Monograph of Bamboo Resources and Utilization Techniques

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A Member of Chinese Agricultural Experts Mission in Ethiopia
Preface

Bamboo is one of the best forest resources in the world, of which the utilization is very extensive. Ethiopia has a high proportion of bamboo resources of Africa and the whole world, and a long history of bamboo utilization. Especially during recent years, Ethiopian bamboo scientists made great efforts and contributed to scientific research on bamboo. As a result of research achievements and technical instructions, there are some Ethiopian enterprises established as modern bamboo processing factories on small scale. This is also a good market opportunity for bamboo growing farmers and processors. However, the proportion of utilized bamboo resources in Ethiopia is still very small. A large number of unutilized bamboo resources have not fully benefited for the farmers in bamboo areas and also the methods of bamboo utilization are not diversified.

To make rational utilization of Ethiopian bamboo resources, it needs more industrial production technologies. There are two ways to achieve this goal: firstly, to strengthen the research on new bamboo technologies; secondly, to introduce the existing successful bamboo techniques of the world including that of China.

This book is a good monograph of modern bamboo processing and utilization techniques for concerned individuals, societies and enterprises in Ethiopia. The book also highlights a comprehensive account of the biological
and morphological characteristics of bamboo, the world bamboo resources including that of China and Ethiopia, the world traditional and modern utilization technologies of bamboo. Most of the modern bamboo products processing techniques and key notes of bamboo cultivation and sustainable management techniques are addressed.

Finally, I hope the book can greatly facilitate and direct appropriate industrial bamboo processing and utilization thereby benefit many bamboo growing farmers, processors and enterprises of Ethiopia.

Wubalem Tadesse (Ph.D)

June, 2014
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Introduction

Bamboo is a treasure of human beings. It has played a very important role in the history of human beings civilization. People began to utilize bamboo resources before 7,000 years ago. In the long course of history, the use of bamboo develops from simple sticks to daily utensils, and furniture.

Bamboo resources utilization technology changes with each passing day. As one of the sustainable eco-friendly natural resources, bamboo materials are even processed into super energy material, clothing fibers, and further into high-power rechargeable battery and a variety of clothing.

There are about 70 genera, more than 1,200 species of bamboo plants in the world, which are distributed in an area of 22 million hectares all over the world, and the annual biomass production of bamboo is estimated to be 20 million tons. Bamboo industry occupies an important position in modern world trade. There are 1 billion people related with bamboo all over the world. In 2012, bamboo output was 16 billion US$, and the export income was 2 billion US$ in China (FU, 2013).

In Ethiopia, there are only two indigenous bamboo species, the production potential is big enough. The indigenous bamboo area is about 1 million ha, which accounts for nearly 5% of the world as a whole, and 67% of the Africa (Ensermu et al, 2000). There are also 27 exotic bamboo species of 7 genera (Seyoum and Yigardu, 2014). Ethiopian bamboo researchers have made fruitful efforts and contributions for developing Ethiopian bamboo industry. There is a long history of traditional bamboo processing and utilization in Ethiopia. Now-a-days there are small scale modern bamboo processing enterprises, such as Bamboo Star in Assosa and Adal Industrial PLC in Dukem. But, the production potential of bamboo resources is far from being fully realized. The large quantity of unutilized bamboo resources can bring tremendous wealth to Ethiopian farmers and revenue to the government.
The book will help to popularize modern technology of bamboo processing and utilization, facilitate the development of Ethiopian bamboo industry and let bamboo resources benefit more Ethiopian farmers, industries, GO’s and NGO’s, investors and other potential stakeholders.
Chapter 1

Bamboo

1.1. Botanical definition of Bamboo

Bamboo is a perennial woody plant. Bamboo is a generic name of all the plant species that belong to Bambusoideae (Poaceae / Gramineae, Poales, Poidae, Monocotyledoneae, Angiospermae, Spermatophyta, Plantae). According to recent findings, it also includes a few herbs and nearly herbaceous species, known as herb-like bamboo.

Bamboo is neither a tree (without secondary growth and main trunk, but with special branching patterns, very long vegetative growth cycle) nor a grass (ever green, with special blade, special mesophyll cell, arm cell and fusoid cell [Figure 1.1]). It is a strange plant, a woody grass. However, there are some Herbaceous Bamboos, such as Indocalamus latifolius and Bambusa multiplex cv. Fernleaf.
According to the characteristics of the culm and the flowering behaviors two groups of bamboo can be distinguished:

- Woody bamboo: characterized by the lignified culm with complex branching patterns and bisexual flowers.
- Herbaceous bamboo: featured with un-lignified culm with unbranched or have simple branching pattern and unisexual flowers.

### 1.2. Bamboo Morphological Features

The basic features of bamboo are as follows:

- It has woody culms above the ground, and rhizome under the ground, which form a frame work of bamboo;

- The leaf has a short petiole;

- Reproduction is mainly through vegetative multiplication;
• It has a perennial, gregarious flowering habit;

• Based on the rhizome, bamboo can mainly be distinguished as two types: Leptomorph / Monopodial and Pachymorph / Sympodial

**Leptomorph / Monopodial**

Monopodial Bamboo, has real subterranean rhizome, the terminal bud penetrates horizontally under the ground normally, which will die after the growing season. Bamboo shoots come from the lateral buds. The culms above ground are scattered. So it is called running bamboo (Figure 1-2).

**Pachymorph / Sympodial**

Sympodial Bamboo, has not real rhizome, the terminal buds sprout directly to form shoot, and the culms above ground are in clumps (Figure 1-3). It also can be further divided into two sub-types: very short culm neck (Figure 1-4) and; more or less elongated culm neck (Figure 1-5).
However, some bamboo species are Metamorph/Amphipodial (mixed type) which are composed of both Pachymorph/Sympodial and Leptomorph/Monopodial bamboos.

The subterranean axis consists of both sympodial and monopodial parts. So the culms above ground are partly clumped, and partly scattered (Figure 1-6).

In general, this type of rhizome is always considered as monopodial which is one in a broad sense.
1.2.1. Characteristics of the Underground Stems

I. Underground stem of monopodial bamboo

There are real rhizomes under the ground; there are also nodes on the rhizomes, and roots on both rhizomes and culm base. There are buds on the nodes (Figure 1-7 and 1-8). Bamboo culms above-ground are scattered (Figure 1-9).
II. Underground stem of sympodial bamboo

There is no manifest rhizome under the ground. Buds and roots are on the culm base (Figure 1-10).

Bamboo culms above-ground are in clumps (Figure 1-11, 1-12 and 1-13).
III. Underground stem of amphipodial bamboo

Rhizome features are between monopodial and sympodial bamboos (Figure 1-14, 1-15, 1-16 and 1-17).
1.2.2. Characteristics of the Above-ground Stems

The buds under ground, either on the culm base (sympodial bamboo) or on the rhizome (monopodial bamboo), begin to sprout to form shoots and then become culms. The young shoot is protected by culm sheath.

A culm consists of nodes, internodes and branches grown from the buds on the nodes.

The node is composed of node ridge, culm sheath ridge and intra-node, inside which there is a diaphragma (Figure 1-18).

On the node, there are 2-3 or more branches, There are two kinds of culm: solid and hollow (Figure 1-19).
I. Some different types of bamboo culm

According to morphology, there are many kinds of bamboo culms. Some are slim, some are fat, some have nodes as knees, etc. (Figure 1-20)
II. Different kinds of bamboo branch

On the nodes of bamboo culms, buds growing into branches. Of different species, the quantity of buds or branches on each node is not the same. Some nodes have only one bud or branch, some have two or three, and some have more (Figure 1-21).
Figure 1-21. Different kinds of bamboo branches
III. Culm structure

Figure 1-22. Bamboo culm structure
IV. Bamboo shoots

Figure 1-23. Bamboo shoots
1.2.3. Characteristics of bamboo Leaves

I. Schematic views of woody bamboo leaves

Figure 1-24. Schematic views of woody bamboo leaves showing homology between culm and foliage leaves. Illustration by G. Strief, redrawn from McClure (1966)
II. Different kinds of bamboo leaves

Figure 1-25. Component parts of bamboo leaf

Figure 1-26. Different kinds of bamboo leaves
III. The features of bamboo culm sheath

Figure 1-27. Component parts of culm sheath

Figure 1-28. Different kinds of culm sheath
1.2.4. Characteristics of bamboo Inflorescences

Bamboo is one of disposable flowering plants which wither after flowering. The flowering cycle of different types of bamboo varies greatly due to the genetic effects. Some are several years, some are decades. For example, *Dendrocalamus strictus* (Roxb.) Nees and *Dendrocalamus hamiltonii* Nees et Arn.ex Munro flower every 30 years. While *Neosinocalamus affinis* (Rendle) Keng f. and *Bambusa tulda* Roxb. flower every 32 years, and some species of *Bambusa* bloom after 80 years; some are even up to a hundred years before flowering, such as *phyllostachys bambusoides*, which needs 120 years’ growth to bloom. Of course, there are a few exceptions, some species flower once a year or so, such as *Ochlandra Thwait;* while *Sinobambusa tootsik* (Sieb.) Makino and *Bambusa multiplex* flower irregularly (Chai et al., 2006).

The following bamboo flower pictures explain that the beautiful is not always the same as the good (Figure 1-29).
1.2.5. Characteristics of bamboo fruits

The fruits of bamboo are mostly caryopsis (Figure 1-30).

An attention must be paid to the seeds of most bamboo species, since they have germination ability for less than one year, which is very important for sexual propagation of bamboo (Figure 1-31, 1-32 and 1-33).
Figure 1-30. Bamboo fruit

Figure 1-31. Moso bamboo seeds

Figure 1-32. Kinds of bamboo seeds
1.2.6. Some known bamboo species

It’s distributed in South Subtropical region. The culm is covered by dense farinose, the internode could be as long as 1.2 M. It is widely cultivated in Southern China.
It’s distributed mainly in South East Asia, like Viet Nam, tropical region of China. It may be the biggest bamboo in the world. The diameter could reach more than 30 cm.
Figure 1-36. *Bambusa ventricosa McClure*

Figure 1-37. *Arundinaria pygmaea*
1.3. The Main Reproductive Modes

Bamboo can be developed by seed breeding (reproductive organ) and vegetative propagation (vegetative organs) methods (Figures 38, 39 and 40).

Figure 1-38. Organs of bamboo
1.3.1. Seeding breeding

The germination ability of bamboo seeds is mostly within one year. So, the propagation of bamboo is mostly by unsexual way.

1.3.2. Vegetative propagation

I. Development of the rhizome

Of most bamboo species, from 3 to 5 year-old rhizome is in the prime stage for shoots’ tillering. The life span of bamboo rhizome is ordinarily 6-8 years. The rhizome’s growth is seasonal. In China, it grows mainly in Spring and Summer seasons; and in Ethiopia, it develops mainly in rainy season.

Figure 1-39. Propagation with rhizome
II. Development of the culm

Generally, 2 years-old bamboo culm has the most productive capacity to shoot. After 4 years-old, the bamboo culm nearly has no shoot capacity. The same as rhizome, bamboo culm’s growth is also seasonally, mainly in Spring and Summer seasons or in rainy season.

Figure 1-40. Propagation with culm
1.4. Ecological Value of Bamboo

Bamboo contributes for environment sustainability as follows:

- Soil and water conservation and degraded land rehabilitation,
- Water filtration through bamboo forest,
- Biodiversity conservation in bamboo forests by providing habitats and food for animals and providing substitutes for timber,
- Climate change, carbon sequestration and adaptation,
- As environmental friendly construction material with high yield/production and sustainable productivity.

Figure 1-41. Bamboo ecological function

- Natural oxygen bar
- Soil and water conservation
- Carbon sink
Bamboo plantations are also perfect for ecotourism.

![Bamboo Ecotourism Sites](image)

**Figure 42. Bamboo ecotourism sites**

### 1.5. Economic Value of Bamboo

While the world forests are shrinking, bamboo could be an excellent timber substitute if properly managed, processed and utilized. It has superior mechanical and physical properties. It is cheap, fast growing, having high-efficiency and easy management and processing and can be harvested sustainably on 3 to 5 years’ rotation.

Bamboo is full of treasure; shoots can be processed into a variety of foods in many ways. Fresh shoots can even be directly cooked into delicious dishes. Rhizome can be carved into a variety of art works. Culms are the most versatile, can be used to carve into a variety of utensils or artworks. The utilization includes both traditional and modern processing. Some of the traditional uses are: housing, ship raft, bridge, pole, bowl, mat, basket,
partition, sieve, broom, table, chair, bed, dustpan, comb, brush pen, lantern shade, cage, zither, flute and other wind instruments.

Modern processing includes mainly two techniques:

Mechanical processing helps to generate products such as picks, mat, pillow, floor, curtain, bag, furniture, computer, laser engraving, the original bamboo fiber, etc.

Chemical processing helps to generate products such as vinegar, charcoal, beer, beverage, cosmetics, toothpaste, toothbrush, pulp fiber, charcoal fiber, medicine, etc.
Chapter 2

Bamboo Resources in the World

2.1. Distribution of Bamboo Resources in the World

In the world, there are around 70 genera, more than 1,200 species. The annual production of bamboo is estimated to be 20 million tons. The area is 22 million ha, which is distributed between 46° N and 47° S of the tropical, subtropical and warm temperate regions, and mainly within North and South regression lines. According to their origin and geographical distribution of bamboo; it can be divided into 3 regions (Figure 2-2):

- Asian-Pacific,
- American and
The three major bamboo regions multiply their own unique native bamboo species, because of the long-term isolated development of different sites.
conditions. It is difficult to find the same bamboo species distribution in the world. Only the distribution of the two bamboo genera (Bambusa and Arundinaria) are simultaneously discovered in three areas.

Bambusa is distributed in tropical and southern subtropical regions, and Arundinaria is located in the north subtropical and warm temperate regions of the world.

Bambusa vulgaris is widely distributed in tropical and southern subtropical of the three bamboo regions called as "pan-tropical" bamboo species.

2.1.1. Asian-Pacific Bamboo Region

There are about 50 genera and more than 900 species of bamboo in this region, the area accounts for about 52% of the world as a whole.

Asian Pacific is the world's largest bamboo distribution area, and the bamboo resources are also the richest. Both the quantity of bamboo species and the area account for over half of the world as a whole. The distribution is from India (54°E) by west to the Pacific Ocean, Oceania islands (180°w) by east, and from the southern part of New Zealand (42°S) by south to the northern part of Japan (51°N) by north.

The clothing, food, shelter and activities of the people from the countries with abundant bamboo production are closely linked with bamboo. There is a long history of bamboo resources utilization. By now, new technologies of bamboo processing and utilization come into being successively.

2.1.2. American Bamboo Region

There are about 18 genera and more than 400 species of bamboo in this region, of which the area accounts for about 41% of the world as a whole.

In this region, the bamboo resources distribute across North and South America, south to latitude 47° S, southern Argentina, and north to latitude
38° N or so, the east of North America. Central America is the distribution center of American bamboo resources. Most herbaceous bamboo species appear in this region.

2.1.3. African Bamboo Region

There are totally 11 genera and about 43 species of bamboo in Africa, the area accounts for about 7% of the world as a whole. In this region, the bamboo resources distribute in tropical area, south to latitude 23° S of Mozambique, and north to latitude 16° N in eastern Sudan. From the west coast of Africa, southern Senegal, to the southeast across the tropic area of the African continent, to Mozambique and Madagascar, there are patches of bamboo distribution. There are only a few native bamboo species in African continent. With both the native and introduced bamboo species, Madagascar has 11 genera, about 40 species.

2.2. Bamboo Resources in China

China is an ancient and powerful country in bamboo planting and utilization.

2.2.1. Bamboo resources of China

<table>
<thead>
<tr>
<th>Area</th>
<th>Subtribes</th>
<th>Genera</th>
<th>Species</th>
<th>Area (thousand ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>9</td>
<td>70</td>
<td>1200</td>
<td>22000</td>
<td>100</td>
</tr>
<tr>
<td>Asia</td>
<td>6</td>
<td>46</td>
<td>900</td>
<td>11500</td>
<td>52</td>
</tr>
<tr>
<td>China</td>
<td>5</td>
<td>39</td>
<td>500</td>
<td>6730</td>
<td>30.6</td>
</tr>
</tbody>
</table>

Table 2-2. Bamboo Resources of China
China is one of the bamboo distribution centers in the world, with the largest area, the most abundant species and biomass production.

**Bamboo land area:** 6.73 million ha. From 1973 (3.04 million ha) until now, it increases year by year (Figure 2-4).

**Bamboo plant stands:** 28.62 billion.

**Bamboo species:** Over 500 species in 39 genera.

**Distribution region:** 27 provinces.

There are more than 500 species of 39 genera with 6.73 million ha in area in China, which accounts for 30.6% of the total bamboo area in the world.

Among all the bamboo species, Moso bamboo (*Phyllostachys pubescens*) covers 3.86 million hectares, nearly 60% of the total bamboo areas of China (Figure 2-5).
2.2.2. Bamboo Distribution in China

Bamboo is distributed mainly in 19 provinces of China located in the southern areas, and intensively distributed in some provinces and cities, such as Fujian, Jiangxi, Zhejiang and Hunan provinces.

60% of bamboo resources can be found in the above mentioned four provinces. Together with other four provinces, Sichuan, Guangdong, Anhui, Guangxi, the bamboo area accounts for 88.64% of China as a whole.
Five bamboo distribution regions could be divided in China.

The distribution law of Chinese bamboo resources is that from north to south the bamboo types transit gradually from monopodial to sympodial through a mixed region, and the most southern bamboo area is a small climbing bamboo region. In southwestern China, on the Yungui Plateau, there is an alpine bamboo region. Most bamboo resources of China distribute in monopodial and sympodial bamboo region (Figure 6).

![Figure 2-6. Bamboo growing regions of China]

### 2.3. Bamboo Resources in Ethiopia

<table>
<thead>
<tr>
<th>Area</th>
<th>Genera</th>
<th>Species</th>
<th>Area (thousand ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>70</td>
<td>1200</td>
<td>22000</td>
<td>100</td>
</tr>
<tr>
<td>Africa</td>
<td>11</td>
<td>43</td>
<td>150</td>
<td>6.82</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>4.55</td>
</tr>
</tbody>
</table>
There are two indigenous bamboo species: highland bamboo (\textit{Yushania alpina}) and lowland bamboo (\textit{Oxytenanthera abyssinica}).


