INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN
(INBAR)

TRANSFER OF TECHNOLOGY MODEL
(TOTEM)

HIGH-YIELDING BAMBOO PLANTATIONS FOR PAPER AND PULP PRODUCTION

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TRANSFER OF TECHNOLOGY MODELS (TOTEMS)

Transfer of Technology Models (TOTEMs) are focussed educational tools providing relevant information and distance training on one specific area of bamboo/rattan management, processing or utilization. They are a means of technology transfer between similar regions throughout the world, with the emphasis on South-South transfer for livelihood development. They enable those involved in the management and use of bamboo and rattan resources to more efficiently and effectively develop and use skills relating to these resources.

TOTEMs are primarily intended as practical information resources and teaching aids for those at the local extension level in their communities, who can utilize them to assist local community development. Each TOTEM consists of a detailed written report of the technology, a PowerPoint presentation, a film, and, where relevant, a set of technical photographs. They also include information on target users, financial analyses of sample set-ups from the partner country preparing the report and information on where to source particular technologies (such as equipment). The TOTEM thus provides all the information required for establishing similar technologies within interested countries and regions.

- The **report** contains all the technical details of the particular processes involved, as well as other relevant information for establishing the technology such as costs of business establishment, running costs and cash flows.

- The **PowerPoint** presentation contains details of the relevant technologies and their applications, and is intended to provide an overview of the potential of the technology for development.

- The **film** provides a visual guide to the processes involved and helps to bring them alive in the minds of the learners.

The different parts of the TOTEM are targetted at slightly different audiences, via the local extension workers. The report and film are intended to be the main means of extension to the individuals and communities who will implement the technology and who will directly benefit from it. The PowerPoint presentation is primarily intended as a tool for the extension worker to sell the technology and its role in development to those who provide the infrastructural, policy and financial support for its implementation, such as government departments, donors and NGOs. There is considerable flexibility, however. Local extension workers will be able to incorporate the TOTEMs in their own work as they wish and adapt and develop the TOTEM to suit their particular requirements and conditions.

This TOTEM on **high yielding bamboo plantations for paper and pulp manufacturing** has been produced by the Research Institute for Subtropical Forestry (RISF) of the Chinese Academy of Forestry. It can be used in conjunction with the TOTEMs on Bamboo Papermaking, Homestead Bamboo Plantations, Medium and Large scale Bamboo Plantations and Community bamboo Nurseries. The report part of this TOTEM describes the technology for establishing and managing bamboo plantations focussing on the consistently high yields required for producing paper and pulp, for rural development in regions where bamboo is available as a raw material. It is intended to be used in conjunction with the illustrative film included in this TOTEM package.

The first part of the report introduces the technology, discusses its history, its development attributes, its benefits and it's applicability. The second part of the report provides information on the technical and management aspects of establishing and managing a high yielding plantation.

This TOTEM is one of the first to be produced by INBAR/RISF and your feedback is most welcome - kindly contact INBAR or RISF with your comments or suggestions.

Note 1: This TOTEM has been edited at INBAR and may differ slightly from the form in which it was received from the authors.

Note 2: All financial calculations are in Chinese Renminbi Yuan (RMB). At the time of writing 1 USD = 8.25 RMB.

HIGH-YIELDING BAMBOO PLANTATIONS FOR PAPER AND PULP PRODUCTION AT-A-GLANCE

Why High-Yielding Bamboo Plantations?

Bamboo culms provide excellent raw material for processing into different kinds of paper and pulp. The physical and chemical characteristics of bamboo fibers allow for them to be used for a much wider variety of papers than most other grass pulps (bagasse, straw, etc.).The total output of paper and cardboard in the world was 287 million tones in 1998, and is increasing continually to meet market demand. Over one million tons of paper were made from bamboo raw materials. In 1998, the demand for bamboo culms increased with the papermaking industry further developing and the establishment of new pulp making factories using bamboo. The potential market for the raw materials for pulp and paper is huge.

