in soil, they are vulnerable to water loss and withering. If there is no good drainage, it will lead to water retention, and thus the

lack of fresh air will result in abnormal respiration which contributes to decay of roots. Fertilizing, on the other hand, helps to stimulate growth of new culms and stands formation in advance, and moreover brings better economic effect.

8.4.3.4 Protection and intercutting

Herding is forbidden in the newly established bamboo stands. After shoots grow out of ground, some weak ones are to be removed as soon as possible only to keep 4 – 6 strong ones if there are too many shoots on one mother culm. Culms in the young stands need to be intercut and cultivated properly because they are numerous but usually thin and small. The principle of "removing the small, the old, the weak and the dense, while keepnng the iig, theyyoung, hhe strogg and tee spars" is bssically followed to enhance young stands to develop into mature ones rapidly and turn into timber ahead of time. Those strong culms growing in denseness can be dug to be mother culms for afforestation.

8.4.4 Management of Mature Stands

8.4.4.1 Soil loosening, handle removing and cultivating

Every 3 or 5 years, bamboo stands is made to loosen soil once, digging land in summer and cultivating in winter. The digging is usually made 6 – 10cm in depth, and loosening 15 – 20cm in depth, but for the space quite distant to clumps, the depth is 12 – 15cm for digging and 20 – 30cm for loosening respectively. Meanwhile, bamboo handle are to be covered with soil to protect shoot buds from exposure and thus reduce evaporation. The lopped bamboo handle needs to be protected with the possibility that buds on the culm base will shoot and turn into bamboo.

8.4.4.2 Fertilizing techniques

The best project of paper pulp stands of *Bambusa chungii* McClure is as follows: more than 10 culms are kept for each clump of 1 to 3 years old in age structure; fertilization is done in August, the proportion of N: P: K being 5: 1: 1, and 250g for each clump. Canals are dug around the bamboo handle for fertilization.

8.4.4.3 Irrigating

Irrigation of sympodial bamboos stands usually achieves good effect. During drought season, irrigation is suggested once each week or every two weeks if possible, to stimulate early shooting and increase yield. If it doesn't rain for a long time during shooting phase, the stand should be watered timely to keep soil moist and make sure vigorous growth of the retained new culms.

8.4.4.4 Cutting techniques for bamboo stands

As for cutting, 12 – 14 culms are often recommended to be retained. All of the 4-year-old culms and part of 3-year-old ones are cut.

8.4.4.5 Other managing techniques

Shoot protection and bamboo cultivation

Herding should be stopped during shooting phase, and animals are forbidden to intrude bamboo stands. Those shoots coming out of ground during the early phase and mid phase are to be retained, while those in late phase should be cut.

Disease and insect pest control

Timely control should be handled when disease and insect pest is found in bamboo stands. Please refer to the section of "bamboo disease and insect pest control" to check the detailed methods.

8.5 *Bambusa pervariabilis* McClure

Systematic name: *Bambusa pervariabilis* McClure

Culms 10 – 15m tall, 4 – 6cm in diameter, internodes 20 – 45cm long, culm wall 8mm thick, green on the surface, covered with white powder and deciduous white thin hair when young; internodes having yellow and white stripes at the base, covered with grayish white hair annulus above each node. Branches strong and short. Culm sheaths green with vertical stripes, thick-chartaceous, sheath tip anisomerous arch; auricles distinct, wrinkled, margins fringed with curly, big auricle oblong extending downward, about twice as big as small auricle, small auricle ovate; ligules 2 – 5mm tall, margin dentelated; foliage leaf erect, long triangular, glabrous on the surface, belly with minute bristly hairs. Blades long lanceolate, 9 – 14cm long, 0.7 – 2.5cm wide, shortly pubescent on the surface.

Being solid and erect, the timber of *Bambusa pervariabilis* McClure is good material for shed, pole, dead stock, furniture and architecture. Its skin can be ripped to weave bamboo products. Additionally, bamboo shavings can be made for medical use to clear heat to treat with such diseases as hematemesis and child hysteria.

It is distributed along river banks in Guangdong, Guangxi, Fujian and other Provinces, with the preference of loose and moist soil.

8.5.1 Nursery Techniques

Its nursery techniques mainly consist of raising with buried culms, buried nodes,

buried handles and raising with branches, etc.

May and April are suitable for the raising with branches, by which 1 and 2-year-old main branches with full latent buds and root point are selected from 2 and 3-year-old culms. Cutting is done at the base of main branch, and avoided harming root point to make it possible for improving the survival rate. The branch is cut about 2cm above the third nodes, branches and leaves of the highest node being kept appropriately for photosynthesis. All the lateral branches at the base of main braches are snipped, only keeping one node of lateral branch along the middle nodes. If there are persistent branch sheath, it should be shuck off to expose its bud eyes. After all these are done, the ready-made branch cutting is soaked with water or placed in the shade, and watered often to keep moist. In cases of long-distance transportation, wet straw is needed for wrapping to make it ventilate and moist.