The indigenous bamboo area is about 1 million ha, which accounts for nearly 5% of the world as a whole, and 67% of the Africa (Ensermu et al., 2000; Kassaahun, 2000). In detail, \textit{Yushania alpina} growing area is more than 130 thousand hectare, which is distributed within the altitude of 2000-3500m of Oromiya, Southern and Amhara states; and \textit{Oxytenanthera abyssinica} growing area is about 850 thousand hectare, which is distributed within the altitude of 1000-1800m of Benshangul-Gumuz, Oromiya and Amhara states.
2.3.1. Distribution map of Ethiopian bamboo resources

Figure 2-7. Bamboo growing regions of Ethiopia (Michael and Tewodros, 2011)
### 2.3.2. Distribution table of highland bamboo *Y. alpina*

Table 2-4: Statistical data of *Y. alpina*

<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>State</th>
<th>Natural area (ha)</th>
<th>Artificial area (ha)</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Injibara</td>
<td>Amhara</td>
<td>30</td>
<td>2,350</td>
<td>2,380</td>
</tr>
<tr>
<td>2</td>
<td>Agaro</td>
<td>Orommiya</td>
<td>-</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>3</td>
<td>Bale Mountains</td>
<td>Orommiya</td>
<td>56,851</td>
<td>-</td>
<td>56,851</td>
</tr>
<tr>
<td>4</td>
<td>Shenen/Jibat</td>
<td>Orommiya</td>
<td>1,774</td>
<td>2,561</td>
<td>4,335</td>
</tr>
<tr>
<td>5</td>
<td>Gera</td>
<td>Orommiya</td>
<td>36,000</td>
<td>1,250</td>
<td>37,250</td>
</tr>
<tr>
<td>6</td>
<td>Bore/Hagereselam</td>
<td>Orommiya</td>
<td>-</td>
<td>2,460</td>
<td>2,460</td>
</tr>
<tr>
<td>7</td>
<td>Chencha/Arbaminch</td>
<td>Southern</td>
<td>2,460</td>
<td>3,250</td>
<td>5,710</td>
</tr>
<tr>
<td>8</td>
<td>Indibir/Jembero</td>
<td>Southern</td>
<td>-</td>
<td>1,850</td>
<td>1,850</td>
</tr>
<tr>
<td>9</td>
<td>Jima/Ameya</td>
<td>Orommiya/Southern</td>
<td>-</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>10</td>
<td>Mizan Teferi/Kulish</td>
<td>Southern</td>
<td>-</td>
<td>1,850</td>
<td>1,850</td>
</tr>
<tr>
<td>11</td>
<td>Debresina/Wofwashra</td>
<td>Amhara</td>
<td>35</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>12</td>
<td>Wushwush/Bonga</td>
<td>Southern</td>
<td>-</td>
<td>1,120</td>
<td>1,120</td>
</tr>
<tr>
<td>13</td>
<td>Bonga/Ameya</td>
<td>Southern</td>
<td>7,997</td>
<td>-</td>
<td>7,997</td>
</tr>
<tr>
<td>14</td>
<td>Masha</td>
<td>Southern</td>
<td>18,652</td>
<td>-</td>
<td>18,652</td>
</tr>
<tr>
<td>15</td>
<td>Munesa Shashemene</td>
<td>Orommiya/Southern</td>
<td>4,183</td>
<td>-</td>
<td>4,183</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>127,982</strong></td>
<td><strong>19,091</strong></td>
<td><strong>147,073</strong></td>
</tr>
</tbody>
</table>

*Source: Ensermu et al, 2000.*
2.3.3. Distribution table of lowland bamboo *Oxytenanthera abyssinica*

Table 2-5. Statistical data of *Oxytenanthera abyssinica*

<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>State</th>
<th>Natural area (ha)</th>
<th>Artificial area (ha)</th>
<th>Total area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hinde/North of Nekemte</td>
<td>Amhara</td>
<td>8,670</td>
<td>-</td>
<td>8,670</td>
</tr>
<tr>
<td>2</td>
<td>Asossa</td>
<td>Benshangul-Gumuz</td>
<td>77,947</td>
<td>-</td>
<td>77,947</td>
</tr>
<tr>
<td>3</td>
<td>Bambasi</td>
<td>Benshangul-Gumuz</td>
<td>64,245</td>
<td>-</td>
<td>64,245</td>
</tr>
<tr>
<td>4</td>
<td>Begi</td>
<td>Benshangul-Gumuz</td>
<td>21,509</td>
<td>-</td>
<td>21,509</td>
</tr>
<tr>
<td>5</td>
<td>Nejo</td>
<td>Orommiya</td>
<td>27,612</td>
<td>-</td>
<td>27,612</td>
</tr>
<tr>
<td>6</td>
<td>Dibate</td>
<td>Benshangul-Gumuz</td>
<td>14,200</td>
<td>-</td>
<td>14,200</td>
</tr>
<tr>
<td>7</td>
<td>Guba</td>
<td>Benshangul-Gumuz</td>
<td>7,757</td>
<td>-</td>
<td>7,757</td>
</tr>
<tr>
<td>8</td>
<td>Kemashi</td>
<td>Benshangul-Gumuz</td>
<td>33,723</td>
<td>-</td>
<td>33,723</td>
</tr>
<tr>
<td>9</td>
<td>Pawe</td>
<td>Benshangul-Gumuz</td>
<td>53,830</td>
<td>-</td>
<td>53,830</td>
</tr>
<tr>
<td>10</td>
<td>Gimbi</td>
<td>Orommiya</td>
<td>29,125</td>
<td>-</td>
<td>29,125</td>
</tr>
<tr>
<td>11</td>
<td>Guten</td>
<td>Orommiya</td>
<td>6,044</td>
<td>-</td>
<td>6,044</td>
</tr>
<tr>
<td>12</td>
<td>Metema/Dansha/Humera</td>
<td>Tigray/Amhara</td>
<td>425,000</td>
<td>-</td>
<td>425,000</td>
</tr>
<tr>
<td>13</td>
<td>Didessa Valley</td>
<td>Orommiya</td>
<td>135,000</td>
<td>-</td>
<td>135,000</td>
</tr>
<tr>
<td>14</td>
<td>Dangur</td>
<td>Benshangul-Gumuz</td>
<td>27,350</td>
<td>-</td>
<td>27,350</td>
</tr>
<tr>
<td>15</td>
<td>Bulen</td>
<td>Benshangul-Gumuz</td>
<td>16,780</td>
<td>-</td>
<td>16,780</td>
</tr>
<tr>
<td>16</td>
<td>Galesa</td>
<td>Benshangul-Gumuz</td>
<td>10,870</td>
<td>-</td>
<td>10,870</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>959,662</strong></td>
<td>-</td>
<td><strong>959,662</strong></td>
</tr>
</tbody>
</table>


2.3.4. A Report of Didesa Valley Bamboo Resources Survey

In order to determine the establishment of modern bamboo plant type and size, through survey and the investigation was done during 18-19/09/2013, to ascertain accurate production potential of bamboo resources in Didesa Valley Area.
Table 2-6. Didesa Valley Bamboo Resources Survey Form-1

Surveyors: HU Huojin, Degafa Negera, Tule Sadiko, Tesfaye Biranu, Yilma Deresa, Desale Mulatu

Total Bamboo area: 23,000ha  
Temperature: 14°C-28°C  
Rainfall: 900-1600mm  
Species: *Oxytenanthera abyssinica*

<table>
<thead>
<tr>
<th>Site name</th>
<th>Abasena</th>
<th>Jality</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td>Low mountain</td>
<td>Low mountain</td>
<td></td>
</tr>
<tr>
<td>Soil type</td>
<td>Loam clay</td>
<td>Loam clay</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td>1431m</td>
<td>1287m</td>
<td>1359m</td>
</tr>
<tr>
<td>Slope</td>
<td>38°</td>
<td>26°</td>
<td>32°</td>
</tr>
<tr>
<td>Bamboo sample plot area</td>
<td>940m²</td>
<td>720m²</td>
<td>830m²</td>
</tr>
<tr>
<td>Number of clumps</td>
<td>51</td>
<td>52</td>
<td>51.5</td>
</tr>
<tr>
<td>Number of culms/clump</td>
<td>38</td>
<td>31.8</td>
<td>34.9</td>
</tr>
<tr>
<td>1-years old culms</td>
<td>3.8</td>
<td>1.8</td>
<td>2.8</td>
</tr>
<tr>
<td>2-years old culms</td>
<td>3.4</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>3-years old culms</td>
<td>5</td>
<td>1.6</td>
<td>3.3</td>
</tr>
<tr>
<td>4-years old culms</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Over 4 year-olds</td>
<td>21.2</td>
<td>21</td>
<td>21.1</td>
</tr>
<tr>
<td>Number of culms/plot</td>
<td>1938</td>
<td>1653.6</td>
<td>1795.8</td>
</tr>
<tr>
<td>1-years old culms</td>
<td>193.8</td>
<td>93.6</td>
<td>143.7</td>
</tr>
<tr>
<td>2-years old culms</td>
<td>173.4</td>
<td>145.6</td>
<td>159.5</td>
</tr>
<tr>
<td>3-years old culms</td>
<td>255</td>
<td>83.2</td>
<td>169.1</td>
</tr>
<tr>
<td>4-years old culms</td>
<td>234.6</td>
<td>239.2</td>
<td>236.9</td>
</tr>
<tr>
<td>Over 4 year-olds</td>
<td>1081.2</td>
<td>1092</td>
<td>1086.6</td>
</tr>
<tr>
<td>Culms / ha</td>
<td>20617</td>
<td>22966.7</td>
<td>21636.1</td>
</tr>
<tr>
<td>1-years old culms</td>
<td>2061.7</td>
<td>1300</td>
<td>1731.3</td>
</tr>
<tr>
<td>2-years old culms</td>
<td>1844.7</td>
<td>2022.2</td>
<td>1921.7</td>
</tr>
<tr>
<td>3-years old culms</td>
<td>2712.8</td>
<td>1155.6</td>
<td>2037.3</td>
</tr>
<tr>
<td>4-years old culms</td>
<td>2495.7</td>
<td>3322.2</td>
<td>2584.2</td>
</tr>
<tr>
<td>Over 4 year-olds</td>
<td>11502.1</td>
<td>15166.7</td>
<td>13091.6</td>
</tr>
<tr>
<td>Total Bamboo Culms</td>
<td></td>
<td></td>
<td>497,630,300</td>
</tr>
<tr>
<td>1-years old culms</td>
<td></td>
<td></td>
<td>39,819,900</td>
</tr>
<tr>
<td>2-years old culms</td>
<td></td>
<td></td>
<td>44,199,100</td>
</tr>
<tr>
<td>3-years old culms</td>
<td></td>
<td></td>
<td>46,857,900</td>
</tr>
<tr>
<td>4-years old culms</td>
<td></td>
<td></td>
<td>59,436,600</td>
</tr>
<tr>
<td>Over 4 year-olds</td>
<td></td>
<td></td>
<td>301,106,800</td>
</tr>
<tr>
<td>Fresh weight of 4-years old</td>
<td>742,957.5</td>
<td>Per day (ton)</td>
<td>2035.5</td>
</tr>
</tbody>
</table>
### culms (ton)

| Dry weight of 4-years old | 414,930.5 | Per day (ton) | 1136.8 |

**culms (ton)**  
Average height/ biggest (m): 8.91/12.2  
Breast diameter/ biggest (cm): 4.05/4.92  
Ground diameter /biggest (cm): 4.90/6.08  
Average weight (biggest) per 4-years old culm  
Bamboo diseases  
Bamboo insects  
Wild plants around  
Wild animals around

---

### 2.3.5. A report of fiber analysis of *Oxytenanthera abyssinica*

**Table 2-7 Test result of the fiber of *Oxytenanthera abyssinica***

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Unit</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of the fiber (FQA analysis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average length (FQA)</td>
<td>mm</td>
<td>1.625</td>
</tr>
<tr>
<td>Average length (visual inspection)</td>
<td>mm</td>
<td>2.10</td>
</tr>
<tr>
<td>Length distribution of the fiber (FQA analysis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3-0.5</td>
<td>%</td>
<td>10.88</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>%</td>
<td>19.10</td>
</tr>
<tr>
<td>1.0-1.5</td>
<td>%</td>
<td>16.35</td>
</tr>
<tr>
<td>1.5-2.0</td>
<td>%</td>
<td>20.12</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>%</td>
<td>16.77</td>
</tr>
<tr>
<td>&gt;2.5</td>
<td>%</td>
<td>16.77</td>
</tr>
<tr>
<td>Average width</td>
<td>Visual inspection</td>
<td>22.5</td>
</tr>
<tr>
<td>FQA</td>
<td>um</td>
<td>20.8</td>
</tr>
<tr>
<td>Length / width ratio</td>
<td>Visual inspection</td>
<td>93.2</td>
</tr>
<tr>
<td>FQA</td>
<td></td>
<td>78.1</td>
</tr>
<tr>
<td>Chamber diameter</td>
<td>um</td>
<td>7.16</td>
</tr>
<tr>
<td>Double wall thickness</td>
<td>um</td>
<td>15.38</td>
</tr>
<tr>
<td>Wall / chamber ratio</td>
<td></td>
<td>2.15</td>
</tr>
</tbody>
</table>

*Source: LEI Xiaojun, 2014.*
2.3.6. Testing of Two Ethiopian Bamboo Species for Value add Products

Table 2-8 Physical and Mechanical properties of finished bamboo floor boards produced in Ethiopia

<table>
<thead>
<tr>
<th>No</th>
<th>Type of product</th>
<th>MOR (N/mm$^2$) N=6</th>
<th>MOE (N/mm$^2$) N=6</th>
<th>Shear (N/mm$^2$) N=6</th>
<th>Ts (%) N=10</th>
<th>WA (%) N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carbonized vertical</td>
<td>144.99</td>
<td>17151.13</td>
<td>6.38</td>
<td>0.95</td>
<td>16.96</td>
</tr>
<tr>
<td>2</td>
<td>Carbonized horizontal</td>
<td>82.41</td>
<td>10142</td>
<td>4.4</td>
<td>0.52</td>
<td>19.72</td>
</tr>
<tr>
<td>3</td>
<td>Uncarbonized</td>
<td>95.05</td>
<td>10495</td>
<td>7.23</td>
<td>1.46</td>
<td>25.14</td>
</tr>
<tr>
<td>4</td>
<td>Untreated carbonized</td>
<td>118.73</td>
<td>14838.7</td>
<td>6.57</td>
<td>1.69</td>
<td>20.66</td>
</tr>
<tr>
<td>5</td>
<td>Untreated carbonized</td>
<td>62.23</td>
<td>8620.63</td>
<td>3.79</td>
<td>1.23</td>
<td>27.6</td>
</tr>
<tr>
<td>6</td>
<td>Untreated uncarbonized</td>
<td>81.76</td>
<td>10991.6</td>
<td>5.11</td>
<td>1.96</td>
<td>25.19</td>
</tr>
<tr>
<td></td>
<td>Chinese standard</td>
<td>90</td>
<td>na</td>
<td>na</td>
<td>15</td>
<td>na</td>
</tr>
</tbody>
</table>

Source: Seyoum, 2008

Table 2-9. Physical and mechanical properties of laminated bamboo lumber and plybamoo boards of two Ethiopian Bamboo species

<table>
<thead>
<tr>
<th>Board type</th>
<th>Species</th>
<th>Board density (Kg/m$^3$)</th>
<th>MOR (N/mm$^2$ )</th>
<th>MOE (N/mm$^2$ )</th>
<th>Ts (%)</th>
<th>WA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminated bamboo</td>
<td>O.abyssinica</td>
<td>775.8</td>
<td>157.92</td>
<td>1808.18</td>
<td>3.23</td>
<td>17.74</td>
</tr>
<tr>
<td></td>
<td>Y.alpina</td>
<td>662</td>
<td>130.22</td>
<td>14673.45</td>
<td>6.46</td>
<td>28.91</td>
</tr>
<tr>
<td>Plybamoo</td>
<td>O.abyssinica</td>
<td>777.6</td>
<td>123.46</td>
<td>17217.31</td>
<td>3.97</td>
<td>20.52</td>
</tr>
<tr>
<td></td>
<td>Y.alpina</td>
<td>648.5</td>
<td>101.45</td>
<td>12867.45</td>
<td>5.46</td>
<td>31.26</td>
</tr>
<tr>
<td>Chinese standard</td>
<td></td>
<td>&lt;98 N/mm$^2$</td>
<td>na</td>
<td>na</td>
<td>Na</td>
<td></td>
</tr>
</tbody>
</table>

Source: Seyoum, 2008
Table 2-10. Physical and mechanical properties of oriented strand boards of two Ethiopian bamboo species properties

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
<th>MOR (N/mm²)</th>
<th>MOE (N/mm²)</th>
<th>Internal bond (N/mm² N=10)</th>
<th>Ts (%) N=10</th>
<th>WA (%) N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. Abyssinica</em></td>
<td>Asosa</td>
<td>36.9</td>
<td>7530.52</td>
<td>0.39</td>
<td>15.51</td>
<td>41.66</td>
</tr>
<tr>
<td></td>
<td>Chagni</td>
<td>17.68</td>
<td>8488.17</td>
<td>0.09</td>
<td>47.59</td>
<td>59.8</td>
</tr>
<tr>
<td></td>
<td>Dedessa</td>
<td>31.19</td>
<td>8121.11</td>
<td>0.45</td>
<td>37.49</td>
<td>55.97</td>
</tr>
<tr>
<td><em>Y. alpina</em></td>
<td>Injibara</td>
<td>27.55</td>
<td>6589.13</td>
<td>0.29</td>
<td>24.67</td>
<td>50.68</td>
</tr>
<tr>
<td></td>
<td>Hagere-selam</td>
<td>50.97</td>
<td>9152.72</td>
<td>0.64</td>
<td>13.03</td>
<td>48.11</td>
</tr>
<tr>
<td></td>
<td>Ambo</td>
<td>24.5</td>
<td>9454.16</td>
<td>0.14</td>
<td>32.42</td>
<td>56.15</td>
</tr>
<tr>
<td>ISO standard</td>
<td></td>
<td>17</td>
<td>2100</td>
<td>0.35</td>
<td>18</td>
<td>na</td>
</tr>
</tbody>
</table>

Source: Seyoum, 2008

Table 2-11. Physical and mechanical properties of medium density fiber boards of two Ethiopian bamboo species

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
<th>MOR (N/mm²)</th>
<th>MOE (N/mm²)</th>
<th>Internal bond (N/mm² N=10)</th>
<th>Ts (%) N=10</th>
<th>WA (%) N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. Abyssinica</em></td>
<td>Asosa</td>
<td>16.28</td>
<td>2237.35</td>
<td>0.68</td>
<td>21.77</td>
<td>66.97</td>
</tr>
<tr>
<td></td>
<td>Chagni</td>
<td>15.21</td>
<td>2004.47</td>
<td>0.32</td>
<td>24.26</td>
<td>84.76</td>
</tr>
<tr>
<td></td>
<td>Dedessa</td>
<td>17.45</td>
<td>2327.97</td>
<td>0.6</td>
<td>22.41</td>
<td>73.73</td>
</tr>
<tr>
<td><em>Y. alpina</em></td>
<td>Injibara</td>
<td>19.95</td>
<td>2809.16</td>
<td>0.61</td>
<td>22.15</td>
<td>64.5</td>
</tr>
<tr>
<td></td>
<td>Hagere-selam</td>
<td>15.93</td>
<td>2085.87</td>
<td>0.69</td>
<td>25.53</td>
<td>72.7</td>
</tr>
<tr>
<td></td>
<td>Ambo</td>
<td>17.55</td>
<td>2213.68</td>
<td>0.38</td>
<td>26.78</td>
<td>80.95</td>
</tr>
<tr>
<td>ISO standard</td>
<td></td>
<td>22</td>
<td>2500</td>
<td>0.6</td>
<td>15</td>
<td>na</td>
</tr>
</tbody>
</table>

Source: Seyoum, 2008
As mentioned above, all parts of bamboo are treasures; human beings began to use bamboo very early. Bamboo made a great contribution to the progress of human civilization. In 1954, there was an excavation in Xi’an Banpo village of China dating back about 6,000 years or so, which is called Yangshao culture. On the pottery unearthed a “bamboo” word symbol can be recognized clearly, which indicates that the Chinese people’s history of research and utilization of bamboo can be traced back five or six thousand years ago, the Neolithic age. Chinese characters originated in the period of Yangshao Culture (BC 5000 ~ 3000 BC), late primitive societies, before which the original symbol of “Bamboo” character should appear already (see Figure 3-1). In Hemudu ruins of Yuyao County, Zhejiang, China (7000 years ago), some physical bamboo wares were also found (see Figure 3-2). In the dictionary Ci Hai (1979 edition), 209 Chinese characters related with bamboo are included, such as pen 笔, classics 籍, book 簿, bamboo slip 简, article 篇, chopsticks 筷, cage 笼, flute 笛, reed-pipe 笙 and so on.
3.1. **Bamboo as writing materials**

In China, during Shang Dynasty (BC 2000) people had known many uses of bamboo, one of which was bamboo slips. Words were written on bamboo (sometimes wood) slips, which were strung together with a rope to form a book. So the Chinese character “book” was also related with bamboo. Bamboo and wooden slips saved a large number of precious literatures before Han dynasty, such as the “Book”, “Book of Rites” and “Analects of Confucius”, which were written on bamboo or wooden slips.