What is the role of a high-yielding bamboo plantation in rural development?

Bamboo production usually is small-scale and labour-intensive. The technology described here does not require special skills. The extension of improved techniques for sustainable management and use of bamboo resources can promote rural economic development, help farmers to shake off poverty and further improve the living conditions of poor rural communities. It can also increase land productivity. The pulp and paper industry needs to consume a large amount of bamboo materials that lead to more income in bamboo forest-based activities, which will promote cultivation and management of bamboo stands. The development of the bamboo sector will not only generate income for both men and women, but will also create more economic and employment opportunities for rural and suburban surplus labor in poverty-stricken regions, and benefit the growth of rural economies in bamboo growing regions/countries.

How do I establish a high-yielding bamboo plantation?

It is equally possible to transform an existing plantation or plant a new one. All that is required is some land, a small amount of capital to purchase tools and propagules and fertilisers, and some plant cultivation skills.

PART ONE

INTRODUCTION

DEVELOPMENT ATTRIBUTES, TARGET GROUPS and BENEFITS of a

HIGH-YIELDING BAMBOO PLANTATION

1. High-yielding bamboo plantations

Bamboo culms provide excellent raw material for processing different kinds of paper and pulp. The physical and chemical characteristics of bamboo fibers allow for them to be used for a much wider variety of papers than most other grass pulps (bagasse, straw, etc.). The "Improved Cultivation Technique for High-yielding Bamboo Stands for Industrial Pulp and Paper Production" aims to meet the increasing demands of raw materials for industrial pulp and paper production.

The total output of paper and cardboard in the world was 287 million tones in 1998, and is increasing continually to meet market demand. Over one million tons of paper were made from bamboo raw materials. In 1998, the demand for bamboo culms increased with the papermaking industry further developing and the establishment of new pulp making factories using bamboo. The potential market for the raw materials for pulp and paper is huge.

2. General development attributes and advantages

The main development attributes of the technology are as follows:

- Income generation for poor rural people.
- Improves and broadens farmers plant cultivation skills base, making them more able to handle shocks and empowering them with new abilities.
- Increasing the area of managed bamboo resources.
- Brings degraded land back into productivity and reduces erosion.
- Promotes the sustainable increased use of bamboo as a wood substitute.

3. Suitable agro-ecological regions

There are rich bamboo resources in the world, especially in subtropical and tropical regions in developing countries, and there are rich experiences and knowledge on technology of management of bamboo stands for pulp and paper production in China. Many poor people in developing countries live in bamboo growing areas, often in remote mountainous areas with poor infrastructure, lack of energy, technology and finance.

The technology described in this report can be extended in those regions and countries where bamboos can grow well and where there is easy access to markets for pulp and paper processing.

4. Target groups

Bamboo production usually is small-scale and labour-intensive. The technology described here does not require special skills. The extension of improved techniques for sustainable management and use of bamboo resources can promote rural economic development, help farmers to shake off poverty and further improve the living conditions of poor rural communities. It can also increase land productivity. The pulp and paper industry needs to consume a large amount of bamboo materials that lead to more income in bamboo forest-based activities, which will promote cultivation and management of bamboo stands. The development of the bamboo sector will not only generate income for both men and women, but will also create more economic and employment opportunities for rural and suburban surplus labor in poverty-stricken regions, and benefit the growth of rural economies in bamboo growing regions/countries.

5. Benefits

Bamboo production usually is small-scale and labour-intensive. The technology described here does not require special skills. The extension of improved techniques for sustainable management and use of bamboo resources can promote rural economic development, help farmers to shake off poverty and further improve the living conditions of poor rural communities. It can also increase land productivity. The pulp and paper industry needs to consume a large amount of bamboo materials that lead to more income in bamboo forest-based activities, which will promote cultivation and management of bamboo stands. The development of the bamboo sector will not only generate income for both men and women, but will also create more economic and employment opportunities for rural and suburban surplus labor in poverty-stricken regions, and benefit the growth of rural economies in bamboo growing regions/countries.

