Ramie (*Boehmeria nivea*)
Production and Its Diverse Uses in China

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Outlines

- General Introduction of ramie
- Ramie Germplasm and Major varieties released
- Cultivation methods for high productivity
- The traditional uses of ramie
- The novel uses of ramie
- The prospects of multi-purpose utilization for ramie
General Introduction of Ramie

- Ramie is a kind of herbaceous perennial crop originated from China.
- Ramie belongs to the nettle family Urticaceae.
- Ramie is in general with heart-shaped leaves, which are white on the underside with dense hairs. White ramie is sometimes called China grass, which is mainly grown as a fiber crop in China.
- Unlike white ramie, there is another kind of ramie with smaller leaves with green color on both sides.
Distribution of Bast Fiber Crops in China

- **Ramie**
- **Flax**
- **Kenaf/Jute**
- **Hemp**
Production of Ramie in China (2011)

- **Ramie Planting Area (×10,000 ha):** 8.40
- **Total Yields (×10,000 tons):** 15.84
- **Productivity (ton/ha):** 1.89
Botanical Morphology of Ramie

- Leaf
- Stem
- Root

aerial part of ramie
Botanical Morphology of Ramie

- pistil
- stamen
Botanical Morphology of Ramie

Inflorescence

Seeds
Ramie Germplasm

There are 2052 collections which belong to 19 species and 8 varieties.
Ramie Germplasm (Root Type)

Shallow Type  Middle Type  Deep Type
Ramie Germplasm (Stems)

- Round
- Four edges

Subglabrous, Sparsely hairy, Dense hair
Ramie Germplasm

- White Ramie
- Green Ramie
Ramie Germplasm (Leaves)

Heart shape  Oval  Long oval

Yellow green to dark green
Ramie Germplasm (Phyllotaxy)

Alternate phyllotaxy
Opposite phyllotaxy
Ramie Germplasm (color of flower)

Yellow white
Yellow green
Reddish
Reddish
Red
Crimson
Major Varieties Released

Zhongzhu No.1, the plantation area is the largest in China.

Xiangzhu No.2/Yuan yeqing
Major Varieties Released

Xiangzhu No.3

Huazhu No.5
Major Varieties Released

Chuanzhu No.8

Chuanzhu No.9
The Growth of Ramie

- Life span: usually 10-30 years, more than 100 years in some special cases.
  - Young ramie: 1-2 years
  - Strong age ramie: 3-8 years or more
  - Aged ramie: declining caused by pests and diseases
The Growth of Ramie

**Seedling Stage:**
needs more nitrogenous fertilizer, optimum temperature is about 23-29°C

**Vigorous Growing Stage:**
closure stage to black stalk stage, optimum temperature is about 24-27°C

**Fiber Maturity Stage:**
needs more phosphorus and potassium, optimum temperature is about 17-32°C
The Growth of Ramie

In general, ramie can be harvested for 3 times per year in the middle and lower reaches of Yangtze River.

- First Season: 85-90 days (Early March to Early June)
- Second Season: 50-60 days (Mid-June to Early August)
- Third Season: 75-85 days (Early August to Early October)
Cultivation Methods (Seedling)

- Seedling from seeds
  - Thousands kernel weight: 0.05 gram.
  - Time: early March in the lower reaches of Yangtze River.
  - Seedling rate: 7.5Kg/ha
  - Advantage: quick reproduction
  - Disadvantage: segregation of character in F1
Cultivation Methods (Seedling)

- Seedling from the vegetative part (root/stem/leaf)
  - The widely used propagation method is by Young shootings cutting
  - Advantage: Offspring has identical characters to parents
  - Disadvantage: slow reproduction speed, high cost
Cultivation Methods (Seedling)

- Cutting tender shoots
- Planting tender shoots
- Seedling Survival
- Mulching
Cultivation Methods (Transplanting)

- Seedlings from seeds or vegetative part are usually transplanted in April when a new ramie plantation is built.

- The planting density is about 9000 to 11000 seedlings per ha according to different varieties.

- Transplanting in cloudy days is recommended as the survival rate can be improved.
Propagation base of ramie
Cultivation Methods (Cultivating and Weeding)

- Weeds may cause very serious damage if it is not controlled before closure stage, especially for the new planted seedlings.