Together with “The Art of War”, the ancient Chinese book “Sun Bin Art of
War” that lost more than 1700 years were unearthed in Yinqueshan excavations of early Western Han Dynasty tombs (BC 200) in Linyi, Shandong Province in April 1972. Both the two famous ancient books on art of war were engraved on bamboo slips (see Figure 3-3).

![Authentic Original](image1)

![Replica](image2)

Figure 3-3. Chinese bamboo book “The Art of War” unearthed in Yinqueshan excavations of early Western Han Dynasty tombs (BC 200)

2000 years ago, Chinese had invented papermaking. In China Han Dynasty, AD 92, Cai Lun transformed papermaking procedures. He used bark, fishing nets and bamboo to produce paper.

Early in the 19th century, China had started to make bamboo paper, about 1000 years earlier than Europe (see Figure 3-4).
Figure 3-4. Chinese processing procedure of bamboo paper in the 19th century

Figure 3-5 Ancient bamboo paper
The invention of Bamboo Pen also has a pioneering meaning in the cultural history of human being. On the bones, jades and pottery pieces unearthed from the cultural relics of Yin Dynasty of China, some red and black pen brush handwriting can be seen clearly.

![Figure 3-7 Well preserved authentic handwriting, Copybook Pingfu written by Luji over 1700 years ago](image)
3.2. Bamboo as musical instruments

Chinese classic music is called “string and wind (bamboo) music”. Chinese bamboo musical instrument first appeared in the Yellow Emperor era, 3000 BC before. It is said that Hongya, the Yellow Emperor’s music minister, sawed bamboo to make flutes and reedpipes, produced Chinese first wind instruments.

![Figure 3-8 The father of Chinese music Hongya, who made the first wind instrument with bamboo before 3000 BC](image)

3.3. Bamboo as water-drawing and irrigation tools

In addition, there are also many other bamboo wares were used in ancient China, such as bamboo arrows, crossbows, ship rafts, bridges, water-drawing tools “Shadoof” and irrigation tools “High water-drawing wheel”.

The gunpowder arrows and guns in Chinese Song Dynasty (960—1279) were also made with bamboo.
Figure 3-9. Water-drawing tool “Shadoof” made of bamboo or tree, which was invented in China over 2500 years ago.

Figure 3-10. High water-drawing wheel made of bamboo, which was invented in China over 1400 years ago.
3.4. **Bamboo as kitchen utensils**

Figure 3-11 Other traditional bamboo products

3.5. **Bamboo as different kinds of baskets**
3.6. Bamboo as different kinds of sieves

Figure 3-12 Many kinds of bamboo baskets

Figure 3-13 Bamboo sieves
3.7. Bamboo as different kinds of furniture

Figure 3-14 Bamboo furniture
3.8. Bamboo as building materials

Figure 3-15 Bamboo building 1
Figure 3-16 Bamboo building 2
3.9. Other traditional bamboo utilization

Figure 3-17 Bamboo ship rafts
Figure 3-18 Other bamboo crafts
Chapter 4
Modern Utilization of Bamboo Resources

Based on the traditional utilization, the modern development of bamboo resources utilization are focuses on three aspects:

- Mechanical application;
- Electromechanical integration technology; and
- Chemical treatment.

4.1. Mechanical Processing Products

4.1.1. Bamboo house wares and furniture
4.1.2. Bamboo houses

Figure 4-3 Bamboo houses made of mechanical processed boards
4.1.3. Bamboo mats

Bamboo sofa mats

Bamboo chair mats

Bamboo bed mats

Figure 4-4 Different kinds of bamboo mats

4.1.4. Bamboo pillows and pillowcases
4.1.5. **Original bamboo fiber and fiber products**

Figure 4-6 Original bamboo fiber and its products

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4.2. Products by means of electromechanical integration

Figure 4-7. Laser machine engraving products

4.3. Chemical Processing Products

Bamboo chemical processing products consist of bamboo charcoal products (including bamboo charcoal fiber and cloth), bamboo pulp and paper, bamboo vinegar and bamboo extracts, and so on.

4.3.1. Bamboo charcoal products

Nine functions of Active Carbon (charcoal)

- Adsorption for air cleaning and humidity regulation
- Release far infrared for physiological health
- Release negative ions for healthy breath
- Release trace elements for soil improvement
- Control microbial proliferation
- Regulating the growth of crops
- Insect sterilization
- Resist oxygen
- Electromagnetic shielding from radiation for body protection

In 1972, there was an excavated tomb in Changsha, China, which buried a Marquise who was died in 186 BC. After 2156 years, her skin was still like just died. So the Marquise was known as the "Oriental Sleeping Beauty". The main cause is that about 5 tons of charcoal was put around the coffin to adsorb moisture and keep it in dry and sterile condition.
Figure 4-9 Bamboo charcoal products (1)

Figure 4-10 Bamboo charcoal products (2)
Figure 4-11 Bamboo charcoal products (3)
Figure 4-12 Bamboo charcoal products (4)

- Tooth brushes
- Pants
- Pillow
- Artificial diamond shoe chain
- Towels

Figure 4-13 Bamboo charcoal products (5)

- Super capacitor electrode material
- Activated Carbon for Organic Solution-type EDLC
- Activated Carbon for Aqueous Solution-type EDLC
The super capacitor electrode material is the key material of super capacitor (EDLC), belonging to the field of new materials; it’s listed as “national high technology industrialization” demonstration project. Main products are two series as aqueous type EDLC carbons and organic type EDLC carbons. As the electrode of super EDLC with the property of high energy density, low resistance and stable electrochemical. Widely used in manufacturing various EDLC for power supply of HEV/EV, high power UPS etc.

### 4.3.2. Bamboo pulp and paper

![Bamboo pulp](image1)

![Tissue paper](image2)

![Printing paper](image3)

![Unbleached](image4)

![Bleached](image5)

![Paper roll](image6)

**Bamboo Paper**

Figure 4-15 Bamboo pulp and paper

### 4.3.3. Bamboo pulp fabric products
4.3.4. **Bamboo vinegar and its products**

**Eight functions of bamboo vinegar**

Bamboo vinegar is abundant of extracts, many of which can be used as the additives of food and feed, medicine and drinking.

- Soil improvement, sterilization, harmful organism and disease prevention.
- Deodorizing disliked odor, especially in toilets, livestock house and fish market.
- Liquid fumigant to dip ham and sausage for preventing from insects and tasting more delicious.
- Plant growth regulators to promote vegetables, fruit trees, flowers, rice, grass and other plants, and inhibit weed growth, reduce pesticide dosage as pest repellent agents.
- Food preservation for anti-mildew, anti-bacterial, and anti-oxidation.
- Healthcare for dermatitis, beriberi, itching disease treatment because its sterilization on anti-itch and anti-inflammatory.
- Healthy beverage additives to remove methanol, formaldehyde and other harmful substances after purification treatment.
- Feed additive to improve the meat quality of livestock and farmed fish and increase nutrition.

Figure 4-17 Bamboo vinegar products (1)
Hu Huojin

Figure 4-18 Bamboo vinegar products (2)

Healthcare

Feed additive

Beverage additive

Food preservation

Cosmetics

Soaps

Skin Care Products

Hand sanitizer

Acne solution

Perfume

Figure 4-19 Bamboo vinegar products (3)
4.3.5. Bamboo salt and its products

The dual role of bamboo salt and fluoride can strengthen the enamel surface of tooth so as to make the teeth stronger.

4.4. Bamboo food products
Figure 4-22. Industrialization production of bamboo shoots

Figure 4-23 Fresh bamboo shoots
Figure 4-24 Dried bamboo shoots

Figure 4-25 Pickled bamboo shoots
Figure 4-26 A kind of edible bamboo fungi, *Dictyophora indusiata*

Figure 4-27 Artificially interplant *Dictyophora indusiata* in bamboo forest
4.5. Bamboo landscape and bonsai

4.5.1. Bamboo landscape

Figure 4-28 Bamboo rat (*Rhizomys sinensis*) keeping

Figure 4-29 Bamboo is used for courtyard greening
4.5.2. Bamboo bonsai

Figure 4-30 Bamboo is used in highway landscape

Figure 4-31 Bamboo is used for park greening

Figure 4-32 Bamboo is used for public holdings greening
4.6. Other utilization of bamboo resources

4.6.1. Bamboo artwork
4.6.2. Bamboo electronic products

Audio equipments

Laptop

Figure 4-35 Bamboo electronic products

4.6.3. Bamboo culture
Figure 4-36 Bamboo culture (1)

Figure 4-37 Bamboo culture (2)
Figure 4-38 Bamboo culture (3)

Vertical flute
Big dulcimer
Small dulcimer
Horizontal flute
Zither
Chapter 5
A brief introduction of some modern bamboo techniques

5.1. Bamboo pulp manufacturing

The raw materials of pulp are composed of wood, bamboo, reeds, straw, wheat straw, cotton stalks, sugar cane bagasse, rags, cotton waste, waste linen plant fibers and so on. Bamboo pulp is one of them, which is made of tender bamboo. The pulp manufacturing is a process to make plant fiber material dissociated into pulp with original or bleached color.

The methods of pulp producing can be broadly divided into three kinds: mechanical, chemical and chemical mechanical.

- Mechanical methods are: raw bamboo grinding method, bamboo slips grinding method.
- Chemical methods are: alkali and sulfite method.
- Chemical mechanical methods use chemical treatment together with milling mechanical refining methods.

Figure 5-1 Procedures of bamboo pulp processing
5.2. Bamboo paper manufacturing

I. Pulp treatment

Before making paper, the bamboo pulp must be treated as follows:

- the pulp must be filtered, boiled and rinsed, sieved, bleached, concentrated and then stored;
- secondly, to beat the stored pulp and make it into paper, then to press and roll it into final paper production for various purposes.
Figure 5-3 Pulp filtering and rinsing machines

- Vacuum washer
- Spiral pulp squeezer
- Vortex cleaner
- Vertical centrifugal cleaner
- Pulp sieving machine
- Vertical rotor sieve
Figure 5-4 Pulp Sieving and Cleaning Equipment

**Continuous multi-stage bleaching equipment**

- Alkali processing tower
- Chlorination tower

**Single-stage bleaching equipment**

- Bleaching tower
- Hypochlorite single-stage bleaching machine

Figure 5-5 Pulp bleaching equipment

**Rotary concentrator**

- Manometry concentrator

Figure 5-6 Pulp concentrating equipment
Pulp beating is a process to deal with pulp fibers suspended in water by mechanical methods to make it suitable for the characteristics required by papermaking machines, so that the paper products can achieve the desired quality. Its aim is to treat pulp fibers mechanically to make them change the shape and physical properties, such as the points cutting, wire separating.
II. Paper making

Papermaking machines

According to the different structure of paper-forming parts, the main types of papermaking machines are: long-net type (Figure 5-9), folder-net type (Figure 5-10), round net type (Figure 5-11) and composite type etc.

Figure 5-9 Long-net type papermaking machine
Figure 5-10. Folder-net type papermaking machine

Figure 5-11. Round net type papermaking machine
The main functions of paper pressing machine are as follows:

- to finish and improve the smoothness, glossiness and tightness of the paper;
- to correct the thickness of the paper by partial heating and cooling of the rolls of the pressing machine so as and
- to reduce the thickness changing of the paper along horizontal upward fluctuations.
5.3. Bamboo charcoal manufacturing

There are two main charcoal production processes: pyrolysis in carbonization furnace and carbonization by direct firing in a kiln.

I. Pyrolysis in carbonization furnace
Take mobile sawdust carbonization furnace as an example:

When we use carbonization furnace to make charcoal, the sawdust must be pre-dried to a moisture content of 20% - 25%. Because in the firing process there is no charcoal oxidation problem, so the yield rate of charcoal is higher (generally about 25%, up to 35%), and the firing cycle is shorter (generally 48 to 72 hours). However, if the refining temperature is not high enough, the density of bamboo charcoal will be impacted; and because the volume of carbonization furnace is small, the charcoal production capacity is lower. Now, to tackle the problem, a kind of continuous carbonization furnaces is invented.
Figure 5-14 Sawdust molding machine

Figure 5-15 Mobile sawdust carbonization furnace

Figure 5-16 Bamboo charcoal by machine
II. Carbonization by direct firing in a kiln

1. Building kilns

When selecting the location to build kilns, three elements must be considered: Firstly, a supplying base rich of bamboo resources, especially with enough old bamboo is needed; secondly, we must choose a wide, dry, firm, flat and open land to build kilns so as to have enough good space for keeping raw bamboo material and firewood and unloading charcoal; thirdly, the kilns’ site is better to be convenient for transportation and electricity. The scale is according to the bamboo resources, economic strength, broad extent of the site location. For easy management, to build 3-4 kilns is appropriate. Specifications for a charcoal kiln are about 5.5m×5.5m. And in the front gate of the kiln, 3m workplace is needed. Around the charcoal kilns, a 0.5m wide, 0.5m deep drainage ditch must be dug. Beside the charcoal kilns, there must be a storage yard for enough raw fuel.
Attention

A) The kiln’s gate must be tilted inward about 5°.
B) Around the kiln, the airtight sealing layer should exceed 60cm (over 25cm on top). Material ratio (mixed enough with water):

mud : gravel =3:1;
mud with gravel : cement : lime : salt =1 m$^3$:100kg: 100kg:5kg .
The top sealing layer needs a solid beat.

C) The outlet of chimney must be 20cm higher than the kiln’s body in case of blocking by dropped things.

2. Firing bamboo charcoal

A) Loading the kiln

Saw the bamboo into segments according to the internal horizontal or vertical length of the kiln and fully load it in horizontal or vertical direction. It’s better to put one row of wood about 10 cm in diameter and one row of bricks about 70-80cm high near the gate in case of direct bamboo burning inside. Then close the gate (on the bottom leave three holes of 10cm height for ventilation and ash clearing; on the top leave a vent of one brick and in the middle leave a window about 25×30cm for adding fuel).
B. Firing charcoal

The charcoal firing will go through six phases [for the former three phases that known as endothermic decomposition phase, it needs adding fuel to provide heat during daytime and close the gate at night (leave the bottom vents)]:

(a) **Pre-drying.** Inside the kiln the temperature is 60 ~ 100 °C;

(b) **Drying.** Inside the kiln the temperature is 100 ~ 150 °C, and the chimney outlet temperature is 60-70 °C, with moisture content of bamboo, the smoke is white and pungent;

(c) **Pre-carbonization.** A slight yellowish pungent smoke appears, inside the kiln the temperature is 150 ~ 270 °C. When the chimney outlet temperature is about 80 degree, the bamboo organic ingredients begin to decompose slowly. During this phase, it needs adding fuel to heat up until the temperature inside the kiln reaches 250 degrees so that the
bamboo itself can produce heat for carbonization by its own pyrolysis reaction, such as the hemicellulose decomposition that produces carbon dioxide, carbon monoxide and small amounts of acetic acid and other substances;

**(d) Carbonization.** After the yellowish smoke with a slight scent appears, close the kiln gate (leave the bottom vents). The temperature inside the kiln is 270 ~ 450 °C. After the temperature of the chimney outlet reaches 85 degrees, by controlling the size of the chimney outlet (usually making it about half open) and reducing the size of the bottom vents to control the carbonization speed and improve the quality of the charcoal. Usually the carbonization process takes 5-7 days, during which the smoke changes from yellowish to white and then to blue. The pyrolysis reaction is so sharp to produce bamboo vinegar that is composed of nearly 300 kinds of chemical components, which can be collected from the chimney outlet;

**(e) Calcination** (refining). When the temperature of the chimney outlet is above 150 °C and a blue smoke appears, open the kiln gate to accelerate the temperature inside the kiln go up to 450 °C- 1000 °C so that the charcoal molecular shrinks tighter;

(f). Natural cooling. Close the kiln gate and chimney outlet for about one week until the temperature of the kiln gate is dropped to 50 ~ 60 °C, and the back of the kiln is not hot by hand touching, then the charcoal can be unloaded.
5.4. Extract technology of bamboo vinegar

About bamboo vinegar

Bamboo vinegar is a liquid substance collected from the gas coming out from the chimney outlet of the kiln when it is cooled to a room temperature automatically, which is a mixture product of pyrolysis reaction during the firing process of bamboo charcoal. It contains nearly 300 kinds of natural polymer compounds, such as organic acids, alcohols, ketones, aldehydes, esters and small amounts of alkaline ingredients. It is composed of many different substances. And it’s not a constant mixture, but a changing mixture according to the exposure time in air and light and other conditions.

The main component of bamboo vinegar is water (over 80%), followed by acids, primarily acetic acid (about 6%), and formic acid, butyric acid, methanol, acetone, alcohols, glycols, aldehydes, 13 bamboo phenols, a small amount of acetone, trimethylamine ((CH₃)₃N), pyridine (C₅H₅), deciduous pine bark hormone (C₆H₆O₃), tar and so on. For the mixture of bamboo vinegar, the PH value is 2.20-3.01, the specific gravity is about 1.02 or so, the color is yellow, bright brown or dark brown. It is clear and transparent, with peculiar smoked odor of vinegar. Bamboo vinegar should be collected when the chimney temperature of the charcoal kiln is 80 °C ~ 150 °C. In order to obtain pure bamboo vinegar, except bamboo fuel, wood and other fuels should not be used during the firing process of bamboo charcoal. The collected bamboo vinegar from the bamboo charcoal kiln is original liquid that can be refined into required pure bamboo vinegar through precipitation, filtration and distillation. Bamboo vinegar preservation should avoid direct exposure to sunlight, because light is very liable to make original bamboo vinegar discompose. So, it better to keep bamboo vinegar in colored and non-transparent containers. And it is not suitable to store bamboo vinegar in metal containers, because it is easy to react with the metal.
The original reddish brown bamboo vinegar obtained from bamboo pyrolysis must be decolorized, separated and purified according to different purposes.

I. Simple purification method

With simple purification method, the bamboo vinegar components are separated and purified preliminarily by using a simple device. The specific methods are classified as follows:

1. Static separation method

   After static placing for some time, the original bamboo vinegar will be naturally divided into two layers: the upper is light clarified vinegar; the lower is precipitated bamboo tar. Static method can be subdivided into two kinds: 1) direct static separation; 2) static separation with drugs (mix organic solvents, such as benzene and chlorine alum, respectively with bamboo vinegar in different proportions and let it place statically and divide into two layers, and then separately distill them to recycle the solvents);

2. Adsorption separation. It can also be subdivided into two kinds: 1) charcoal adsorption method (by mixing vinegar with different proportions of carbon particles or powder, stirring and then filtering it to obtain purified bamboo vinegar); 2) activated carbon adsorption method (by putting amorphous carbon particles, formed carbon and powder of activated carbon in different proportions into the original bamboo vinegar, mixing and stirring it, then filtering it after static placing for some time to obtain refined bamboo vinegar).

II. Distillation

Distillation is a separating method according to the different boiling points of original bamboo vinegar components. Generally there are two kinds of distillation: 1) simple distillation (By putting the bamboo vinegar mixture to be separated into the distillation kettle and heating to evaporate it, conducting the vapor from the distillation kettle into the condenser, the
steam in the condenser changes into a liquid and flows into a collector because of the cooling effect.; 2) refining distillation (by making the vapor generated from distillation apparatus interact with the reflux liquid partly cooled from former generated vapor).

5.5. Bamboo fibers manufacturing (1)

---Original bamboo fibers manufacturing

Bamboo fiber is a kind of cellulose fiber extracted from the natural growing bamboo, which is the fifth natural fiber utilized by human being after cotton, linen, wool and silk. It has good air permeability, water absorption, strong wear resistance and good dyeing properties, and meanwhile it has natural antibacterial, antimicrobial, anti-mites, deodorant and anti-ultraviolet functions. So it can be called an eco-friendly green natural fiber on a real sense. Because bamboo fiber textiles is the complete copy of bamboo fiber with its inherent characteristics, it has more and more consumers, and the product demand of bamboo fiber textiles is rising year by year.