Ditch are dug with 14 – 16cm in individual plant spacing and 25 – 30cm in row spacing on the prepared site. Then the cuttings are buried obliquely in an angle of 30° and 40° against ground, its branches (buds) facing two sides and the lowest node going 3-6cm deep into soil. The cutting edge is made level with ground, branches and leaves on the highest node being exposed. Straws are then covered on soil with about 3cm in depth and watered enough. Cuttings need proper shading 10 days after the burying. Still attention should be given to such circumstances as the removal of drained water after long time of rain, frequent watering in dry days, and soil covering for those exposed nodes. Since branches produce roots quickly, nitrogenous fertilizer or human manure is suggested 20 days later. Consequently, roots give rise to seedlings within 3 months. The raising with handle-attached main branches usually enjoys high survival rate.

8.5.2 Afforestation Techniques

8.5.2.1 Site selection

Bambusa pervariabilis McClure grows best on the auuvial terrain along banks of brooks and rivers where there are deep and thick soil which is loose and fertile. Mountain foot of hills or slope field that are less than 300 – 400m in altitude make possibility of establishing *Bambusa pervariabilis* McClure stands after ploughing and site preparation on condition that the upper layer of soil is deep and thick enough. However, soil that is dry and barren, with too many stones and gravels, or too heavy, is not the optimum for afforestation.

8.5.2.2 Afforestation season

Afforestation with transferred culms of *Bambusa pervariabilis* McClure is best undertaken between January and March. In places with distinct drought season and rainy season, afforestation is best done before rainy season comes, to take advan-

tage of humid and hot weather in the rainy season. Mother culms are dug up and immediately followed by planting. In addition, if after-planting management is strengthened, the surviving rate will not be too low. But the technique requirement is relatively high, therefore it is not suitable for large-area planting.

8.5.2.3 Afforestation methods

Selection and protection of mother culms

Those 1-year-old culms with low branches or low latent buds, strong and with no disease and insect pest are usually selected as mother culms. These culms are usually 1.5 – 4cm in DHB, and 3 – 4 branches are kept for the culms, each 1 – 2m long with its tip removed. For the digging, soil is first dug up around the periphery that is 25 – 30cm away from the mother culm, from far to near, and dug deeper gradually to avoid injuring bud eyes on the culm base, but keep rootlets and fibres of the bamboo handle as much as possible. Situated close to one side of the old culm, the joint connecting culm handle of the mother culm and culm base of the old culm is then found and the culm handle of mother culm is cut by sharp chisel and hoe with force and then dug up with handle and soil. Be aware to dig mother culms carefully, avoiding damaging bamboo handle and protect shoot eyes and fibres on the bamboo handle, and wrap it with wet straws.

Planting

culms with attached handles is planted by the way with buried culms and the way of erection and intersection, usually 2.5m × 4.0m in row spacing for individual culm, and 1.0m × 0.5m × 0.5m for the hole. When planting, mother culms should be handled gently, and bamboo handle is made in close contact with soil, following the requirement of "erect, shallow, and tight planting". The culm is watered after the planting to make the handle fixed.

8.5.3 Nursery of Young Stands and Management of Mature Stands

Please refer to the nursery of young stands in 8.4.3 and management of mature stands in 8.4.4 of *Bambusa chungii* McClure to get the details.

8.6 *Bambusa rigida* Keng et Keng f.

Systematic name: *Bambusa rigida* Keng et Keng f.

Culms 6 – 12m tall, 2 – 6cm in diameter, nodes smooth, new culms covered with white wax powder, glabrous internodes 30 – 50cm long, the primary branch obvious. Sheaths celadon, covered with easily deciduous minute bristly hairs abaxially, subtruncate at apex or oblique are protruded from the middle; ligules short, only

2 – 4mm tall; blades erect, triangular or narrow ovate triangular, usually shorter than sheath, shortened slightly at the base, intending to turn into 2 distinct ligules with different size, oblong and ovate each with wrinkles, margin twisted with long. Each small branch having 5 – 12 leaves, blades rectangular, 7 – 25cm long, 1 – 3cm wide, bottle green on the belly, glabrous, pale green beneath, minute pubescent especially obvious close to leave stems. Shooting period 7 – 9 months.

Being straight in culm and strong and thick in timber, it is good material for poles, sheds, handles of dead stock, and paper making as well. Its shoot tastes bitter and hence not edible.

It is distributed in the mountain foot, along the road and rivers in Guangdong, Guangxi, Sichuan, Fujian, Jiangxi and other Provinces.

8.6.1 Nursery Techniques

The raising with buried culms and with branches are suitable for *Bambusa rigida* Keng et Keng f.

8.6.2 Afforestation Techniques

8.6.2.1 Site selection

Those places with deep and thick soil layer, good soil fertility, wetness, leeward and lower altitude (optimum if below 600m, but grow normally around 1,000m in altitude) are good areas for afforestation.

8.6.2.2 Site preparation

Generally, the way of digging big holes are used for site preparation rather than land clearing in complete cultivation. First the planting site is determined according to the row spacing of individual culm required by afforestation density. Second, weeds and shrubs are cleared 2m in diameter around planting sites. Planting holes are dug afterward, the size of which is dependent on the size of bamboo species, usually 50-70cm in diameter, and 30cm in depth. They are 0.5 times and 1 times larger than bamboo handle of mother culm, and therefore make possible for the stretching of root system. Site preparation is naturally undertaken in autumn and winter before afforestation.