- In general, it needs 2-3 times weeding for new planted seedlings or first season ramie. Mechanical weeding is recommended if both labor costs and environment protection are taken into account.
Cultivation Methods (Fertilizing)

- Rational fertilization may increase the productivity significantly.

Fertilizing based on the amount soil manure (Kg/667m²)

<table>
<thead>
<tr>
<th>Season</th>
<th>Nitrogen</th>
<th>Phosphorous</th>
<th>Potassium</th>
<th>N:P:K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>First</td>
<td>8.7</td>
<td>8.0-10.0</td>
<td>3.5</td>
<td>3.1-4.5</td>
</tr>
<tr>
<td>Second</td>
<td>5.5</td>
<td>4.5-7.0</td>
<td>3.0</td>
<td>2.5-3.5</td>
</tr>
<tr>
<td>Third</td>
<td>5.1</td>
<td>4.5-6.7</td>
<td>1.5</td>
<td>1.0-2.2</td>
</tr>
</tbody>
</table>
Cultivation Methods (Irrigation)

- Adequate light and water are favorable to ramie growth.

- It is not necessary for irrigation in the first season as it is coincided with rainy season in central south China. To the contrary, draining becomes more important as excess water in soil may damage the root.

- It needs 2-3 times irrigation in the second season as it is usually lack of rain.
Cultivation Methods (Winter Cultivation)

- Winter cultivation may facilitate ramie sprouting in the next Spring as it loosening the soil, providing nutrition and avoiding cold damage, etc.
The agronomical characters of ramie in the first season in 2014

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Plant height(cm)</th>
<th>Stem diameter(mm)</th>
<th>Bark thickness(mm)</th>
<th>The effective strain rate(%)</th>
<th>Fiber content of fresh stem(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhongzhu No.1</td>
<td>224.67 ± 6.30</td>
<td>13.68 ± 0.15</td>
<td>1.18 ± 0.05</td>
<td>91.19 ± 3.38</td>
<td>5.32 ± 0.30</td>
</tr>
<tr>
<td>Zhongzhu No.2</td>
<td>219.61 ± 12.85</td>
<td>10.88 ± 0.87</td>
<td>0.83 ± 0.04</td>
<td>95.11 ± 2.79</td>
<td>6.36 ± 0.32</td>
</tr>
<tr>
<td>NC03</td>
<td>194.87 ± 12.41</td>
<td>11.79 ± 0.38</td>
<td>0.87 ± 0.06</td>
<td>93.83 ± 4.10</td>
<td>5.07 ± 0.25</td>
</tr>
</tbody>
</table>
Harvesting

- Ramie is in general a bast fiber crop and it is harvested for three times when half to 2/3 of stalks from the ground become black.

- Ramie harvesting can be done by hand or by machine. Hand harvesting is now rarely seen as the intense use of labor, however, the harvesting machine is not so effective that may hander the development of ramie industry.
Harvesting

Reverse pulling decorticating

Direct delivering decorticating
The Traditional Uses of Ramie

- It was shown by archaeology that ramie was planted 4700 years ago in China. Ramie and Hemp are the two major fiber crops which supplying the materials for clothes in ancient China.
- Ramie fabric was found in the west han tomb which was excavated in 1973.
The Traditional Uses of Ramie

- Fiber extraction: The fibers extracted from ramie bark are called undegummed fibers, which contain pectin, lignin, semi-cellulose, etc. except for cellulose.

- The undegummed fibers need to be treated by chemicals or bacterium/enzyme to remove pectin, lignin, semi-cellulose, etc., which account for 25% of the total weight.

- The degummed fibers are consisted of many single fibers, which can be spun to yarn and woven to fabric, clothes, etc.
Ramie degumming by chemicals was invented in 1940s. This method needs sulphuric acid and sodium hydroxide, which may cause serious pollution to the environment if the waste water is discharged directly without treatment.

Alternatively, biological degumming may decrease 60% of the pollutants.
The Traditional Uses of Ramie

From left to right: undegummed fiber, degummed fiber by bacteria, degummed fiber, ramie stripes, ramie yarn
Factory bio-degumming

Undegummed fiber (yellowish-brown)

7 hr fermentation by bacteria (blue-green)

Degummed fiber (white)
The Traditional Uses of Ramie

Ramie fabrics woven by bio-degummed fiber
Ramie cloth woven by traditional techniques
Ramie fabric woven by 500 count yarn
The novel uses of ramie

- As a traditional fiber crop, only the bark of the stalk is used effectively, while the residues including leaves, shives, etc. are discarded.