Original bamboo fiber is a natural bamboo fiber produced with a combination of physical and chemical methods.

The producing process is as following:

Raw bamboo material →bamboo slips (firstly cut raw bamboo culms into segments and then remove the nodes, secondly cut the bamboo segments into slips in required length) →boil bamboo slips with water for refining→crush and hammer the slips into filaments→steam the bamboo filaments in pressure cooker to remove some pectin, hemicellulose and lignin→degum with biological enzyme for further decomposing of pectin, hemicellulosas and lignin to obtain cellulose fibers (to obtain finer bamboo fiber, we can also add some cellulase enzyme into the treatment liquid)→comb the degummed bamboo fibers (including washing and cleaning, bleaching, oiling, softening and combing) →textile fibers

5.6. Bamboo fibers manufacturing (2)
**Bamboo pulp fibers manufacturing**

Bamboo pulp fiber is made of bamboo pulp. That means it needs preparing pulp slurry from raw bamboo material at first, and then made it into fibers by wet spinning. However, in the process the natural characteristics of bamboo fiber are destructed, for example, the functions of deodorizing, antibacterial, anti-ultraviolet are decreased. So, the quality of bamboo pulp fiber is not as good as that of original bamboo fiber.

**The main processes include:**

1. To prepare bamboo pulp;
2. To extract pure α-cellulose that is called pulp grains in distilled liquor;
3. To prepare spinning solution (to treat the pulp grains with caustic soda and carbon disulfide to obtain yellow-orange xanthogenate cellulose sodium that is later dissolved into a viscous spinning dope in dilute sodium hydroxide solution);
4. To press the spinning liquid out from the orifice to form a trickle;
5. To let the liquid trickle pass a coagulation bath (Commonly aqueous solution of sulfuric acid and sodium sulfate, etc. is used. The sodium sulfate coagulates the liquid trickle; and the sulfuric acid makes the cellulose xanthogenate sodium decompose into primary cellulose) to solidify into a spun fiber;
6. To roll and pack the primary fiber or treat it directly.

**5.7. Bamboo fibers manufacturing (3)**

**Bamboo charcoal fibers manufacturing**

Bamboo charcoal fiber is such a fiber product spinned in an approximate conventional spinning process from viscose spinning solution that is added with bamboo charcoal incense nanometer powder by a special process.
Bamboo charcoal fiber preparation process comprises the following:

- Bamboo charcoal carbonization (to heat over 5 year-old alpine bamboo to 450-550 °C to carbonize it, and then heat it continuously up to 800-900 °C to carbonize it in high-temperature) →
- to prepare activated bamboo charcoal (to rapidly cool the heated charcoal by spray treatment. At this time, due to physical and chemical action of water, the charcoal produces such a complex porous structure that the surface area increases by several times, and the sorptive capacity is greatly improved. The density of the charcoal after activation treatment increases greatly, and it becomes extremely hard. The carbon rate is 85% or more) →
- to crush the activated bamboo charcoal into sub-nanometer charcoal powder→
- to mix the sub-nanometer charcoal powder with protoplasmic, such as polyester or viscose by whisking to make them disperse uniformly →
- spinning (through a spinning device, to draw out a long bamboo charcoal powder string from the protoplasmic, which is bamboo charcoal fiber).

5.8. Bamboo salt manufacturing

Bamboo salt is such a substance that is extracted from solarization salt by putting it into a three year-old green bamboo cylinder and sealing both ends of the bamboo section with loess and then calcining it under a 1000 °C ~ 1500 °C temperature condition with pine trees as fuel. It is said that bamboo salt was handed down as folk remedies by the temple's monks of Korea 1300 years ago. Its industrial production began in 1988. Afterward, the commercialization of bamboo salt product is more and more widely circulated.

Bamboo salt preparation process comprises the following:
• To choose 3 year-old bamboo with the diameter less than 7cm (If the diameter is greater than 7cm, it is difficult for the bamboo liquid to dissolve into the salt, so the quality of bamboo salt can not be guaranteed.) and truncate it into cylinder sections;
• To fill some solar dried salt rich of minerals into the bamboo sections and seal the ends with natural loess;
• To calcine the bamboo sections for 24 hours with pine firewood, which must repeat eight times to reach about 1000 °C. During the ninth calcination, add more pine fuel to raise the temperature up to 1500 °C to make the salt melted;
• To cool the molten salt block, and then crush and sieve it to obtain finished bamboo salt.

5.9. Bamboo charcoal diamond manufacturing

Currently, there are two ways to produce artificial diamonds from carbon:

One is to mimic the natural environment to form diamonds, i.e., to use high temperature (above 1000 Celsius degrees) and high pressure (900 atm) to break the carbon structural chains and open the bonds of carbon atom, and then let them absorb enough energy for transforming into diamond structure. In this case, the carbon has been changed into diamond. The world’s first artificial diamond synthesized in 1954 by the researchers of the U.S.A. General Electric Company’s laboratory was applied in this approach.

Another method to manufacture synthetic diamonds was also successfully developed in the fifties of last century. This method is called chemical vapor deposition (CVD) method. Compared with the first method, the carbon is deposited as a diamond substrate from the mixed gas of carbon under a lower pressure and relatively lower temperature condition.

5.10. Bamboo boards manufacturing
Bamboo boards manufacturing procedures are as following:

- **Cutting.** Choose the lower part (The wall thickness is more than 8mm.) of 3-5 year-old bamboo that is over 8 cm in diameter and has no insect infestation, no damage, and then cut it into segments according to the board size.

- **Splitting.** Use bamboo-splitting machine to split the sawn bamboo segments into bamboo strips in required specifications. There are 16 sets of split knives for the bamboo-splitting machine, which is appropriate to different size of the bamboo diameter.
- Rough planing. Plane the bamboo strips into the same thickness and width. The rough planing machine has a set of mills with fixed width and 5-6 cutter knives and a set of straightening side knives. The mills fix the bamboo strips’ width; the upper and lower cutter knives remove the bamboo nodes and fix the bamboo strips’ thickness.

![Figure 5-25 Rough planing](image)

- Bleaching and degreasing. Put the rough planed bamboo strips into water pools that bleach H₂O₂ (hydrogen peroxide) is mixed with inside and heat it for 40-60 minutes’ boiling. The pools are made of stainless steel for corrosion-resistance, so that the bamboo strips can be fully bleached and degreased.

- 5. Drying. Put the degreased and bleached bamboo strips into drying room for drying. Of the ordinary drying room, the length is 20-25 m, and width 2 m, height 2.2 m.
• Fine planing. After drying, plane all the four sides of the bamboo strips with fine planing machines to make them flat and with 90 degree angle edges. The fine planing machine has four high-speed knife shafts. The speed is 12,000 rev/min.
Coating with glue. Paint glue onto the fine planed bamboo strips double-sided or single-sided with gluing machines. The glue must be evenly coated on the surfaces to be spliced.

Hot pressing. Manually match the coated bamboo strips into semi finished products and then put them into pressing machines to heat and press them. Each pressing time is 10 minutes. Then take the bamboo planks out. The bamboo flooring planks process completes.
5.11. Electromechanical integration technology

CNC (Computer Numerical Control) laser engraving process is based on modern CNC technology, of which the processing medium is laser. The processing aim is realized by laser irradiation on the processed material to produce instant physical modification of melting and vaporization. Laser processing has following superiorities: 1) there is no direct contact with the material surface; 2) it is without impact by the mechanical movement; 3) the processed material surface will not be deformed; 4) it generally does not need to be fixed; 5) it is not affected by the elasticity, flexibility of the processed material, so it is convenient for processing soft material; 6) it has high precision and quality, high speed and efficiency.

Figure 5-30 Laser bamboo cylinder engraving machine
5.12. Bamboo sticks manufacturing

Bamboo is also processed into sticks that are widely used for incense stick, toothpick, skewer stick, chopsticks, knitting stick and so on. The processing machines are as following:
5.13. **Bamboo shoots processing**

For bamboo shoot processing some precautions must be mentioned at first as following:

- The shoots must be harvested at a appropriate age. If it is too tender, although the quality is good, but the yield is too low. If it is too old, there will be too much crude fiber content to decrease its quality.
- The raw materials must be selected seriously. It needs choosing fresh and good bamboo shoots and removing dead, infestation, deteriorated one.
- The processing must be in a timely manner. Fresh shoots cannot be stored for long time. It must be fixed as soon as possible to prevent aging and quality reducing.
• The processing must be reasonable. Each process must be interrelated closely to avoid stalling for time and to prevent spoilage and deterioration.

• The products must be health and safety. During the whole processing, food hygiene and strict disinfection must be assured. After processing, the finished packaging and cautious storage are needed to prevent all kinds of pollution.

Bamboo shoot products can be broadly divided into two categories: dried bamboo shoots and canned (wet) bamboo shoots. Dried bamboo shoots are traditional products, many of which are famous brand and boutique. In order to ensure the authentic product, the traditional processing techniques are essentially retained. Even for packaging, the traditional packaging materials are basically used. Production of canned bamboo shoots has 60 years history. But in the past, it is limited to small-scale production of only seasoned bamboo shoots. Large-scale industrial production is developed rapidly in recent years. Now the production process is so matured that not only large volumes of canned water bamboo shoots can be produced, but also a variety of flexible packaging and seasoned bamboo shoots, including a series of bamboo shoot products, such as large packaging and small packaging, instant and fresh bamboo shoots for both family and tourism consumption with different flavors, different specifications.

From the technological process point of view, bamboo shoot products are generally divided into 4 categories: fresh bamboo shoots, dried bamboo shoots (including filamentous bamboo shoots), canned water bamboo shoots and seasoned bamboo shoots. Because of the bamboo shoots’ easily aging, it is still unable to carry out long-distance distribution or storage of fresh bamboo shoots. The so-called fresh bamboo shoots on the market are all water bamboo shoots through high-temperature fixation and vacuum packaging (flexible or rigid cans), which can maintain the natural flavor of bamboo shoots in some extent. There are many kinds of seasoned bamboo shoots, such as spiced bamboo shoots, spicy hot bamboo shoots, oil cooked bamboo shoots, sour bamboo shoots, sauced bamboo shoots and so on. Now
some processing techniques of common bamboo shoot products are briefly described below:

I. White bamboo shoot

White bamboo shoot is such a kind of bamboo shoot that is cooked, pressed, sun dried or kiln dried from fresh Moso bamboo (*Phyllostachys pubescens*) shoot.

1. Preparation

- Construction of shoot shack: Bamboo shoot shack is a place to process bamboo shoots, which must be the center of bamboo forest with flow of water resources.

- Construction of drying kiln: The area of a drying kiln is about 10m², which must be sealed around to keep the indoor temperature. For sun sundried bamboo shoots it doesn’t need to build any drying kiln.

- Preparation of cook stove and Amoy pot: Buy a large Amoy pot that can boil 250 ~ 275kg of bamboo shoots at one time. The Amoy pot is composed of two parts: an iron pot as the lower part and a wooden cask as the upper part. The upper mouth diameter of the iron pot is 85 ~ 100cm appropriately. The cask height is 105 ~ 150cm, and its upper mouth diameter is about 82cm, the bottom diameter equals to that of the upper mouth of the iron pot. The cask’s cover can be made of wood or bamboo. The cook stove is about 1m high, with a fuel gate of which the height is 60 ~ 70cm, and width is 50cm. The side width of the cook stove must be bricked enough big for convenient shoot-processing operation.
- Preparation of shoot presser: The shoot presser is composed of two parts: frame and shoot holders. The frame is composed of some columns, beams, connectors, ladders, and holder bearers. The shoot holders are made of wood layer by layer, of which the size is about 200 square centimeters. It is used to press shoots by the lever principle.

In addition, it also needs to prepare some buckets for shoot washing, and some shoot forks, shoot baskets, and a fire fork, etc. For sun dried shoots, some bamboo mats are needed to be prepared, too.
Production procedure

- Digging shoots: Start digging shoots of appropriate age on the season when bamboo shoots begin to come out of the earth, such as spring season or raining season. After digging, peel the sheathes of the shoots, and then send them to the shack and stack them on some bamboo mats.

- Scraping off roots: Scrape off the shoot roots with the back of a knife blade, the more cleaner the better. If there is any sludge, the shoot also must be washed.

- Boiling shoots: To clean the Amoy pot by edible oil frying and water washing. Then add water and boil it. When water begins to boil, fill it with fresh bamboo shoots, then cover and boil it with fierce fire for 2 ~ 3 hours.

- Rinsing shoots: Arrange three buckets filled with water beside the stove, make water constantly flow from the cask into the pot, then take out the cooked bamboo shoots with a fork from the cask to the middle bucket for cooling. After cooling, poke through each shoot
from the slender end to the root end with an iron stick so that the internal heat can thus be dissipated, and in the future when pressing bamboo shoots, the water can also be fully squeezed out. And then put the shoots into the left and right buckets to be rinsed for one night. All the shoots must be cooled thoroughly, otherwise, if the shoots are pressed with even a little heat, they are very liable to be rot and ferment.

- Pressing shoots: Arrange the first shoot holder on the holder bearer that is covered with clean grass, then load the thoroughly cooled shoots. When loading shoots, put a circle of inferior shoots to the outer ring first, then add bamboo shoots in the circle. Let the slender end of the first layer of bamboo shoots inward, and the that of the second layer outward, and so on, alternately. Thus, the bamboo shoots can be compacted with each other. And then load the second shoot holder, the third, the fourth, and so on. For each shoot holder, the central area should be loaded a little more so that it will be a little higher and can avoid the occurrence of voids. If there is any space, we can infill with some bamboo clothing.

After loading, put on the cover plate and the skids, then press the shoots with the pressing beam. The pressure must be added gradually. During the first few days, add pressure two or three times per day. Afterward, the pressure can be added every few days. The total pressing time is about one month.

After pressing, seal it for future drying. After sealing, the opening can not be arbitrarily, especially for the sun dried shoots, it must be just the time when the weather is sunny.

3. The standard of quality white bamboo shoot

1. The shoot body is clean and flat, spindle, i.e. the middle is big and the two ends are small. 2. The shoot color is light, yellowish like jade. 3. It is short, thick and tender with dense nodes. 4. The root end is small with white color. 5. It is dry with some bayberry stars inside. 6. It has aroma,
but with a little sour. It has such a large expanding capacity that after soaking 1kg dry shoot can become more than 7kg wet shoot.

II. Fermented bamboo shoot

Fermented bamboo shoot is such a kind of bamboo shoot that is cut, cooked, fermented, sun dried from fresh shoot of *Dendrocalamus latiflorus*.

1. The main processing equipment

   Bamboo shoot shack, cook stove, steamer or pot, fermentation cage, bamboo mat, and so on.

2. Production procedure

   - Shoot harvesting: It is appropriate to harvest the shoot when four leaflets have come out and the shoot length is 60 ~ 100cm.
   - Bamboo sheath peeling: While digging, the bamboo sheath should be peeled. After peeling, the shoot weight will reduce about 10% to 15%.
   - 3) Shoot cutting: After peeling, cut the bamboo shoot into flake or filamentous according to needed specifications. Firstly, cut the shoot into two segments from the base about 30cm, then slit the lower segment into two vertically, and cut them into 4 ~ 5cm long and 1cm wide or according to needed specifications. Secondly, slit the upper segment into two vertically. If the shoot is up to 1m or more long, remove the bamboo base, then cut the tender part into flake or filamentous, and the other into any specification according to customers’ requirement. Of the shoot flakes, the length is usually 40 ~ 50cm and the width is 12 ~ 15cm. But for small shoots, it doesn’t need to cut horizontally first.
   - Cooking: Fully load the cut shoot into a steamer or pot to cook, which is filled with about 80% water before. When cooking, adding 0.1L of peanut oil each time can improve the shoot color. Cooking time is one hour for each.
   - Fermentation: Put the cooked bamboo shoots into the fermentation cage layer by layer and let them ferment. Before putting in bamboo
shoots, some banana or other plant leaves must be put around inside the cage as a mat. Cover the cage with banana leaves or cotton cloth tightly, and add some grass mat or plastic sheet, then put some stone or sand for pressure. The optimum fermentation temperature is 25 ~ 30 °C. After 10 days fermentation, the bamboo shoots weight is about 55% to 60% of that of fresh bamboo shoots. The longer the fermentation, the more weight reduction. The fermented shoots can be stored more than six months.

- Drying: The fermented bamboo shoots should be taken out and straddled on bamboo mats for drying when the weather is sunny. After being exposed to the sun for 4 ~ 5 days, when the color changes to yellow brown and slightly transparent, it can be collected or sold. The weight of dry bamboo shoot is about 4% to 5% of that of fresh bamboo shoot.

- Classification: The classification standards vary in different place. But the color of the finest products should be golden yellow or brown and shiny. The color inferior products is dark and often with spots.

- Packing: After classification, load the shoots into sacks 30kg each, then seal it for sale.

### III. Canned water bamboo shoot

Canned water bamboo shoot is a traditional product in southern China, which is sold all around the world.

#### 1. The main technical targets

(1) **Sensory target**

- **Color:** The shoot body and buds are yellow and soup clear;

- **Taste and odor:** The smell should be with delicate fragrance and without rare delicacy;

- **Form:** Regardless of whole, flaky, filamentous or any other shape, the shoot must be tender and with flat cut.
(2) Physical and chemical target

①Net weight: No matter 500g or 2950g package, the weight deviation must be less than ± 3 %;

②Tangible weight: For 500g package, the tangible weight is not less than 55%, and for 2950g package, the tangible weight is not less than 61%;

③Heavy metal contents: The tin, lead and sodium contents must be not more than 200mg, 2mg, and 10mg respectively.

(3) Microbial target: There is no pathogen or corruption.

2. Raw material specifications

(1) Raw bamboo shoots:

First class shoot: The shoot body must be wholly, thick, turriiform, fresh, tender, white, and without aging, infestation, deformity, injury, mold, deterioration and jointing, etc. And when digging, the shoot is not exposed out of soil.

Second class shoot: When digging, the shoot is already exposed out of soil, but the proportion of green part is not more than 1/5 of the total shoot length, and the length of the aged shoot end does not exceed 1cm. Others are the same with the first class shoot.

(2) Citric acid: The citric acid must be dry, clean, with granular or powder shape, and a purity of more than 99%.

3. Production procedure: Checking and accepting raw materials → rinsing and grading → pre-cooking → cooling → trimming and classification → checking → → cooking again → canning → labeling → adding soup → sealing → sterilization and cooling → cleaning and storage.

4. Processing detail

(1) Acceptance of raw materials: Exclude infested and rotten bamboo shoots;

(2) Rinsing and grading: Clean the shoots with water and classify them into
three levels by large, medium and small;

(3) **Pre-cooking:** Boil the water first, then put shoots into the pot and heat up to boiling again. The larger shoots must be precooked for 55 ~ 60min, the medium shoots for 50 ~ 55min, and the smaller shoots for 40 ~ 45min. The proportion water and shoots in the pot is about 1:1.5 for the degree to inundate the shoots;

(4) **Cooling:** Pick up the pre-boiled shoots and put them into the rinsing pool, cool them with flowing water;

(5) **Trimming and classification:** Peel off the bamboo sheath and remove the roots, tender bamboo clothing, and fine hair between nodes. Then classify them into two by size and put them into clean water respectively. The tender part of shoots and broken shoots can be produced into flaky shoot, filiform shoot and nubbly shoot, etc.;

(6) **Checking:** Check the shoots according to the standard of semi-finished product;

(7) **Re-cooking:** Wrap the trimmed shoots with etamine bags respectively according to the size put them into boiling water for 10 ~ 12min;

(8) **Canning:** Empty cans must be tested to make sure no leak, and cleaned and disinfection-ed then put inversion for later canning. Canning must be operated when the shoots are still hot. The shoot size of each can must be consistent.