6. Scope for small enterprise development

A bamboo plantation can be run as an individual enterprise or a community enterprise. In either case, The cost of bamboo stand management for paper and pulp production can be recovered reapidly because bamboo grows fast and productive stands are established in 3-4 years. If you want to manage a bamboo stand for paper and pulp, you can improve natural bamboo stands or plant bamboo, and cultivate it using this technology. The required inputs for bamboo plantations include seedlings, land cost, labor, management and fertilizers and the total investment is about 8500 RMB/ha for a new sympodial bamboo plantation.

7. Requirement for success

The technology requires the availability of adequate land resources for the purpose of planting bamboos or large bamboo areas with poor management. Access to water is needed to mitigate droughts. Infrastructure is required to bring bamboo culms and shoots to the market. Technical assistance may be necessary in pest control and to organize seminars and training courses related to the technology for high-yielding bamboo stands for industrial pulp and paper production. Financial and policy support may be needed to stimulate farmers to manage bamboo stands for pulp and paper production, such as preferential taxes.

8. Technology Assessment

Bamboo is fast growing, highly productive and very versatile if managed properly. It has not only great economic importance in rural communities but also brings ecological benefits. It has been highly prized for a long time for its multi-use culms, edible shoots as well as special cultural value. There are about 20 million ha bamboo area, widely distributed in developing countries in Asia, Africa and South America. The usefulness of bamboo in the daily lives of people in China, especially in the rural areas, has been well documented in the literature.

Bamboo culms provide excellent raw material for processing of different kinds of paper and pulp. By far the largest industrial use of bamboo is in the pulp and paper industry. Bamboo has a higher cellulose (40~60%) and lower hemicellulose content than wood. Because of the long fibers (2~3mm), the strength of bamboo paper pulps allows them to be used for a much wider variety of papers than most other grass pulps (bagasse, straw, etc.). Tear strength is the same as that of soft wood pulp, making it possible to produce packaging papers, and because of the slenderness of the fibers, high-quality printing papers can be made. Bamboo pulping has been well accepted by the industry, especially in Asia (including producing dissolving pulp in India) and the full potential should be explored in countries where the resource is presently underutilized (e.g. Indonesia and Malaysia).

The key points of this technology are as follows:

a. Selection of superior bamboo species for pulp- and paper-use stands;
b. Maintaining a appropriate structure of bamboo stands, including density, age structure, evenness of culm distribution and average diameter at breast height (DBH) etc., which influence bamboo growth;
c. Sustainable harvesting techniques;
d. Fertilization techniques, including fertilising regieme;
e. Management of bamboo stands including inter-cropping, soil-loosening and clearing stumps;

Socio-economic and bio-physical setting

The technology has been utilized in Changning County, Sichuan Province, China in the low hill areas. The altitude is 300m asl, the average temperature is 18.3°C, and the average precipitation is 1,179mm. The technique was applied in *B. rigida* bamboo stands. Therewere three trial plots with different soil conditions (aluvial, barren, and shallow, respectively). Various improvements regarding fertilization and cultivation were introduced. The results show that the output increased on all three plots after the technique had been applied. The average annual output was 43,670 kg/ha, an increase of 28,170 kg/ha. The highest output reached was 53,650 kg/ha. The highest annual output value reached 21,460 RMB, and it increased by 11,268 RMB per ha per year. During 1992-1995, this technique has been applied on altogether 1,140 ha. The total output value increased by 5,387 thousand RMB. The technique increased farm incomes obviously. For example, one farmer got more than ten thousand RMB from about one ha of *B. rigida* in 1996 as a result of using the improved method.