8.6.2.3 Afforestation density

Planting density is decided by size of culms and site condition. 4m × 4m or 4m × 3m of row spacing for individual culm is adopted in sites with high soil fertility, but for those with ordinary site condition, the required row spacing is quite often 3m × 3m or 2.5m × 2.5m.

8.6.2.4 Selection and digging of mother culms

Young culms are selected as mother culms for afforestation, much better if planted together with 1-year-old culms. Attention should also be given to choose culms with no disease and insect pest and with moderate size. Be aware not to injure bud eyes on the culm base when digging, and avoid damaging culm stipes and culm base when cutting culm stipes off from mother culms, otherwise its survival will be greatly affected.

8.6.2.5 Planting techniques

Mother culm is placed obliquely in the hole, its culm being in bevel of 45° - 60° against ground. Meanwhile, the cutting in the shape of horse ear should be kept upward to make available for water. After the oblique position of mother culm is adjusted, soil is filled in layers. Then soil is impacted from outside to inside to make a close contact between handle root system and soil. Loose soil is ultimately covered. The bamboo handle of mother culm is best to be planted after root soaking and watered often when in sunny days and when soil turns to be dry.

8.6.3 Nursery of Young Stands and Management of Mature Stands

Please refer to nursery of young stands in 8.4.3 and management of mature stands in 8.4.4 of *Bambusa chungii* McClure to get the details.

8.7 *Bambusa distegia*(Keng et Keng f.)Chia et H. L. Fung

Systematic name: *Bambusa distegia* (Keng et Keng f. Chia et H. L. Fung)
culms 6 - 10m tall, 5 - 10cm in diameter, culm top slightly are curved but not drooped, internodes green and yellow after fully growing up, 40 - 60cm long, covered with white powder or easily deciduous minute white bristly hairs on the upper part when young; a ring of downward brown bristly hairs above sheath after sheathing. Sheaths thick-leathery, densely covered with bristly hairs from golden to brown in color with no directions or sometimes in bunches (the covered triangular area glabrous in the inner margin at the base), wide truncate at sheath tip, protrusion from each shoulder; auricles not distinct, only slightly marked on the tip of each shoulder, bearing 5 - 10mm ; ligules low and short, only 1 - 2mm tall, fringed with easily deciduous dentelated cilia; foliage leaf from triangular to lanceolate, shortened in rotundity at the base, belly bearing minute bristly hairs. Each small branch over 10 leaves, blades long lanceolate, 5 - 16cm long, 0.8 - 1.6cm wide, green and covered with minute white hairs abaxially.

Its culm can be used to weave mat, make products, fans and other crafts, and it is also good material for paper - making.

Distribution: it is introduced in Sichuan, Fujian, Guangxi, Yunnan, etc.

8.7.1 Nursery Techniques

Such techniques as ground layering, original branch layering, the raising with buried nodes and main branches are used to cultivate seedlings of *Bambusa distegia* (Keng et Keng f.) Chia et H. L. Fung.

8.7.2 Afforestation Techniques

8.7.2.1 Site selection

The great majority of *Bambusa distegia* (Keng et Keng f.) Chia et H. L. Fungare distributed in plains and hilly areas, especially auuvial terrain along two sides of brooks and rivers. Deep, loose and fertile soil layer is the key factor for extensive distribution and good development of sympodial bamboos. Mountain foot of hills or slope field that are less than 300 – 400m in altitude make possibility of establishing *Bambusa distegia* (Keng et Keng f.) Chia et H. L. Fung Bamboo stands after ploughing and site preparation on condition that the topsoil is deep and thick enough.

8.7.2.2 Afforestation season

Afforestation with transferred culms is best undertaken between January and March. Mother culm produces shoots the very year, and develop into stands within 3 or 4 years. In places with distinct drought season and rainy season, afforestation is best done before rainy season comes.

8.7.2.3 Afforestation method

Young culms are selected as mother culms for afforestation, much better if planted together with 1-year-old culms. Transplanting of mother culms with attached handles is realized by the way with buried culms and the way of erection and intersection, usually 3m × 4m in row spacing for individual culm, and 1.0m × 0.5m × 0.5m for the hole. Mother culm is placed obliquely in the hole, its culm being in bevel of 45° – 60° against ground. Meanwhile, the cutting in the shape of horse ear should be kept upward to make available for water. After the oblique position of mother culm is adjusted, soil is filled in layers. Then soil is impacted from outside to inside to make a close contact between root system and soil. Loose soil is ultimately covered. The bamboo handle of mother culm is best to be planted after root soaking and watered often when in sunny days and when soil turns to dry.

8.7.3 Nursery of Young Stands and Management of Mature Stands

Please refer to nursery of young stands in 8.4.3 and management of mature stands in 8.4.4 of *Bambusa chungii* McClure to get the details.

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