(9) **Adding soup:** Prepare soup in a proportion of every 100kg water with 40g citric acid, then boil and filter it for canning.

(10) **Sealing:** Seal the finished can with a vacuum sealing machine and print a 6-digit code of national standard. Before sealing, the air in the can must be exhausted out for 8 ~ 10min when the temperature of the center of the can is 68 ~ 72 °C;

(11) **Sterilization and cooling:** The sterilization formula is 10' ~ 35' ~ 5 '/ 116 °C for 500g package and 15' ~ 40 '/ 10' / 116 °C for 2950g package. After
sterilization, cool it rapidly to 38 °C.

(12) **Cleaning and storage**: Clean the outer of finished cans and putting them into storage.

**IV. Preservative shoot**

**1. Preparations**

- Raw materials: Raw bamboo shoots, edible citric acid and other edible additives.
- Main equipments: Cooking tank (use sandwich pot if there is steam), rinsing pool (pot), sterilization (pot), packaging machines.
- Packaging materials: Standardized 2 ~ 3layered composite cooking bag.

**2. Processing method**

- Production procedure:
- Checking and accepting raw shoot materials → peeling the sheath and removing the roots → cutting and classification → pre-cooking → cooling → shaping → rinsing → flavoring → packaging → air-exhausting and sealing → sterilization → cooling → product storage.
- Processing detail

**Checking and accepting raw shoot materials:**

Select and weigh newly dug fresh bamboo shoots.

**Peeling the sheath and removing the roots:**

Peel off the shoot sheath, and cut the inedible old part, but the edible tender bamboo clothing can be reserved.

**Cutting and classification:**

Cut the shoot into two segments from the tip about 15cm and separate them. Then cut the lower segment into blocks by similar size, and make a classification accordingly.
Pre-cooking:
Separately cook the tender shoots and shoot blocks according to classification. Add 0.06% ~ 0.07% citric acid into the water. After boiling, cook 40 ~ 50min for the tender shoots, and 60 ~ 80min for the other; but for the shoots dug underground, cook 40min for the tender shoots, and 60min for the other.

Cooling:
Take out the pre-cooked bamboo shoots and put them into clean flowing water immediately for cooling for 1 ~ 2h.

Shaping:
After cooling, trim and slice the shoots.

The first rinsing:
After shaping, put the shoots into clean flowing water for rinsing. For better rinsing, keep regular turning around.

The second rinsing:
Before packaging, put the shoots into hot water for rinsing.

Flavoring:
Prepare ingredients according to flavoring recipes, prefabricate them into a sauce, then boil and filter it. Add the sauce to the finished shoots according to required ratio.

Packaging:
Package the finished products according the proportion of 95% tangible shoot weight and 5% sauce weight.

Sealing:
Seal the packaged shoot with a vacuum sealing machine and carefully check it to assure the sealing quality.
**Sterilization:**

Place the cooking bags in an autoclave (pot) for sterilization.

**Cooling:**

After sterilization, take out the bags into clean flowing water for cooling.

**Product storage.**

Take out the cooled bags and check the quality, dry the water outside bags, then put them into containers for dark storage.

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**5.14. Some key notes for bamboo cultivation and management**

**5.14.1. Seedling from seed**

For both monopodial and sympodial bamboo, regardless of any utilization purpose, the cultivation and management of seedling from seed in the first year are similar.

1. **The seed collection**

   Bamboo seeds generally mature in autumn or dry season. The seeds should be harvested in time before falling.

2. **The seed storage**

   The collected seeds should be dried in the shade with ventilation. They should not be dried with fire or under hot sun light. After purification through wind, the dried seed should be treated with 150g ~ 200g trichlorfon powder every 100kg seeds for later package and storage. Since no dormancy period, bamboo seeds are better to be sown immediately after harvest. For storage, it must be at a low temperature condition between 0 °C and 5 °C. And the storage time must not be more than six months.
3. The seed quality

3.1 Seed selection

Select newly matured bamboo seeds with proper grain weight, more than 90% purity and over 20% germination rate for seedling. Germination rate is an important indicator to determine the quality of the seeds, which is appropriately more than 20% for sowing. Before sowing, bamboo seeds must be tested through germination.

3.2 Identification of seed quality

Bamboo seed categories are: newly matured seeds, prematurely harvested seeds, last year harvested seeds and moldy seeds. The main distinguishing characteristics are shown in Table 5-1 Seed pros and cons.

Table 5-1. The main distinguishing characteristics of bamboo seeds pros and cons

<table>
<thead>
<tr>
<th>Seed category</th>
<th>Main distinguishing characteristics of appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly matured seeds</td>
<td>Dried and purified, without moist feeling and infestation, and with orange-yellow or yellow-brown shiny husk, milky white, plump, fresh, uniform, and hard grains and fresh appearance of both palea and lemma, tough caryopsis.</td>
</tr>
<tr>
<td>Prematurely harvested seed</td>
<td>With green or light yellow-green appearance, shrieveled caryopsis, less grain weight.</td>
</tr>
<tr>
<td>Last year harvested seeds</td>
<td>With yellow-brown appearance, fragile palea and lemma, majority of light black or black awn-broken caryopsis, and white powder of grains.</td>
</tr>
<tr>
<td>Moldy seeds</td>
<td>With musty smell, black brown or light black husk, rotten degenerate caryopsis.</td>
</tr>
</tbody>
</table>

4. Sowing date

Ordinarily, the sowing date is in autumn and early spring or at the end of rainy season and about one month before rainy season. If no water problem, and the daily average temperature remained above 10 ℃, the sowing date can be any time.

5. Seeds pre-germination
5.1 Sand germination

Mix the seeds with sand in a ratio of 1:3 and place the mixture in the shade indoor with good ventilation. Keep appropriate moisture, at which the sand can become a clump in hand, and cracked rather than dispersed after dropping to ground. Check it once every week. If the sand is dried of dehydration, add appropriate amount of water, be careful avoiding excessive moisture in case of moldy seeds. Usually, after 2 ~ 3 months when the radicles become white, sieve out the sand and sow the seeds into nursery.

5.2 Lukewarm water soaking germination

Rinse the seeds with water two times, and then soak them with 40 ℃ of warm water for 24 hours, remove floating seeds, and take out the sunk seeds then sow them into nursery. 20ppm HC composite auxin solution can also be used (firstly dissolve 1g HC composite auxin into 200ml 95% alcohol, then add 50Kg 40 ℃ warm water for diluting) to soak the seeds for 1 ~ 1.5 hours.

6. Sowing

Sowing methods are: line sowing, bunch sowing and broad sowing.

In line sowing, the line spacing is 20cm ~ 25cm, the furrow width is 10cm, the furrow depth is 1.5cm ~ 2.0cm, and the seeding rate is 25Kg ~ 33Kg per hectare. After the seeds are sown in the furrows, it’s better to cover them with fertilizer fired from organic manure mixed with soil.

In bunch sowing, the dibble spacing is 20 cm × 25 cm, with 8 ~ 10 grains of seeds per dibble, the seeding rate is 22 Kg ~ 28 Kg per hectare. After sowing, cover the sown seeds first with 0.5 cm ~ 1.0 cm thick soil then with straw or plastic film.

Broad sowing is used in hotbed breeding. The key technique is evenly sowing to control the seeding rate between 18 kg and 25 kg per 1000 m².
nursery for 1 hectare transplanting area.

After sowing, cover the seedbed with straw, and keep the soil moist. Ramets nursery also can be applied in greenhouse. The seedling output is 1050 ~ 1350 clumps per 100 m².

7. Seedling management

7.1 Irrigation and Drainage

In dry season, irrigation should be more frequent to keep the soil moist; in rainy season, the ditches should be dredged timely to drain so as to avoid accumulation of water on nursery.

7.2 Weeding

From seedling emergence, after 20 ~ 30 days growth, when the seedlings (embryo bamboo) grow to 0.1cm ~ 0.2cm diameter, 8cm ~ 12cm height with 7 ~ 9 true leaves, it’s appropriate to weed manually. To avoid injuring seedlings, weeding is better when the weather turns fine after raining. The weeding must be "as far as early and entirely, when the grass is as small as possible" for keeping no grass in the nursery.

7.3 Fertilization

Usually about 60 days after seedling emergence, young roots appear. At this time, apply 5% ~ 10% decomposed manure to water the seedlings. After entering tillering period, topdress 10% ~ 40% decomposed human waste. After fertilization, earth up the seedling base.

For more detailed seedling management, see Table 5-2.

5.14.2. Material bamboo cultivation and management

1. Sympodial bamboo cultivation and management

1.1 Introduction
Of typical sympodial bamboo, new bamboo culms grow from the side buds at the base of the old culms and get together in clumps, which generally distributes in hills, plains, open area around villages and roads and on both sides of streams generally with a lower altitude and latitude. Its common requirement about average annual temperature is $18^\circ\text{C} \sim 21^\circ\text{C}$, and that of annual rainfall is generally above 1400mm.
### Table 5-2 The growth periods and management of bamboo seedling

<table>
<thead>
<tr>
<th>Growth period</th>
<th>Lasted days</th>
<th>Environmental requirement</th>
<th>Characteristics of growth</th>
<th>Main management measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence period: between sowing</td>
<td>About 45 days</td>
<td>There are adequate</td>
<td>The seeds absorb water and swell, of which the enzyme activity increases; the radicles</td>
<td>1. Keep the seedbed moist but not too much water, pay attention to drainage.</td>
</tr>
<tr>
<td>and emergence of most seedlings</td>
<td></td>
<td>moisture and oxygen; the</td>
<td>begin to grow, and the buds gradually emerge. On the seedbed, the tubular bud sheaths</td>
<td>2. Cover the seedbed with plastic film, pay attention to adjust the temperature inside the film.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>temperature of air and</td>
<td>appear. At this time the young seedlings is tender with weak resistance.</td>
<td>3. Avoid wild animals damaging and eating seeds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>soil is above 11 °C.</td>
<td></td>
<td>4. Pay attention to expose the seedbed gradually.</td>
</tr>
<tr>
<td>Newborn period: between true leaf</td>
<td>More than</td>
<td>Keep the soil loose, moist;</td>
<td>The aboveground growth is slow; the root distribution is shallow with less fibrous roots.</td>
<td>1. Timely take the shade, cover and uncover plastic film (but no need for nursery located in shade).</td>
</tr>
<tr>
<td>emergence and the start of tillering</td>
<td>60 days</td>
<td>right amount of</td>
<td>At this time, the seedlings can carry out photosynthesis. But the stems are crisp,</td>
<td>2. Sprinkle some sawdust on the seedbed to avoid &quot;mud trousers&quot; on the seedling stems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>topdressing, earthing up;</td>
<td>tender and susceptible to disease. The main diseases are damping-off and blight.</td>
<td>3. Spray 0.3% potassium permanganate or 1% Bordeaux liquid once a week.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the temperature of air</td>
<td></td>
<td>4. Timely weed, tillage and fertilize.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and soil is roughly 15 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 20°C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillering period: between the first</td>
<td>Over 180 ~</td>
<td>The soil temperature is</td>
<td>The roots, stems and leaves are growing vigorously and the resistance is enhanced;</td>
<td>1. Focus on nitrogen fertilizer, combined with phosphate fertilizer, and successively increase the amount of fertilizer. Keep the soil loose and moist, and earth up timely.</td>
</tr>
<tr>
<td>and the last tillering.</td>
<td>200 days</td>
<td>roughly 20 °C ~ 25°C.</td>
<td>tillering and growth are simultaneous.</td>
<td>2. Combined with earthing up at the seedling base, carry out tillage and weeding.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. After the secondary tiller emergence, remove the</td>
</tr>
</tbody>
</table>
shade.
1.2 Nursery propagation

Few bamboos flower and bear fruit, so the most used method of nursery propagation is asexual. Sympodial bamboo is different from monopodial bamboo. It has no rampant underground rhizome, so the new culms sprout from the buds of both sides of the old culms base. Moreover, the sprouting ability of dormant buds on the branches and culms is strong, which is helpful for nursery propagation.

**Separated culm-stumps nursery**

Choose 1~2 years old healthy and strong culms that are in appropriate size and with lush foliage, fat base buds and no pests as mother bamboo. Avoid any damage to the culm base buds when digging, and retain all the rootlets of the stumps as far as possible. Find out the connection point between the chosen mother bamboo culm and the old culm and cut off the mother culm from the old culm side of the point with a sharp chisel, hoe or knife, together with its stump and the soil around. For small bamboo species, such as *Bambusa multiplex*, *Bambusa textilis*, *Schizostachyum pseudolima*, because the culms are very small in intensive clumps with concentrated root distribution, they can be dug and planted in clumps with 3~5 culms each. The branch number reserved on mother bamboo is generally 2-3. For keeping moisture, it’s better to plant the mother bamboo immediately after digging. After 1-2 years growth on the nursery, the seedling can be transplanted to bamboo production bases.

**Buried culms nursery**

There are some buds on bamboo culms and branches, which keep being ungerminated or dormant state ordinarily, but can be promoted to germinate and grow root and then grow into new independent bamboo culms. Thus, all the bamboo species with dormant buds can be propagated into bamboo seedlings with their culms or branches for bamboo reforestation.

The culms must be buried before the buds germination and the start of
bamboo fluids flowing when rich nutrients are accumulated within culms. Buried culms nursery can be divided into two kinds as following.

**a. Non-isolated culms burying nursery**

In spring or just before rainy season, select 1-2 years old culms with fat dormant buds and in heathy growth state as mother bamboo from sparse bamboo forest with big transmittance of light on flat fertile terrain. Reserve about 20 nodes and cut off the upper part of the mother bamboo culm. For the branches, reserve all of the most upper reserved node, and 2~3 nodes of the main branches of the other nodes, and cut off all the other from the base. Outward from the base of chosen mother bamboo culm, dig a ditch with depth and width both about 15-20 cm. Then cut a notch at the base of mother bamboo culm in a depth of 2/3 of the culm with a knife, and then press the culm to ditching direction slowly, and bury it into the ditch 3-5 cm deep, only leave the branches of the last upper node outside. Make the soil compacted gently, water and cover it with straw (Figure 5-35).

**b. Isolated whole culms burying nursery**

The methods of isolated whole culms burying nursery are basically the same with that of non-isolated whole culms burying nursery. The only difference is isolating the mother culm from the clump or not.
Firstly, isolate the chosen mother culm from its clump. On the plowed and leveled seedling bed, dig parallel ditches with depth and width both about 12-15 cm every 20-25 cm. However, the depth and width of the ditches must be appropriately bigger for the stump buried place. And then put some mud onto the stump of the mother bamboo, settle it into the ditch with a downward incision and sideward buds direction. Cover it with soil about 3 cm, slightly thicker at the bamboo stump, then compact the soil and water it adequately, and finally cover it with straw.

**c. Isolated aboveground culms burying nursery**

Cut off the selected mother bamboo culm from the base without stump. And all the other methods are the same with that of the isolated whole culms burying nursery. In order to promote the germination and rooting of the dormant buds, we can saw two circles with a half thickness depth at 8-10 cm above each node of mother bamboo culm. After sufficient rooting, saw the rooted nodes off from the circles sawn before to breed them into independent seedlings for convenient direct transplanting or re-breeding.

**Buried Nodes Nursery**

It means breeding bamboo with nodes. Cut the selected mother bamboo culm above ground node by node or every two nodes according to the health degree of the culm and its dormant buds. For strong one with fat buds, node by node, and for weak one, every two nodes. Reserve only one node with its branches of the main branch for each node of the culm and cut off all the others. And bury them immediately after cutting. The burying can be horizontal, slant or vertical. However, of surviving rate, the slantly buried is the highest. Ordinarily, two nodes segments are buried horizontally, single node segments are mostly buried slantly or vertically. If the nodes or culms cannot be buried immediately after cutting, they must be conserved in clean flowing water or buried in wet sand to keep it moist.

**Buried stumps nursery**

After felling or the death of bamboo shoots and young culm, the root system
of the stump remaining in the soil is not dead yet, but has a certain life ability, and some buds of it can also germinate and sprout. According to this feature, by separating the remnant bamboo stump, burying it in plot and maintaining proper cultivation conditions, we can make it sprout, root and grow into seedlings.

**Bamboo branches nursery**

On each productive node of sympodial bamboo culm, there are main branch and side branches. The branches come from the dormant buds on the base of the main and side branches are called secondary branches. New root may grow from the base of secondary branches, which can develop into independent bamboo culms. According to this feature, we can breed bamboo with branches.

**a. The main branches nursery**

Select 1 ~ 2 years old healthy and strong main branches with root points and fat dormant buds from 2 ~ 3 years old bamboo culms, and cut them off the culms from their own base. When cutting, the root points should be protected to avoid any damage as far as possible in order to improve the survival rate of bamboo seedling. From about 2 cm above the third node, cut off the upper part, and cut off all the collateral branches at the base of main branch. Then according to the specification of 14 ~ 16cm individual plant space and 25 ~ 30cm row space dig ditches. And bury the prepared branches slantly, then cover them about 3 cm thickness with straw. After burying, it should be kept under appropriate shade for more than 10 days. The seedlings will be grown up in 3 months.

**b. The secondary branches nursery**

Secondary branches are collateral branches except the main branches of bamboo culm. On 1 year old new culm, there is little secondary branches. But on 2-3 years old bamboo culm, especially the remaining lower part of broken culm, because of the loss of apical dominance, branches are more and stout with clear root points and plump dormant buds, which are easy to root
and sprout for breeding.

For the secondary branches selection, some notes must be taken of as following: 1. The selected secondary branches must be healthy and stout with short internodes. 2. The buds on 1st ~ 3rd nodes must be fat, plump, and at the state about to sprout. 3. The branch stump must be big with exposed root points. 4. The sheaths must be dropped off or loosed and about to be off, and on some top nodes there have been foliage showing. 5. The branch stem has been lignified, and the branch color is green or with light yellow.

(3) Transplanting cultivation

The sympodial bamboo seedlings in a nursery should be transplanted to field cultivation. Now the main procedures of transplanting and field cultivation of sympodial bamboo are introduced as following:

**Transplanting season**

Sympodial bamboo shoots in summer or rainy season. So it’s better to transplant the seedlings in spring or at the beginning of rainy season. When transplanting, for improving the survival rate, deeply amputate the upper part of the seedling culm, reserve more soil for the roots of the seedling, be careful with protection measures of transportation and keep the seedling moist.

**Land preparation**

Choose a land with fertile soil and no water during rainy season, clean it, dig planting holes and apply some discomposed manure as base fertilizer before transplanting.

**Seedling digging**

Dig the seedling stump out with soil around, try not to damage the stump and its roots. Prune the upper part of the seedling culm for reducing transpiration strength to avoid dehydration.

**Seedling transportation**
Transport the seedlings after digging as soon as possible. On the way of transportation, do not make the soil around the stump shedding, and cover the seedlings with tarpaulin tightly to prevent survival rate reducing because of water loss.

**Seedling transplanting**

The planting hole should be larger than the seedling stump. The planting density is according to the culm diameter. For small culm sympodial bamboo, it is 1500-3000 per hectare; for medium culm sympodial bamboo, it is 900-1800 per hectare; for large culm sympodial bamboo, it is 600-1200 per hectare. After planting, compact backfilled soil layer by layer, and water adequately for rooting. If the transplanting area is windy, it’s better to make supports to prevent wind shaking.

**(4) Management**

For both the nursery and transplanting field, the bamboo should be taken careful management. The main measures are:

**Moisture management**

When water is accumulated, it should be promptly drained; and during drought, it should be timely watered. During dry weather before shoots, water once a week or every other week, which can promote early and more shoots.