The technique has also been applied in Shanqian village, Yihuang County, Jiangxi Province, about 70 km from the Fuzhou papermaking factory. The average temperature ranges from 16-18°C and the average precipitation is 1,748mm per year. There are 1,334 ha of Moso bamboo stands (*Phyllostachys pubescens*) which belong to the village. Before the trial began, the culm density ranged from 3,000 to 3,750 culms/ha, and the average DBH of culms was 9.2cm, the annual output was about 100,000 culms and the annual income was about 1,500 RMB per capita in this village. There were many old and small bamboo culms left in the stand because the strong culms had been cut by the farmers. Three years after the introduction of the improved technology on a trial basis, 900,000 culms have been harvested, which is an increase of 600,000 culms. As a result of the demonstration, the technique has been adopted on 10,000 ha of Moso bamboo stands. The total output value increased by 20,790 RMB.

The technology aims at achieving high-yielding bamboo stands, and thus it can easily be applied on favourable sites with good soil and water conditions. On the other hand, the site must be located close, i.e., within 150 km, to a pulp and paper making factory because of the transport cost. Plantation establishment costs about 8,000-12,000 RMB per ha. This includes the cost for preparing the land, transplants, fertilization, etc. After three years, the farmer can get a return from the planted bamboo stand, and the payback period is five years. To improve an existing stand, the investment is about 1,000-1,500 RMB, and the payback period is 2-3 years.

The role of support services

The technology, developed under a key project of science and technology by the Research Institute of Subtropical Forestry (RISF) of the Chinese Academy of Forestry (CAF), aims to supply sufficient raw materials for many pulp and paper making factories which have been newly founded to promote the paper making industry. It requires a technical and information services network to provide technical assistance in production, to organize seminars and training courses related to the technology for high-yielding bamboo stands for industrial pulp and paper production, and to support technology

extension by the local governments, using media such as newspaper and radio. Extension officers should help to solve problems farmers face with regard to loans and transportation.

There appears to be little need for policy measures such as subsidies, intended to directly encourage bamboo cultivation. The evidence that farmers adopt bamboo growing because of its low capital costs and good benefits in the short term suggests the need to reexamine the rationale and effectiveness of the widespread practice of subsidizing the cost of bamboo seedling supplies and fertilizers. When big pulp and papermaking enterprises dictate the price of culms, interventions to support market prices for the bamboo products may become necessary, e.g., a minimum price should be guaranteed. To ensure producers' access to market may be more effective than subsidies.

Analysis of potential transferability issues/constraints

There are two factors that can have an effect on the adoption of this technology. Firstly, the price of bamboo culms can obviously affect its competitiveness. If the price rises, paper and pulp factories may look for other raw materials instead of bamboo culms. Secondly, the cutting has to be controlled strictly in the first 2-3 years when there are not enough bamboo culms in the stand, because developing an appropriate bamboo stand structure is very important and overharvesting will impinge on that. During this time, there will be little or no income from the plantation.

Livelihood impact

Bamboo, one of the most versatile groups of plants known to mankind, is a common feature of the landscape in many hilly areas up to middle mountain level. This multipurpose non-timber forest product (NTFP) has a wide variety of uses and occupies a special place in the lives of the rural people in many developing countries. The technology has a relatively high labour demand as bamboo stands are managed intensively. Technicians and farmers, both men and women, the elderly and the poorly educated can easily master and apply this technology.

It is obvious that this technology has economic and social benefits such as (i) saving timber and reducing production cost, (ii) increasing farmers' incomes, and (iii) creating revenues for local governments. The bamboo sector can play an important role in poverty alleviation, restructuring rural industry, generating employment, and reducing migration to the cities.

To give an example, the technique of fertilization has been applied in a *B. chungii* bamboo stand for paper and pulp, where no fertilizers had been applied before at Gaofeng Forest Center and Mushuang station of Cangwu County. The annual output increased by 6,800kg/ha and the annual output value has increased by 1,972 RMB/ha in 1992-1995. The results convinced farmers to use the technology. The area of bamboo stands receiving fertilizer reached about 300 ha. The fertilization technology combined with soil loosening has been applied also in a Moso bamboo stand in Erdou village, Shaowu City, Fujian Province, where there was previously no management technology used. Because

of the support by the local government, most farmers in the village received a loan of 500,000 RMB to manage 466 ha of Moso bamboo stands by using this technology in 1993. In the second year, the income reached 1.02 million RMB, and the loan could be paid off.