- On the one hand, high protein content in ramie leaves and high biomass yield make it possible to develop novel uses for ramie.

- On the other hand, ramie production has declined steadily since 2006 as a result of competition of synthetic fibers, and this will lead to the diverse uses of the old crop.
The novel uses of ramie (bio-energy)

- Bio-energy or bio-ethanol has been a hot research topic in recent years as it is clean and renewable.
- Many plants with high biomass yield are candidates for bio-energy research.
- The dry biomass of ramie is about 18 tons per ha on average, thus ramie is a possible candidate for bio-energy as well.
## Major components of different materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Cellulose (%)</th>
<th>Semi-cellulose (%)</th>
<th>Lignin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramie</td>
<td>68-72</td>
<td>18-20</td>
<td>2</td>
</tr>
<tr>
<td>Kenaf</td>
<td>50-52</td>
<td>18-21</td>
<td>14</td>
</tr>
<tr>
<td>Reed</td>
<td>36</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Corncob</td>
<td>38</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>Corn stalk</td>
<td>37</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>Rice straw</td>
<td>25-40</td>
<td>35-50</td>
<td>10-30</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>30</td>
<td>50</td>
<td>15</td>
</tr>
</tbody>
</table>
The effect of enzymatic degradation of several materials (15 gram)

<table>
<thead>
<tr>
<th>Material</th>
<th>Total glucose after enzymatic degradation /g</th>
<th>Conversion rate /%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramie bast</td>
<td>10.055</td>
<td>67.03</td>
</tr>
<tr>
<td>Ramie stalk</td>
<td>6.659</td>
<td>44.39</td>
</tr>
<tr>
<td>Corncob</td>
<td>8.806</td>
<td>58.69</td>
</tr>
<tr>
<td>Reed</td>
<td>6.762</td>
<td>45.08</td>
</tr>
<tr>
<td>Corn stalk</td>
<td>5.591</td>
<td>37.27</td>
</tr>
</tbody>
</table>
Bio-ethanol produced by ramie with enzymatic degradation and fermentation

1. Ramie plant
2. Decorticating
3. Undegummed fiber
4. Bio-degumming
5. Residues/shives
6. Grinding
7. Enzymatic degradation
8. Bio-ethanol
9. Fractionation
10. Fermentation
The novel uses of ramie (mulch)

- The use of plastic mulch has improved the yields of crops greatly, but it has deteriorated the environment increasingly.

- The substitute of plastic mulch needs to be developed and it will improve the yields of crops and protect environment simultaneously.

- Ramie noil/short fibers mixed with other natural fibers can be used to produce ramie mulch with non-woven technology.
Mulch manufactured by ramie and other natural fibers
Degradation after 3 months
Left: ramie mulch
Right: plastic mulch

Ramie mulch used in cabbage cultivation
The novel uses of ramie (Feed)

- Ramie, known as China grass, is mainly used as a fiber crop which we already discussed above.

- Many kinds of grass are suitable for animal feed, so is ramie, the China grass.

- Although ramie leaves were used as animal feed by farmers many years ago, it was not studied systematically until 1980s.

- The rapid development of husbandry has facilitated the use of feed for ramie in south China since 2000.
The novel uses of ramie (Feed)

- Special variety for feed
  - The aerial parts including leaves and stems are all used for feed.
  - To guarantee the nutritional quality of the end products, the feed ramie plants are harvested for 7-8 times per year when the plant grows up to 70-100 cm.