**Fertilization management**

For and fast shooting and vigorous growth, sympodial bamboo needs more fertilizer. In late spring or the beginning of rainy season, apply compound fertilizer for new grown culms. And in autumn or at the end of rainy season, apply 1kg compound fertilizer per clump for lignification of new culms, and loosen soil and weed simultaneously. The fertilization method is burying. From the clump, dig a circle ditch with 15~30 cm depth and apply fertilizer in it, then cover it with soil.

**Tillage and weeding**
In winter or dry season when buds are dormant, make a comprehensive soil loosing with 20cm depth, and bury the cleaned weeds beside bamboo stump as manure.

**Harvesting and thinning**

For different utilization and different bamboo species, the harvesting ages of culms are not the same. Therefore, we must choose the exact harvesting age of each bamboo species according to every utilization purpose. For example, the harvesting age of material bamboo for fiber manufacturing is less than that for charcoal production, but more than that for manual and mechanical processing. Anyway, the best harvesting age of sympodial bamboo culms for material utilization is ordinarily between 3-7 years. So, if sympodial bamboo culms less than 3 years old are harvested, it will impact the sustainable development of the bamboo forest and waste the resources. And similarly, if sympodial bamboo culms more than 7 years old are not harvested, it will impact the growing of new bamboo culms and waste the resources, too. For the sustainable utilization, we must cut out the over aged bamboo culms. And with bamboo forest of over density, it also needs thinning, including the appropriate cutting of young culms. The culms reservation must follow some principles, such as: cut weaker reserve stronger, cut older reserve younger, cut denser reserve sparser, cut inner reserve outer, cut infested reserve intact, and so on. The cutting season should be in winter or dry season, when the physical activity of bamboo is weakened, the mechanical properties of culms are good and the infestation is not easy. For bamboo species with year alternation of rich and poor shoot sprouting, only cut culms with yellowish leaves which will change their leaves next year, and no cutting of culms with dark green leaves which are in shoot pregnant stage, so as to prevent obvious alternation. The cutting height is as low as possible in case of material waste. After harvesting, break the diaphragm of the stump for its faster decay.

No digging of unearthed shoots. The shoots of the first sprouting batch can be dug because they are small from shallow buds, and the shoots late sprouting are also not worthy for reservation because most of them are weak
with slow growth. After shoot digging, apply some decomposed organic fertilizer and backfill the soil. Be careful no direct contact between fertilizer and rhizome.

For exact identification of culm age, it’s better to mark the culm shooting year every year.

**Identification of sympodial bamboo culm age**

The identification of bamboo culm age is based primarily on the aboveground part of bamboo, of which the identification of sympodial bamboo culm age is based primarily on the culm color and branching characteristics.

a. 1-year-old new culm of sympodial bamboo is dark green with no lateral branch;

![1-year-old new culm of sympodial bamboo](image)

Figure 5-36 1-year-old new culm of sympodial bamboo

b. Of 2-year-old culm of sympodial bamboo, the color is lighter than that of 1-year-old culm, there are more lateral branches; but there is no second lateral branch on the collateral branches.
c. Of 3-year-old culm of sympodial bamboo, the color changes to yellowish green.

d. Of 4-year-old culm of sympodial bamboo, the color changes to golden yellow.
e. Of 5-year-old culm of sympodial bamboo, the color is golden yellow, and there are second lateral branches growing on the lateral branches, which grows closer to the center of the clump.
2. Monopodial bamboo cultivation and management

(1) Growth characteristics of monopodial bamboo

Compared with sympodial bamboo, monopodial bamboo is more cold-tolerant, which distributes in the area of higher altitude and latitude with an average annual temperature of 12 ~ 17°C. Its suitable growth temperature is 15 ~ 25 °C, and the minimum average daily temperature is -5°C.

Usually in spring or the beginning of rainy season, the bamboo shoots extend themselves and come out of soil. Afterward, they grow quickly, and until summer or 2-3 months later from the beginning of rainy season they start to extend branches and leaves. After the branches and leaves extending, the rhizome starts to grow. And the growth of rhizome is the fastest in autumn or before the end of rainy season. In late autumn or after the end of rainy season, monopodial bamboo starts the pregnancy of shoots, while the rhizome growth slows and gradually stops.

(2) Cultivation technology of monopodial bamboo

a. Choosing appropriate planting season

According to the biological characteristics, the ideal planting season of monopodial bamboo is from late autumn or the end of rainy season until the beginning of spring or rainy season, especially just before the beginning of spring or rainy season or in late autumn.

b. Land preparation

The growth of monopodial bamboo needs only 50 cm for soil depth requirements, and 4.5 to 7.0 for appropriate pH values. The best land preparation is a comprehensive plowing with a depth of 30 cm. And before plowing, make a good basic manure application so that it can be plunged into the soil when plowing. After plowing, dig planting holes with a length of 40 cm, a width of 40 cm and a depth of 30 cm.

c. Preparation for mother bamboo
It is the best to choose 1-2 years old individual culms as mother bamboo, and the over 3 years old culms are not suitable for mother bamboo. The diameter of mother bamboo culms is modest appropriately, which must be in robust growth, with low branches, no pests and no signs of flowering. When digging mother bamboo culm, it is appropriate to keep a soil ball of 25-30 cm diameter with the roots. After digging, cut off the upper part of the mother bamboo and retain only 4-5 lower branches. When the mother bamboo is transported for long-distance, the soil ball must be wrapped. After loading the mother bamboo into a car, spray a little water on the culms, and then cover them wholly with tarpaulins.

d. Transplanting of mother bamboo

The seedling density for planting of material monopodial bamboo is 2700 ~ 3300 per hectare. Monopodial bamboo can not be planted too deep, it must be shallow. The root of mother bamboo is 3-5 cm deep appropriately. Firstly, backfill the topsoil to the planting hole. Secondly, put the mother bamboo into it and make the rhizome stretch. Thirdly, backfill the rest of topsoil, then fill the subsoil, and make the soil tight layer by layer so that the roots can join the soil closely. Fourthly, sprinkle enough "root water" for further joining between roots and soil. After all the water infiltrated into the soil, cover with a layer of loose soil at the base of the mother bamboo as a bread shape. Finally, cover a layer of straw on the bread-shaped mound to reduce water evaporation. In windy place, it also needs a bracket for supporting.

(3) Management of monopodial bamboo

a. Water management

Bamboo is suitable for growing in humid environments, but also fears of water. The water management of bamboo is the most important during the first year after planting, which will directly affect the survival of the mother bamboo. After digging, transporting and planting, the root system of mother bamboo is hurt, so its capacity to absorb water is decreased. It is most likely that the culm will wither and die due to dehydration and the roots and rhizome will be rot because of poor drainage. Therefore, if the drought lasts
for long time, when the soil is dry, it must be timely watered; and during long period of rain when water is accumulated, it must be promptly drained.

After bamboo surviving, water management is also very important. During drought period, it must be timely watered to promote its growth. Especially when the shoots are growing (in spring or at the beginning of rainy season), because the growth of shoots require more water, it’s better to water before the shoots unearthing and keep the soil moist after the shoots are unearthed. And when the buds of shoots are differentiating (from late summer until autumn or before the end of rainy season), if dry, it will affect the growth of rhizome and the shoots differentiation and reduce the number of new culms in the coming year.

b. Fertilizer management

For monopodial bamboo, the fertilizer must be mainly organic fertilizer, and with some fast-acting fertilizer combined. Of new bamboo forest, the rhizome elongation is not far, so it’s better to apply fertilizer around the bamboo plant with ditch. With the increasing of bamboo stands, the amount of fertilizer can be added year by year, and the fertilization method can also be changed from ditch application to uniform applicator. And after application, bury the fertilizer combined with soil loosing.

Fertilization can be carried out in the following four different growth stages of each year: The first one is shoots fertilization for long and big shoots before the shoots unearthing (in the beginning of spring or just before rainy season), which is mainly fast-acting chemical fertilizer. The second time is rhizome fertilizer after new culms has grown to enough height (in summer or rainy season, but with late shoots it can be delayed appropriately), which is mainly chemical fertilizer combined with some organic manure. The manure should be decomposed first, then spread on the land and plowed into the soil. The third is buds facilitating fertilization when the buds of shoots begin differentiation (in autumn or at the end of rainy season), which is better to be fast-acting or liquid fertilizer, such as human excrement. The fourth is shoots pregnancy fertilization for more shoots (in winter or dry
 season), which is mainly organic fertilizer, such as animal manure, compost. The organic fertilizer is laid directly on bamboo land, which can be plowed deep underground when loosing soil in next year's summer or rainy season.

**c. Weeding and soil loosening**

Of new bamboo forest, because the culms are sparse, there is enough sunlight for weeds breeding. Thus, before the closure of bamboo canopy, it needs weeding and soil loosening 2 to 3 times every year. After the bamboo canopy density gets enough big and the weed growth is under control, the main purpose of plowing is to improve the physical properties of the soil, such as permeability, and renew the rhizome and root system. Generally, the time of soil loosening is in summer or rainy season (with slowly growing bamboo forest, it can be delayed appropriately), and the depth is 25-30 cm. In the process of scarification, the old rhizome and bamboo stump must be excavated timely to release more space for new bamboo plants.

**d. Harvesting and thinning**

The principles of harvesting and thinning monopodial bamboo is similar with that of harvesting and thinning sympodial bamboo. Anyway, the best harvesting age of monopodial bamboo culms for material utilization is ordinarily between 4-8 years. So, if monopodial bamboo culms less than 4 years old are harvested, it will impact the sustainable development of the bamboo forest and waste the resources. And similarly, if monopodial bamboo culms more than 8 years old are not harvested, it will impact the growing of new bamboo culms and waste the resources, too. For the sustainable utilization, we must cut out the over aged bamboo culms. And with bamboo forest of over density, it also needs thinning, including the appropriate cutting of young culms. It’s very important that the rhizome shoots and strong shoots cannot be dug in case of growth stop of rhizome, reduction of shoots and quality decreasing of culms in the next year. The cutting season should be in winter or dry season, when the physical activity of bamboo is weakened, the mechanical properties of culms are good and the infestation is not easy. For bamboo species with year alternation of rich and
poor shoot sprouting, only cut culms with yellowish leaves which will change their leaves next year, and no cutting of culms with dark green leaves which are in shoot pregnant stage, so as to prevent obvious alternation. The cutting height is as low as possible in case of material waste. After harvesting, break the diaphragm of the stump for its faster decay.

No digging of unearthed shoots. The shoots of the first sprouting batch can be dug because they are small from shallow rhizome, and the shoots late sprouting are also not worthy for reservation because most of them are weak with slow growth. After shoot digging, apply some decomposed organic fertilizer and backfill the soil. Be careful no direct contact between fertilizer and rhizome.

**Identification of monopodial bamboo culm age**

The identification of monopodial bamboo culm age is mainly according to the new sub branches on lateral branch, supplemented by color distinguishing. The lateral branch of monopodial bamboo culm develops new sub branches every year, which drop off and leave marks that are called inflection points the next year. So, to identify culm age of monopodial bamboo, just observe its lateral branch carefully and count the number of inflection points on it. The number of inflection plus one is the age the investigated monopodial bamboo. However, of some monopodial bamboo species, such as *Phyllostachys pubescens*, the lateral branch develops new sub branches every two years. Therefore, to count the culm age of it, the number of inflection must time two.

Culm age identification of monopodial bamboo is shown as following pictures:
Figure 5-41 Age marks (inflection) on *Phyllostachys pubescens* of different ages

(1) 1-year-old bamboo (2) 2 ~ 3 years old bamboo (3) 4 ~ 5 years old bamboo (4) 6 ~ 7 years old bamboo

3. Amphipodial bamboo cultivation and management

The growth characteristics of amphipodial bamboo are between sympodial and monopodial bamboo. So the cultivation and management of amphipodial bamboo are also between that of both sympodial and monopodial bamboo. We can cultivate and manage amphipodial bamboo according to its similarity degree of growth characteristics with sympodial and monopodial bamboo.

III. Shoot bamboo cultivation and management

1. Main bamboo species for shoot cultivation

The best species for bamboo shoot cultivation must be with some advantages as following: a. The shoot must sprout early with a long shoot duration; b. The edible shoot rate must be high; c. The shoot yield must be high with good benefits; d. The shoot must be delicious and nutritious; e. The shoot must sprout every year with a good yield stability, and the shoot individual must be thick with thin sheath and fat meat; f. The fertilizer conversion rate must be high with low cost and less labor; g. The bamboo cycle must be
short with quick effectiveness; h. The growth adaptation must be a wide range. According to the above mentioned criteria, the following species are commonly used as shoot bamboo species:

(1) Monopodial species

a. Phyllostachys:


b. Chimonobambusa:

Chimonobambusa utilis, Chimonobambusa grandifolia, Chimonobambusa arnata, Chimonobambusa hejiangensis, etc.

(2) Sympodial species

a. Dendrocalamus:

Dendrocalamus giganteus Munro, Dendrocalamus yunnanicus Hsueg et D.Z.Li, Dendrocalamus hamiltonii Nees et Arn.ex Munro, Dendrocalamus aspera (J. A. et J. H. Schult.) Backer ex Heyhe, Dendrocalamus brandisii (Munro) Kurz, Dendrocalamus barbatus Hsueh et D.Z.Li, Dendrocalamus latiflorus, etc.

b. Bambusa:

Bambusa emeiensis (former Neosinocalams affinis), Bambusa tulda, Bambusa vulgaris var. striata, Bambusa vulgaris var. green, Bambusa balcooa, Bambusa oldhami, Bambusa bambos, Bambusa textilis, etc.

2. Shoot bamboo forest management

Shoot bamboo cultivation technology is basically the same with that of material bamboo. But the seedling density for planting of monopodial
bamboo is different. For material monopodial bamboo, it is 2700 ~ 3300/ha; for material-shoot monopodial bamboo it is 2250 ~ 2700/ha; and for shoot monopodial bamboo it is 1950 ~ 2250/ha. However, the seedling density for planting of shoot sympodial bamboo is similar with that of material sympodial bamboo.

The difference of forest management between shoot bamboo and material bamboo is much more than that of cultivation. The main differences are as following:

(1) **Fertilization management**

For different soil, the fertilization amount is quite different. So, nobody can give an common standard of fertilization amount. But some data are very useful for consideration about fertilization. According to experiments, the production increasing of every 100kg material bamboo needs 1.5kg urea, 1.5kg superphosphate and 1.7kg potassium chloride; but the production increasing of every 100kg fresh bamboo shoot needs 4.5kg urea, 2.5kg superphosphate and 0.9kg potassium chloride. It means that the need of nitrogen for shoot bamboo is three times as that for material bamboo; the need of phosphate for shoot bamboo is more than that for material bamboo; and the need of potassium for shoot bamboo is about half for material bamboo.

Another key note is that the fertilizer for shoot bamboo is better to be organic fertilizer for more sanitary and security shoot production, especially without any radioactive and other hazardous substances. The organic fertilizer must be decomposed before application. However, for high yield shoot production and better sprouting of shoot, some fast-acting fertilizer also can be used as shoot fertilizer in spring or just before rainy season.

For sympodial shoot bamboo, exposing bamboo buds and shoot eyes is often used to promote shoot sprouting and production, which is often combined with fertilizer. The exposing time is ordinary in early spring or before rainy season (about 20-30 days before natural shooting). However, if the shoots are exposed too early, they will die of rotting or drying; and if the shoots are
exposed too late, it's meaningless. Generally, 5~6 days after exposing, apply some organic fertilizer, and then cover the fertilizer with soil.

**(2) The best age structure of reserved bamboo culms**

The best average age of shoot bamboo culms should be younger than that of material bamboo culms. And the age structure of reserved culms of both shoot bamboo and material bamboo is also different. For material bamboo, whether monopodial or sympodial, the reserved culms number of every year is better the same or nearly the same. But for shoot bamboo, the best age structure of reserved sympodial culms is as following: 1-2 years old culms account for 30 ~ 40% of the total; 3-4 years old culms account for 30 ~ 35%; 5-6 years old culms account for 25 ~ 30%; 7-8 years old culms are just for filling the open space of bamboo forest land, and the proportion cannot be more than 5% of the total. And the reserved monopodial shoot bamboo culms are 3000-3500 plants / hm². The culms reservation must follow some principles, such as: cut weaker reserve stronger, cut older reserve younger, cut denser reserve sparser, cut inner reserve outer, cut infested reserve intact, and so on.

**(3) Scientific method of digging shoots**

Scientifically digging shoots can make the shoot bamboo forest develop sustainably and bring better economic efficiency for bamboo farmers, which means that the reserved shoots must be uniform and modest on both space and time. It can stimulate more new shoots sprouting and more dormant buds germination. The shoot age when digging also must be modest. If the shoots are dug too young, the yield will be too low; and if the shoots are dug too old, the quality will decrease too much. Similar with material bamboo management, what must be emphasized is that the shoots of the first sprouting batch and the shoots late sprouting are not worthy for reservation because most of them are small and weak with slow growth. After shoot digging, it’s better to apply some decomposed organic fertilizer and backfill the soil. No direct contact between fertilizer and rhizome.
IV. Landscape bamboo cultivation and management

1. Landscape bamboo cultivation and management

(1) Landscape bamboo species

There are a wide variety of landscape bamboo with high ornamental value. According to their view parts, they can be divided into four types as following: a. culm-shaped type, such as *Chimonobambus quadrangularis* with square culms, *Phyllostachys aurea* Carr. ex A. et C. Riviere with short and swollen culms, *Phyllostachys heterocycla* (Carr.) Mit ford with culms like tortoise shell, *Bambusa ventricosa* McClure and *Bambusa vulgaris* cv. Wamin of which the internodes look like belly of Buddha, etc.; b. culm-colored type, such as *Phyllostachys nigra* with purple culms, *Phyllostachys aureosulcata* with yellow culms, *Dendrocalamopsis oldhami* (Munro) Keng f. with green culms, *Phyllostachys sulphurea* cv. houzeauana with interleaved yellow and green, *Phyllostachys bambusoides* cv.tanakae with spots on the culms, etc.; c. Foliage types of both color and shape, such as *Sasa fortunei* (Van Houtte) Fiori, *Sasa argenteastriatus* E.G.Camus, *Sasa pygmaea* (Miq.) E. G. Camus, *Shibataea
chinensis Nakai, etc.; d. Shoot type, such as Phyllostachys iridescins C.Y.Yao et S.Y.Chen, Bambusa albo-lineata (McClure) Chia, Phyllostachys dulcis McClure, etc..

(2) Landscape bamboo cultivation and management

Landscape bamboo cultivation and management is basically the same with that of material bamboo. The difference is that landscape bamboo needs pruning of branches and leaves according to different landscape design to maintain desired shape. And different planting layout must be designed for different landscape. The main planting methods are: a. Clump planting, i.e., more than three culms of the same or different bamboo species are planted in one clump; b. Group planting, i.e., many bamboo culms of the same species are planted together as a group; c. Solitary planting, i.e., only one bamboo culm is planted at one place. In this method, the bamboo plant must be very large with more and big branches and leaves; d. Row planting, all the culms are planted in one row or more rows.

2. Potted landscape bamboo (bamboo bonsai) cultivation and management

(1) Potted landscape bamboo species

Bamboo species with peculiar short and thin culms, and small leaves are more appropriate for potted landscape, such as Bambusa ventricosa McClure, Chimonobambusa quadrangularis(Fenzi),Bambusa multiplex cv. Fernleaf, Phyllostachys nigra, Sasa fortunei (Van Houtte) Fiori, etc..

(2) Potted landscape bamboo cultivation and management

Transplanting

The transplanting time of potted landscape bamboo is appropriate in spring or at the beginning of rainy season. Select well-developed one or two years old culm and dig it together with its rhizome and roots and soil around the roots. The culm must be cut short to about 50cm. And it’s better to plant the culm into an ordinary small earthen pot firstly, and then transplant it into a shallow pot after 30~40 days when it’s survived. Humus soil is the best for
bamboo bonsai soil, but loose, well-drained sandy loam also can be chosen. The soil cannot be filled too much, because too much soil will make the bamboo roots grow too fast to control the height of the bamboo easily. Due to the controlled growth, the new culms growing from potted bamboo in spring and autumn or both the end of rainy season are relatively slim and dwarf, which are therefore very suitable for bonsai material. After planting, water it a permeable, then place it in a cool, moist, well-ventilated place to cultivate for one year, the second year it can be made into a small bamboo bonsai.

**Scenery setting modes**

According to different types of bamboo, the scenery setting modes can be adopted in different ways, for example, the small bamboo *Sasa fortunei* (Van Houtte) Fiori can be planted in a square or oval pot; the medium bamboo such as *Phyllostachys acuta* ChuetChao can be planted in a shallow rectangular or oval pot. If there is any imbalance because of planting on one side of a pot, one stone with a beautiful shape and appropriate size of the bamboo culms can be collocated on the other side of the pot, which can not only achieve a balance, but also increase the bonsai taste and make it be lively and natural. As to large bamboo used to make bonsai, such as *Phyllostachys viridis*, *Phyllostachys glauca* McClure, *Phyllostachys bambusoides* cv. tanakae, etc., they need a dwarf processing manually and to be planted in small shallow pots in order to achieve an effect of "shrink big into small". Bamboo bonsai should be sparsely and scatteredly planted, and cannot be planted densely and complicatedly. Only a handful of three, five or seven culms make an arrangement both high and low, and a layout both dense and sparse naturally. If planted in a shallow pot decorated slightly with beautiful stones and moss, the whole bamboo bonsai can show a natural bamboo scenery. Otherwise, it will be messy with no delight of bonsai and lose its ornamental value, like bunches of reeds and grass.

To increase the beauty of bamboo bonsai, when planting, the roots of bamboo can be enhanced. After the bamboo grows and develops for a stage, remove part of the topsoil around the roots so that some bamboo roots
expose above the topsoil, which looks like some claws hanging and shows the beauty of exposed bamboo roots.

**Fertilization and water management**

It’s appropriate to place bamboo bonsai in a warm, moist, leeward, transmissive environment. It can not be exposed in sunlight in summer or dry season. The water and fertilization management should be appropriate. Although bamboo likes fertilizer, but potted bamboo should be fertilized as less as possible, and small fertilizer is enough; although bamboo likes wet, but water cannot be accumulated in the pot. Any improper conservation can cause abnormal and poor growth of bamboo bonsai. Appropriate less watering can dwarf bamboo in summer or rainy season when new culms grow vigorously. 2 or 3 times thin organic liquid fertilizer in every summer or rainy season can keep bamboo leaves always fresh and green. Note that appropriate shade when the weather is hot in summer or dry season. Change pot and soil in spring or before rainy season every 2 ~ 3 years, and remove part of the old roots and soil around, then add new soil, the bonsai bamboo will grow well.

**Reasonable pruning**

Because of rapid germination and growth, bonsai bamboo needs regularly pruning so as to maintain its beautiful showing. Potted bamboo should be short and concentrated. The number of conserved shoots is often singular, such as 3, 5 or 7 shoots per pot. The shoots and culms with long node, poor location, big density and weak growth should be promptly cut off. The later new shoots also should be immediately removed to avoid the impact of the shape of bamboo bonsai, the consumption of the nutrients and the affection of the growth of mother bamboo. In every summer or rainy season, when the new culm growth is complete, prune for new modeling. When the conserved culms reach an ideal height for the desired patterning, the upper parts should be cut off to promote their collateral branches, and even the collateral branches must be cut off the upper parts when they grow to a certain length. If the bamboo bonsai is carefully maintained to keep a beautiful landscape,
green, elegant and beautiful foliage, it can be viewed for long time by people.

**Dwarfing technology of large bamboo**

**Appropriate sheath peeling:**

After new shoots have unearthed for 7~10 days, and reached about 10 cm high, according to the growth, peel 1~2 bamboo sheaths from the bottom up every other day to make them mature early, control their growth and promote their dwarf. This method can reduce half length of the internodes of bamboo culm.

**Chemical treatment:**

When shoots excavated 20 cm above the earth surface, inject chlormequat, MET or B9 into bamboo cavity with a 5 ml syringe every 1 ~ 2 days, 1 ~ 2 nodes each time, 3 ~ 5 drops per node. The chemical concentration is 0.1 ~ 0.2%. According to the growth, the general injection times are 3~5. This method can shorten 1 / 4 of the original culm length.

**Rhizome burying:**

In winter or dry season, cut rhizome into sections of 30 cm length, and bury them into pots, then cover them with soil of 10~15 cm thickness, pour enough water and keep them indoor for 15-30 days. Then take them outdoor and water accordingly. The principle of this dwarf method is that: Due to the limited nutrient storage of rhizome and roots, new bamboo culms get dwarf because the nutrients can not meet the normal growth after shooting.

**Fertilizer and water control:**

The principle is to achieve the purpose of controlling their growth by artificially making unsuitable cultivation conditions for the growth of bamboo. For example, use comparative barren sandy loam or calcareous soil that is not very suitable for bamboo growing to reduce the absorption of nutrients, and water less, especially no water spraying onto the foliage.
V. Control of bamboo diseases and pests

During the process of both growth and utilization, bamboo is endangered by a variety of pests and diseases, which results in continuously reduction of yield and degradation of quality. Therefore, bamboo pest and disease control is an important task of bamboo production and utilization.
### Table 5-3 Main techniques of pest and disease control for bamboo seedling

<table>
<thead>
<tr>
<th>Name of pest or disease</th>
<th>The main symptoms</th>
<th>Control methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bamboo seedling blight</strong></td>
<td>The disease occurs in the seedling neck between seedling emergence and tillering. The roots of diseased plants are black or dark brown; the cortical of fibrous roots are rotten; the aerial parts wither and lodge.</td>
<td>Timely remove diseased plants, and cast 375 kg lime or 750kg plant ash per hectare on the seedbed surface; spray 0.3% potassium permanganate or 1% Bordeaux mixture once a week for two weeks consecutively; spray 1000 times fluid of 50% wettable powder of the anilazine or carbendazim for two or three times at intervals of 10 days.</td>
</tr>
<tr>
<td><strong>Bamboo seedling etiolation disease</strong></td>
<td>The disease occurs at the beginning of seedling emergence. The whole diseased plant is yellow.</td>
<td>In addition to enough base fertilizer, pay special attention to topdressing before tillering; spray foliar fertilizer consecutively for 3 ~ 4 times at intervals of 5 days and spray 1% Bordeaux solution once a week for 2 times.</td>
</tr>
<tr>
<td><strong>Bamboo shoot armyworm (Oligia vulgaris)</strong></td>
<td>The larvae eat bamboo shoots. So the pest is also called shoot borer.</td>
<td>Combined with tillage and weeding, spray 500 ~ 1000 times liquid of trichlorfon or deltamethrin once a week.</td>
</tr>
<tr>
<td><strong>Mole crickets and grubs (underground pests)</strong></td>
<td>The pests bite tender stems of bamboo seedlings and bite roots by digging tunnels around the rhizosphere in soil.</td>
<td>Trap and kill with black light or drench roots with 800 times water solution of rotenone; spray 500ml 40% emulsifiable concentrate of methyl isofenphos together with 60 kg water on seedbed, or sprinkle bait formulated with 3000ml 20% emulsifiable concentrate of methyl isofenphos and 75kg bran per hectare between seedling lines.</td>
</tr>
</tbody>
</table>
Bamboo pest and disease control should be based on prevention, which is focused on improving the ability of bamboo resistance to pests and diseases to reduce the incidence of pests and diseases through strengthening of bamboo management. On prevention strategies, different measures are carried out according to different types of pests and diseases. By implementation of comprehensive control, aim at better economic and social benefits; based on the principles of ecology, study the variation laws of the population of each target pest and pathogen; focused on the weak links of the target pest and pathogen life cycle, control pest and disease below the level of the economic limitation economically, effectively and safely.

1. Control of bamboo seedling diseases and pests

The common pests and diseases of bamboo seedlings are: bamboo seedling blight, bamboo seedling etiolation disease, bamboo shoot armyworm (shoot borer) and underground pests (mole crickets and grubs). The main symptoms and control methods are shown in Table 5-3.

For prevention of bamboo seedling diseases, the following measures are also very important:

- Choice of proper nursery. Land on which vegetables, cotton, melons and pine, fir seedling, etc., are planted should not be used as bamboo seedling nursery.
- Soil disinfection when land preparation. When preparing nursery, first apply pesticides such as fenaminosulf (the dosage is 2kg / 1,000 m² fenaminosulf evenly mixed with 30 ~ 40 times of fine soil).
- Pre-sowing seed disinfection. Mix the seeds together with tuzet (0.2% ~ 0.3% by weight of the seed) or 0.5% fenaminosulf and 10 ~ 15 times fine soil before sowing.
2. Control of bamboo forest diseases and pests

(1) Bamboo forest diseases

When planting new bamboo, the mother bamboo and bamboo seedling must be strictly quarantined and disinfected, no mother bamboo from infected bamboo forest. When bamboo is infected diseases, chemical control must be implemented combine with management timely. The pathogens should be cleared up, the infected bamboo plants should be burnt out in case of spreading. Bamboo culms more than 4 years old are prone to be infected with bamboo branch clump disease and bamboo culm rust disease, so the aged infected culms should be promptly cut down to increase air and light for the forest. Better management and improved sanitation will enhance disease resistance of bamboo stand.
a. Bamboo shoot rot disease

![Image of bamboo shoot rot disease symptoms]

**Figure 5-44 Symptoms of bamboo shoot rot disease**

**Symptoms**

The infected shoots decay with brown spots.

**Control methods**

(A) As soon as the leaves or tender tip of bamboo shoot are found to be rotten, immediately cut off the shoot from the base.

(B) From the beginning of infection, spray 50 times solution of Bordeaux or potassium permanganate once every 10 days until the bamboo forest becomes healthy.
b. Bamboo top blight

![Bamboo forest infected with bamboo top blight disease](image)

**Symptoms**

Of the infected bamboo plant, the top part of the culm or even the whole culm withers to death. The disease often occurs on 1-year new culms. At first, on the top part or branches of infected new culm, there are some tongue like or fusiform lesion, of which the color gradually deepened from light brown into dark purple-brown. When the lesion becomes a ring to circle the culm, the leaves above the ring turn to yellow and brown, then gradually begin to curl and fall off, the branches and even the whole plant wither to death. The material quality of withered bamboo culm becomes brittle with lower utilization value.

**Pathogenesis law**

Blight bacteria is *Ceratosphaeria phyllostachydis* Zhang. In onset zone, when hot and dry year, bamboo top blight disease will be pandemic.
Control methods

(A) Clear pathogens: Cut down and burn out infected culm and branches timely. Don’t make any use of infected culm and its branches.

(B) At the peak of onset, the investigation should be strengthen. As soon as yellow leaves are found on new culm or brown spots appear on any node of culm, it should be timely to cut off the top part of the culm from 1 ~ 2 nodes below the diseased part to avoid the continuous spreading and causing the whole plant dead.

(C) Spray 1,000 times solution of 50% wettable powder of carbendazim or 70% wettable powder of thiophanate-methyl, or 1% Bordeaux mixture every 15 days from new leaves appear on new culm.

c. Bamboo branch clump disease/bamboo broom disease

Bamboo branch clump disease is also called bamboo nestle disease or bamboo broom disease. It often infects *Phyllostachys viridis*, *Phyllostachys glauca* McClure, *Pleioblastus amarus* (Keng) keng, *Phyllostachys vivax* McClure, etc..

![Figure 5-46 Symptoms of bamboo branch clump disease](image)

**Symptoms**

The infected bamboo grows weakly, of which the branches are thin, small, the leaves become smaller, and some branches extend longer with more node number. The infected branches grow more subbranches with shorter
internodes, of which the leaves leaf degenerate into scaly. In summer or rainy season, there are white rice-like objects, which are the spores meristem device of pathogenic fungus, a kind of Ascomycetes. After autumn or rainy season, the majority of infected branches wither to death. All branches of the infected bamboo plant are gradually attacked by the pathogenic fungus, which at last results in the whole plant death. The pathogenic fungus spread their spores by means of wind, rain, etc., and also through infected mother bamboo. The aged bamboo forest with high canopy density and poor management is more easily infected.

**Control methods**

Strengthen the management of bamboo forest, cut down aged bamboo culms to maintain proper canopy density. Make tillage, fertilization to promote vigorous growth of bamboo. Cut down and burn out infected bamboo plant as soon as possible. To develop new bamboo forest, choose mother bamboo from bamboo forest without any disease.

**d. Bamboo culm rust**

Bamboo culm rust is also known as bamboo mattress disease.
Symptoms

Bamboo culm rust often infects *Phyllostachys glauca* McClure, *Phyllostachys viridis*, *Phyllostachys vivax* McClure, *Fargesia spathacea* Franch, *Bambusa blumeana* Schult.f, etc..

The infected bamboo culm becomes black with brittle material and low processing value. The seriously infected bamboo plant might wither to death. The growth of seriously infected bamboo forest declines with less shoots. The disease mostly occurs on the lower part or base of bamboo culm, sometimes also on small branches. In summer or rainy season, some yellow-brown or dark brown silty pad-like substance (spores stack of pathogen) appears on the infected part of bamboo culm, which is in an oval or elongated shape. In winter or dry season, some orange-brown velvet-like, leathery pad-like substance (spores stack of pathogen) appears, which is closely and can not be easily separated. After the pad-like substance drops off, the infected part changes into black-brown.
The pathogenic fungi is *Stereostratum corticioides* (Berk.etBr) Magn, which spreads its spores by means of wind. Bamboo forest with high canopy density and poor management is more easily infected. This disease occurs on more than 2 years old bamboo culms, and hasn’t been seen on new culms.

**Control methods**

(A) Strengthen bamboo forest management, harvest reasonably to keep the canopy not too dense in order to reduce infection possibility.

(B) Cut down and burn out infected bamboo plant as soon as possible to avoid further spread of the pathogen. If the bamboo forest is infected heavily, spray 0.5 ~ 1 degree (Baume) of lime sulfur, or aminobenzene sulfonic acid, once every 7 days for continuous 3 times.

**e. Bamboo coal disease**

![Figure 5-48 Symptoms of bamboo coal disease](image)

**Symptoms**
Bamboo coal disease occurs more commonly on a variety of bamboo species, mainly infects on leaves and small branches. Initially, on infected leaves there are some black sooty spots in irregular shape. Later, the spots expand to the entire leaf surface to form a black sooty layer so as to impact leaf photosynthesis. The infected leaves often are prone to fall off, which results in a debilitating growth of bamboo forest.

Bamboo coal disease is caused by the infestation of aphids or scale insects. Secretions of aphids and scale insects are just the nutrition source of bamboo coal disease pathogen. Therefore, aphids or scale insects infestation is often accompanied by the occurrence of bamboo coal disease. On thin and dense bamboo culms, bamboo coal disease is often prone to occur. Bamboo coal disease is a caused by a variety of sooty blotch fungus, of which *Meliola sp.* is the main. The pathogen spreads by means of wind, rain and insects.

**Control methods**

To prevent bamboo coal disease, it should be primary to eliminate aphids and scale insects. Dimethoate can be used to control nymphs of aphids and scale insects; pine resin mixture can control scale insects; lime sulfur can kill nymphs of scale insects. Proper culm felling can improve ventilation and light condition for bamboo forest so as to greatly reduce the possibility of disease.

**f. Bamboo red lump disease**

Bamboo red lump disease is also known as bamboo meat disease.
Symptoms

Bamboo red lump disease often infects bamboo species of the two genus, *Phyllostachys* and *bambusa*. Bamboo red lump disease occurs on small branches. In spring or early rainy season, the leaf sheathes of infected twigs swell, break and expose small, gray, soft, lumps, of which the color gradually turns to yellow and red-gray. Afterward, the small lumps continue to swell into pink, fleshy surface, oval or irregularly shaped lumps with a diameter of 2 ~ 4cm. The pathogen of bamboo red lump disease is a kind of *Ascomycetes, Shiraria bambusicala* P. Henn, of which the spores spread by means of wind and rain.

Control methods

(A) Bamboo red lump disease mostly occurs on small dense bamboo. So, the bamboo forest should be thinned appropriately to reduce the density. Strengthened management for promotion of vigorous growth of bamboo forest can reduce the possibility of infection. Cut down and burn out infected bamboo branches after infection.

(B) Spray lime sulfur solution.

g. Bamboo black mole disease

Bamboo black mole disease is also known as bamboo black swelling disease
or bamboo rash disease.

![Symptoms of bamboo black mole disease](image)

**Symptoms**


Bamboo black mole disease occurs on leaves. After early autumn or rainy season, some small gray-white spots appear on bamboo leaf surface. Afterwards, the spots enlarge into round or spindle-shaped, of which the color also changes into orange-yellow and red gradually. Until the second year, on the spots surface some black lacquer-like lesions appear with slightly swollen surface, of which the edges are still red. If severely infected, a number of lesions can occur simultaneously on one bamboo leaf, and the infected leaves are prone to wither and drop off. The pathogen of bamboo black mole disease is *ascomycetes*, of which the most are *Phyllachora*. The spores of pathogen spread by means of wind.

**Control methods**

(A) Strengthen management of bamboo forest, thin the forest appropriately to improve ventilation and light condition so as to reduce infection.

(B) Spray 1% Bordeaux mixture on severely infected bamboo forest over the
years.

(2) Bamboo forest pests

Common pests of bamboo shoot are *Oligia vulgaris* Butler, *Cyrtotrachelus longimanus*, etc., which are all borers. They bore and eat bamboo shoots, and cause degraded bamboo shoots or culm deformity. The best control measure of bamboo shoot pests is making good prevention work. Combined with tillage cultivation, clear weeds and shrubs within the bamboo forest to improve sanitary environment, which is good for the eradication of early instar larvae of *Oligia vulgaris* Butler. The degraded bamboo shoots should be dug out so as to kill the larvae inside.

a. *Oligia vulgaris* Butler

The larvae of *Oligia vulgaris* Butler often bore and eat shoots of *Phyllostachys pubescens* Mazel ex H.de Lehaie, *Phyllostachys glauca* McClure, *Pleioblastus amarus* (Keng) keng, *Phyllostachys bambusoides*, *Phyllostachys glabrata*, etc.. In severely infested region, a large number of bamboo shoots are damaged and cannot grow into culms, and even if they grow into culms, the culms will be broken and incomplete.
The biological characteristics of *Oligia vulgaris* Butler

*Oligia vulgaris* Butler has one generation in a year. When there is no bamboo shoot, the larvae firstly eat grassy and sedge weeds to cause their dead heart and white ear. When bamboo shoots come out of ground, the second instar larvae crawl to the small leaves and bore into them on shoot tips, leaving green debris accumulation outside, then the third instar larvae bore into the shoots to bite the soft and tender part of them. The surface of infested shoot is dull, inside which there are wormholes and frass. Young larvae live within shoots for 20 ~ 25 days; the mature larvae crawl out from bamboo shoots into soil to spin cocoons and pupate. The pupal stage is 16 ~ 24 days. Then the pupae change into adult insects. The adult insects spawn on the foliage of grassy weeds, dozens of which line
into strips.

**Control methods**

(A) Strengthen management of bamboo forest, clear out weeds, eliminate eggs and early instar larvae of insects, especially at the beginning of rainy season or early spring.

(B) Dig out infested degraded bamboo shoots as soon as possible and kill the larvae inside.

(C) For material bamboo forest, spray 1000 times solution of 80 % dichlorvos emulsion, or 800 times solution of 40 % omethoate onto shoots once every 7 days for continuous 2 ~ 3 times; at the beginning of rainy season or early spring, spray herbicides in the forest to eliminate the host plants of *Oligia vulgaris* Butler. However, the attention must be paid to human and animal safety.

b. *Cyrtotrachelus longimanus*

*Cyrtotrachelus longimanus* is one of the main pests of bamboo. The larvae bore and eat bamboo shoots and cause them wither to death, and also eat tender culms up to one meter tall to result in their worse growth, shortened internodes, breaking down, abnormal clumps of top sprigs and longitudinal crack or decay of tender bamboo.