- Dual purpose variety for both fiber and feed
  - Traditionally, ramie is harvested for 3 times for fiber annually, and the residues after decorticating can be used for feed.
The novel uses of ramie (Feed)

The comparison between ramie and alfalfa

<table>
<thead>
<tr>
<th>Character</th>
<th>Ramie</th>
<th>Alfalfa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>87.00</td>
<td>87.00</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>21.30</td>
<td>19.10</td>
</tr>
<tr>
<td>Lysine (%)</td>
<td>0.99</td>
<td>0.82</td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>16.20</td>
<td>22.70</td>
</tr>
<tr>
<td>Crude ash (%)</td>
<td>14.95</td>
<td>7.60</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>3.94</td>
<td>1.40</td>
</tr>
<tr>
<td>Productivity (t/ha)</td>
<td>18.00–22.50</td>
<td>7.50–12.00</td>
</tr>
</tbody>
</table>
Dual purpose variety for both fiber and feed

- Ramie plant
- Decorticating
  - Residues
  - Fiber
  - Baling
  - Silage
  - Grass powder
  - Pellets
Special variety for feed

Zhong Sizhu No.1

Grazing directly

Rotational grazing

Cutting into pieces

Silage

Pellets
In general, many kinds of crop residues can be used as substrates for edible mushrooms.

Ramie residues have been developed as the substrate for edible mushrooms in order to explore a new market for ramie industry in the past decade.
## The comparison of components between ramie residues and other materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Crude protein/%</th>
<th>Crude fiber/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramie leaves</td>
<td>21.46</td>
<td>18.28</td>
</tr>
<tr>
<td>Ramie stalk core</td>
<td>6.69</td>
<td>50.19</td>
</tr>
<tr>
<td>Ramie residue</td>
<td>12.21</td>
<td>35.35</td>
</tr>
<tr>
<td>Cottonseed hull</td>
<td>8.36</td>
<td>40.60</td>
</tr>
<tr>
<td>Corncob</td>
<td>~2</td>
<td>31.8</td>
</tr>
<tr>
<td>Rice straw</td>
<td>3.4</td>
<td>35.6</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>4.1</td>
<td>36.7</td>
</tr>
<tr>
<td>Maize straw</td>
<td>5.6</td>
<td>29.3</td>
</tr>
<tr>
<td>Sawdust</td>
<td>~1.7</td>
<td>54.6</td>
</tr>
</tbody>
</table>
The use of substrate for edible mushrooms

Ramie plant → Mechanical decorticating → Fiber → Residues → Substrate preparation → bagging → Mushroom cultivation
The nutritional quality of ablone mushroom cultivated by ramie residues and cottonseed hull

<table>
<thead>
<tr>
<th></th>
<th>Protein /%</th>
<th>Fat /%</th>
<th>Reducing Sugar /%</th>
<th>Total sugar /%</th>
<th>Crude fiber /%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramie residue</td>
<td>3.9 ± 0.1a</td>
<td>0.2 ± 0.02a</td>
<td>0.2 ± 0.03a</td>
<td>47.3 ± 0.2a</td>
<td>2.4 ± 0.1a</td>
</tr>
<tr>
<td>Cottonseed hull</td>
<td>3.0 ± 0.2a</td>
<td>0.3 ± 0.02a</td>
<td>0.24 ± 0.02a</td>
<td>61.9 ± 0.4b</td>
<td>2.2 ± 0.3a</td>
</tr>
</tbody>
</table>
The novel uses of ramie (Water & soil conservation)

Growing ramie in hilly and mountain area may reduce erosion. The erosion modules of slope land planted with ramie is 0.45 ton/ha per year, reducing 87% erosion compared with annual crops.
The prospects of multi-purpose utilization for ramie

- Ramie has many uses because of its high productivity for both fibers and biomass, as well as the high protein content.

- The continuous shrink of ramie textile industry has stimulated the novel uses of ramie, however, many of the novel uses are still in research stage because of cost concerns.
The prospects of multi-purpose utilization for ramie

- Ramie mulch was developed to replace plastic mulch in the beginning, but it is now being used as seedling substrate, which is more promising for bigger markets and lower costs compare to the use of mulch.

- The use of feed has changed the traditional concepts that ramie is only a kind of fiber crop. Ramie feed will promote ramie industry as there is a huge market for the vegetable protein feed.
The prospects of multi-purpose utilization for ramie

- The use of bio-ethanol needs to be further studied as the conversion rate is still low and the costs are relatively high.

- There are some other novel uses such as composites, medicines, etc., but they are still in the research stage.
A sketch map of the diverse uses of ramie

Reduce erosion

Fiber ramie plantation

Mechanical harvesting

Leaves

Shives

Fiber

Fabrics, Clothes

Mulch

Bio-ethanol

Composites

Grazing

Substrate for mushroom

Silage

Tender shoots

Mechanical harvesting

Forage ramie plantation
Thanks for your attention.