**The biological characteristics of *Cyrtotrachelus longimanus***
Cyrtotrachelus longimanus has one generation in a year. Adults of Cyrtotrachelus longimanus eat, mate and lay eggs on new bamboo shoots. The eggs are mostly laid on the top part of shoot. Before spawning, the adults bite holes on the top part of shoot, and then lay eggs into them, 1-2 eggs per hole. The orifice is wet, around which there are fibrous protrusions sometimes. The eggs hatch after 3-7 days. Larval stage is 15-19 days. Mature larvae bite holes on the infested part and come out, and then drill into soil at a depth of 8-10 cm to pupate. After eclosion, the adults hibernate in the soil. From egg to adult it lasts one month. After emergence, the adults fly and make activities often in 8-10 o’clock. Adults have suspended animation. They are good at flying, mostly in hot days. However, after rain sometimes they also appear in the evening.

**Control methods**

**A) Cover shoots**

Make a conical cover with bamboo filament and other materials and cover the newly unearthed bamboo to prevent spawning of adult insects.

**B) Kill adult insects**

Combined with soil tillage, kill adult insects. After unearthed, adults of Cyrtotrachelus longimanus hide at the shady and cool back of bamboo leaves,
so they can be easily captured and killed.

(C) Chemical control

In oviposition period, spray 500 times solution of 90% trichlorfon or 1000 times solution of 50% dichlorvos on bamboo shoots once every seven days. Within the five days after oviposition, paint wormholes with 3-6 times solution of 40% dimethoate emulsion (one day after oviposition, wormhole is fresh, green and wet; 2 days after oviposition wormhole is gray with blue; 3 days after oviposition wormhole is gray-black and dry; 4 days after oviposition, a small amount of fiber can be seen around the wormhole; 5 days after oviposition there is no fiber, only frass can be seen).

Bamboo culm pests

The common pests of bamboo culm are *Pantana phyllostachysae* Chao, *Ceracris kiansu* Tsai, and some bamboo spider mites.

c. *Pantana phyllostachysae* Chao

*Pantana phyllostachysae* Chao often infest *phyllostachys pubescens, Neosinocalamus affinis, phyllostachys bissetii* McClure, *Phyllostachys bambusoides* Sieb. et Zucc. f. shouzhu, etc.. It can eat out all the leaves of bamboo to result in water accumulation in culm internodes and bamboo plant death.
The biological characteristics of *Pantana phyllostachysae* Chao

*Pantana phyllostachysae* Chao has three generations in a year. The newly hatched larvae cluster around and eat egg shells. The 1st-3rd instar larvae cluster at the back of bamboo leaves to eat the leaves. The 4th instar larvae begin to eat dispersedly. The adult emergence is mostly in early morning and evening. Mature larvae spin cocoons on the upper leaves or culms.

**Control methods**
(A) Trap and kill with fire: In the peak of adult emergence, Trap and kill the adult insects with fire at 19-21 o’clock, and pay attention to fire safety.

(B) Strongly protect natural enemies of the pest, give full play of self-control function of forest ecosystem.

(C) In the case of the larger pest population density, smoke with a fumigant to kill the larvae, the dosage is about 15kg per hectare.

(4) Drill a small hole at the culm base and inject 1~2ml omethoate into the hole.

d. Ceracris kiangsu Tsai

When severe occurrence, all of the bamboo leaves are eaten out, the new culms wither to death like fired, the old culms don’t sprout new shoots in 2~3 years. The infected bamboo culm often has water inside and is not available.

Figure 5-56 Adults of Ceracris kiangsu Tsai
The biological characteristics of *Ceracris kiangsu* Tsai

*Ceracris kiangsu* Tsai has one generation in a year. The nymphs at first cluster to eat low small bamboo and grassy weeds, 10 days later cluster on the top of big bamboo culms to eat. The infested bamboo looks yellowish with fragmentary leaves. After 3 instar, the nymphs gradually disperse. *Ceracris kiangsu* Tsai has a characteristic of migration, i.e. when weather is hot, they often come down from culms and hide in shade in groups at noon, and until the air temperature becomes lower, they go up to the top of culms. Generally, from evening until next day, before the dew is dry, they move little in the dark. The adults cluster to eat bamboo leaves. They like to fly before their genitals are mature. When weather is hot, about 16 days after mating they obliquely insert their abdomen into soil and lay eggs layer by layer within an foamy substance, which form egg masses. Each egg mass has about 20 eggs, on which there is a cover, and each female adults lay about six egg masses. The spawning sites are mostly sunny and windward hillside slopes with soft soil. After spawning, the adults gradually die.

**Control methods**
(A) Dig eggs manually. The spawn of *Ceracris kiansu* Tsai is concentrated, so we can dig the egg masses on sunny and windward hillside slopes in late autumn or dry season.

(B) Within 10 days after *Ceracris kiansu* Tsai unearthed, sprayer 1,000 ~ 2,000 times solution of 80% dichlorvos emulsion.

(C) When *Ceracris kiansu* Tsai cluster to eat on the top of big bamboo culms, smoke with 15kg dichlorvos fumigant per hectare in bamboo forest of big insect population density.

(4) Use the fungal pesticide *Beauveria bassiana* to make nascent *Ceracris kiansu* Tsai infected to death.

(5) Trap and kill with straw soaked with human urine pesticide. The preparation formulation is 50kg fresh human urine with 0.05-0.1kg wettable trichlorphon powder. And the soaking time is 24 hours. Put the soaked straw heaps at headwind places of bamboo forest, which is better when sunny weather.

e. Bamboo mites

The main pest mites of bamboo are: *Schizotetranychus nanjingensis, Schizotetranychus bambusae, Aponychus corpuzae*, etc..

**Damage symptoms of bamboo mites**

The leaves of infested bamboo are withered to yellow and fall off, and the bamboo canopy becomes sparse; of severely infested bamboo, most of the leaves look like scorched and fall off to result in bald tops, bare branches, bald culms and death. Some bamboo culms become gray-white, some bamboo forest looks like been fired, and large tracts of culms wither to death.
Figure 5-58 Aponychus corpuzae

Figure 5-59 Bamboo infested by Schizotetranychus bambusae
Bamboo mites comprehensive control countermeasures

Bamboo mites mechanized units countermeasures:

(A) Protect and develop mixed forest of bamboo and tree, breed mite resistant bamboo species. For management of bamboo forest, pay attention to the retention of deciduous trees, protect Leguminosae shrubbery such as Lespedeza bicolor Turcz. etc.. In pure bamboo forest, after harvest we can plant some accompanying tree species such as paulownia, Cunninghamia lanceolata (Lamb.) Hook, Pinus massoniana Lamb., etc. in the open space to gradually transform it into a mixed forest of bamboo and tree, of which the ratio of bamboo and tree is 7:3 or 8:2 appropriately. It will restore biodiversity of bamboo forest, and create a good ecological environment for the natural enemies of pests to perch and reproduce. At the same time, gradually adjust the structure of bamboo species, select and develop anti-mite bamboo species.

(B) Improve management level of bamboo forest to enhance its ability to resist mites. At first, reasonably improve stand condition, properly preserve
weeds with shallow roots. No reclamation in bamboo forest with loose soil and without lush grass and shrubs. On the slope above 25 °, apply plots plowing; and on the slope below 25 °, apply rows plowing along the contour interval. Secondly, rationally harvest to maintain a reasonable canopy density and age structure. Finally, properly fertilize to promote vigorous growth of bamboo forest. It is appropriate to apply 375 kg / ha of compound or organic fertilizers suitable for bamboo growth at both ends of summer-autumn or rainy season for two times. When fertilization, it has significant effect of control of mites to mix pyridaben with fertilizer into medicine fertilizer in a proportion of 1:14 to apply around bamboo roots. The dosage is 100 ~ 150 g per plant of bamboo. In 30 days, the control effect of spider mites will reach 95.4% ~ 99.0%.

(C) Protect and make use of natural enemies of bamboo mites. It should be advocated to use biological control, such as *Beauveria bassiana*, biological pesticide, parasitic wasps, etc. to avoid extensive use of chemical pesticides like deltamethrin, trichlorfon and so on to kill predators like ladybugs, predatory mites in bamboo forest. In bamboo forest infested with mites, we can release artificially bred predatory mites, help their migration to strengthen their position in bamboo ecological communities. 20 ~ 30 days prior to the 1st and 2nd peak of mites occurrence (in China May~June and August~September), the release effect is better. The release proportion is l: 100 ~ l: 200 appropriately.

(D) Bamboo cavity injection control. The mite control effect of bamboo cavity injection is remarkable. In high temperature and drought season, inject high absorption pesticides, such as 10 ml per culm of 30 times solution of 40% omethoate, deltamethrin into bamboo cavities on culms base, the stubbornly high mite density will be rapidly reduced. If add right amount of nutrients into the injection liquid, such as urea, potassium dihydrogen phosphate, etc., the control effect is better. The injection time is appropriately at the peak of mite occurrence.
6.1 Conclusions

Bamboo is socio-economically and environmentally versatile treasure of human being. Modern technology of bamboo utilization is highly developed. As one of the sustainable eco-friendly natural resources, bamboo has made a great contribution to the improvement of ecological environment and socio-economic development for the society of many countries in the world. It can be processed not only into house utensils, furniture and buildings in traditional ways, but also it can be processed in industries into high value-added forest products, such as pulp and paper, fibers and super energy storage charcoal.

Developing bamboo industries can bring not only good ecological benefits, but also big benefits for both farmers and bamboo based enterprises. It can also generate high revenue to the Government.

1. Advantages of developing bamboo industries in Ethiopia

There are many advantages for developing bamboo industry in Ethiopia, since both the climate and soil conditions of the country are suitable for the growth of the shallow-rooted plant – bamboo that grows in warm and humid climate and acidic soil.
(1) The existing bamboo resources of Ethiopia account for a large proportion of the world especially the Africa.

The world bamboo area is about 22 million hectares (more than 70 genera, 1200 species). And the Africa bamboo region accounts for about 7% of the world bamboo area (totally 11 genera and about 43 species), in which the Ethiopian bamboo area is more than 100 million hectares, accounting for about 5% of the world as a whole and 67% of the Africa.

(2) Compared with other African countries, Ethiopian bamboo processing and utilization have certain base and the products have more regional competitiveness.

The bamboo processing and utilization history of most African countries is very short, which is basically in its infancy. Although compared with developed countries, Ethiopian bamboo processing and utilization is lagging behind, but it has a long history. Traditional uses include simple houses, simple furniture and tools. Currently, there are more than 100 bamboo furniture manufacturing enterprises with a certain scale in the country. And its product design is aesthetic and the quality is better enough. In the capital Addis Ababa, almost in every major street some small exquisite bamboo furniture workshops can be seen. Meanwhile, there are four modern enterprises producing bamboo floor, bamboo door, bamboo curtain, bamboo charcoal and other products in the country.

(3) Abundant bamboo-like plant resources such as *Arundo donax*.

In addition to bamboo, there is another plant - *Arundo donax* (in Amharic ዓምበቆ, and some people call it Reed Grass), of which the characteristics, appearance and utilization are very similar to bamboo. The area of *Arundo donax* in Ethiopia is not yet estimated, but it is very popular in Ethiopia. For example, Addis Ababa, it is very flourish wherever the soil is relatively moist, especially on both sides of the river and ditches. Many people use it to make yard and street sapling fences, weave drying mats, baskets and other kinds of bamboo products. If not carefully identified, it is easy to be confused with bamboo products.
In addition, there are a large number of straw plants and delicate straw craft in Ethiopia. The Pennisetum grass Pennisetum schimperi, *P. adoense* (in Amharic ምንደዶ) is used to compile the skeleton that is wrapped in *Cyperus duclouxii* (in Amharic ውርምጣ) and *Scirpus paniculato-corymbosus* (in Amharic ትምሎም), which are also called ከምሉ in Amharic and used in coffee ceremony. The *Cyperus duclouxii* is mainly grown in north of Lake Tana, and the *Scirpus paniculato-corymbosus* in the south of Lake Tana. Straw products include various kitchen supplies and other utensils.

2. Main constraints to bamboo production and processing

There are some constraints to bamboo production and processing. Followings are the main:

**(1) Low input and irregular felling cause lower bamboo production and quality.**

Currently, Ethiopian bamboo supply is scattered and without regulated management and felling standards. There is no coordination mechanism between farmers and plantations. The bamboo felling depends on the needs of brokers and lacks of storage places. The selling is just after felling. The lowland bamboo is nearly all natural, virtually no investment. Even the highland bamboo, there are few planted areas. So, the bamboo area is in a declining trend, and the quality becomes lower and lower unless efficient interventions and measures are considered.

**(2) Transportation cost is expensive and the necessary market is stunted.**

There are no processing factories near bamboo forests. The site of bamboo processing is far away from the bamboo plantation. So the transportation cost is very expensive. Even in the three bamboo processing cities, there is no collecting and distributing center, and also no decent bamboo products market. Most of bamboo products are placed on the roadside for sale. The necessary market system is stunted.

**(3) Strength of research and technology linkage and promotion could be weak**
The Ethiopian bamboo research began in 1992. Currently, the bamboo research projects engaged in the federal forestry research centers and universities are focused on: 1) bamboo propagation; 2) bamboo forest management; 3) the physical and mechanical properties of bamboo; 4) the anatomical and chemical characteristics of bamboo; 5) bamboo plywood; 6) bamboo plate; 7) bamboo particle board / chipboard; 8) bamboo medium density fiberboard; 9) bamboo wettability / contact angle characteristics; 10) bamboo durability, treatability and effective protection measures against biodeteriorating (termite, beetles and fungi) agents.

But only the general research and experiments (e.g. bamboo breeding and management) can be carried out domestically, and some research tests are required to be implemented abroad because it is lack of research facilities. Only some few researchers in some Federal and State universities and Forest Research Institutes are engaged in the research and extension of bamboo cultivation and processing technology, and most of whom are part-time. It cannot meet the modern needs of utilization and development of bamboo resources.

6.2 Recommendations

The following issues are recommended for sustainable management and utilization of bamboo resources in Ethiopia:

(1) **Carry out a detailed inventory of bamboo resources**

The bamboo resource data of Ethiopia has changed greatly. In order to take better advantage of the existing bamboo resources of the country and further development of bamboo industries in Ethiopia, it is very necessary to make a comprehensive detailed inventory on the existing bamboo resources so as to work out a more realistic plan for developing bamboo processing industries.

(2) **Establish a research, demonstration and technology popularization system for Ethiopian bamboo industry**
Development of any industry must rely on advanced technology. To develop the Ethiopian bamboo industries, we must establish a more comprehensive research, demonstration and technology popularization system. Firstly, we must establish some research bases to make experiments on different geographical and climatic conditions, cultivation and management technology with all the bamboo species, including the two indigenous and 27 exotic bamboo species. Meanwhile, we would better introduce the new bamboo species to make the same experiments. Thus, we can choose the most appropriate bamboo species and the corresponding cultivation and management technologies. We must make all-round tests of bamboo physical and chemical properties to get a reliable technological basis for its processing and utilization. Secondly, we must establish a nursery technical system to provide the necessary bamboo seedlings for large-scale cultivation through further testing on selected bamboo species for best planting periods. Thirdly, to establish technology demonstration bases and training centers of bamboo industry to strengthen the technology promotion of bamboo cultivation and processing, focusing on training workers directly engaged in the first production line and expanding the practitioners’ team of bamboo industry.

(3) Establish commercial marketing system of bamboo materials and bamboo products

Production and commercial marketing are interdependent of each other. They have a mutually reinforcing effect. Certain scale of production requires a certain scale of corresponding supporting commercial marketing system in order to maintain its sustained and stable development, while producing its proper economic benefits. We must establish enough bamboo material markets based on the distribution of bamboo resources; select best processing establishments according to bamboo materials markets, production, transportation and other conditions; choose proper processed products and production scale based on market potential; choose and establish an appropriate scale of product markets according to the needs of consumer groups. Through a full investigation to establish a reasonable
system of commodity marketing for bamboo industry to reduce the cost of all aspects of commercial circulation, we can benefit a lot to all employees of bamboo based industries and bamboo products consumers.
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Annex 1

List of bamboo Species by Scientific name

Monopodial species

1. *Phyllostachys*:
   Phyllostachys pubescens
   Phyllostachys praecox Chu et Chao
   Phyllostachys fimbriligula Wen
   Phyllostachys iridescens C. Y. Yao et S. Y. Chen
   Phyllostachys glabrata,
   Phyllostachys dulcis McClure,
   Phyllostachys vivax McClure,
   Phyllostachys prominens,
   Phyllostachys rutila,
   Phyllostachys incarnata Wen,
   Phyllostachys hispida S. C. Li, S. H. Wu et S. Y. Chen,
   Phyllostachys rubromarginata,
   Phyllostachys nidulariaf. smoothsheath McClure,
   Phyllostachys glauca McClure, etc.

2. *Chimonobambusa*:
   Chimonobambusa utilis,
   Chimonobambusa grandifolia,
   Chimonobambusa arnata,
   Chimonobambusa hejiangensis,

Sympodial species

1. *Dendrocalamus*:
   Dendrocalamus giganteus Munro,
Dendrocalamus yunnanicus Hsueg et D.Z.Li,
Dendrocalamus hamiltonii Nees et Arn.ex Munro,
Dendrocalamus aspera (J. A. et J. H. Schult.) Backer ex Heyhe,
Dendrocalamus brandisii (Munro) Kurz,
Dendrocalamus barbatus Hsueh et D.Z.Li,
Dendrocalamus latiflorus,

2. Bambusa:

Bambusa emeiensis (former Neosinocalams affinis),
Bambusa tulda,
Bambusa vulgaris var. striata,
Bambusa vulgaris var. green,
Bambusa balcooa,
Bambusa oldhami,
Bambusa bambos,
Bambusa textilis.
Annex 2.

Bamboo Resources in Ethiopia

- *Yushania alpina* (highland bamboo)
- *Oxytenanthera abyssinica* (Lowland bamboo).

- Introduced 27 exotic bamboo species of 7 genera (*Bambusa*, *Dendrocalamus*, *Phyllostachys*, *Gigantochloa*, *Thrysotachyas*, *Schizostachyum* and *Guadua*):
  1. *Bambusa emeiensis* (former *Neosinocalams affinis*);
  2. *Bambusa tulda* (also referred to as *Dendrocalamus tulda*);
  3. *Bambusa vulgaris* var. *Striata* (English name is Golden Bamboo, which is a variation of *Bambusa vulgaris* like *Bambusa vulgaris* var. *green*);
  4. *Bambusa vulgaris* var. *green*;
  5. *Dendrocalamus asper*;
  6. *Dendrocalamus brandisii*;
  7. *Dendrocalamus hamiltonii*;
  8. *Dendrocalamus membranaceus*;
  9. *Bambusa balcooa*;
  10. *Dendrocalamus giganteus*;
  11. *Dendrocalamus peculiaris*;
  12. *Phyllostachys pubescens*;
  13. *Guadua amplexifolia*;
  14. *Dendrocalamus barbatus*;
  15. *Bambusa oldhami*;
16. *Dendrocalamus latiflorus*;
17. *Gigantochloa apus*;
18. *Bambusa multiplex alphonsekarr*;
19. *Bambusa multiplex silverstripe*;
20. *Bambusa textilis var fasca*;
21. *Thrysotachyas siamensis*;
22. *Gigantochloa sumatra*;
23. *Schizostachyum jaculans*;
24. *Guadua angustifolia*;
25. *Gigantochloa atter*;
26. *Bambusa bambos*;
27. *Bambosa vulgaris sub. Variet vitata*. 
A good way by better using bamboo resources to a better life