Extension of the technology can promote rural economic development. It can also increase land productivity per unit and sufficiently utilize land resource including wasteland. The bamboo plantation can be established on degraded land, which can improve physical and chemical soil characteristics, prevent soil and water losses, and protect riverbanks. This can also reduce the pressure on land due to high population densities.

Concluding remarks

The bamboo sector is not easily affected by climate and environment. A good plantation can be established with the help of local unskilled manpower who can be taught the necessary skills. Developing the use of bamboo for paper and pulp by ensuring it is available in the quantity and quality required will bring environmental and employment benefits and contribute to the development of sustainable livelihoods for rural peoples in bamboo growing areas.

PART TWO

THE HIGH YIELDING BAMBOO PLANTATION

1. Introduction

This chapter provides a detailed description of the technology including bamboo species selection, cultural measures, culm harvesting and a financial analysis.

2. Establishment and management of high-yielding bamboo plantations for paper and pulp production

2.1 Selection of superior bamboo species for pulp and paper

Bamboos can be divided into monopodial, sympodial and amphipodial bamboo. Monopodial bamboo is mainly distributed in subtropical areas and sympodial bamboo mainly in subtropical to tropical areas. In general, sympodial bamboo has a lower cold resistance than monpodial bamboowith the exception of a few species, such as *B. multiplex* with low yield.

Bamboo culms usually contain about 40-60% fibers with a fiber length of more than 2 mm. This is suitable material for pulp- and papermaking.

There are over 1300 bamboo species in the world; 500 can be found in China alone. There are differences between bamboo species as to their suitability for pulp- and papermaking. A bamboo species' suitability for pulp and papermaking is determined by the fiber characteristics and the chemical characteristics of the culm (e.g., the content of cellulose, lignin, ash etc.), the cost, and the yield of bamboo culms. In addition, alternative end-use should be considered when selecting bamboo species in case of lack of demand for raw materials for pulp and paper in the market. Thirty-three species of bamboo from China are considered suitable for paper and pulp making material (Table 1).

The yields of different bamboo species are different even when they are grown in the same soil and managed in the same way. In general, the yield of medium-height and tall bamboo species is higher than that of small species. Moreover, although both *Bambusa rigida* and *Neosinocalamus affinis* are medium-height bamboo species and even look similar, the specific weight of the *Neosinocalamus affinis* culm is only half of that of *Bambusa rigida*.

Table 1. Suitable bamboo species for pulp and paper making

Name	Distribution
Bambusa rigida Keng et Keng f.	Middle subtropics* and south subtropics**
B. textilis McClure	Middle subtropics and south subtropics
B. chungii McClure	Middle subtropics and south subtropics
B.gibba McClure	Middle subtropics and south subtropics
B. distegia (Keng et Keng f.) Chia et H.L. Fung	Middle subtropics and south subtropics
Dendrocalamopsis oldhami (Munro) Keng f.	Middle subtropics and south subtropics
B.pervariabilis McClure	Middle subtropics and south subtropics
Neosinocalamus affinis	Middle subtropics and south subtropics
Dendrocalamus giganteus Munro	South subtropics and tropics
D.stricus (Roxb.) Nees	South subtropics and tropics
D.yunnanicus Hsueh et D.Z.Li	South subtropics and tropics
D.minor (McClure) Chia et H.L. Fung	South subtropics and tropics
D.hamiltonii Ness et Arn Ex Munro	South subtropics and tropics
D.membranaceus Munro	South subtropics and tropics
D. latiflorus Munro	South subtropics and tropics
D.sinicus Chia et J.L. Sun	South subtropics and tropics
Gigantochloa levis (Blanco) Merr.	South subtropics and tropics
Cephalostachyum pergracile Munro	South subtropics and tropics
Thyrsostachyum siamensis (Kurz ex Munro) Gamble	South subtropics and tropics
Melocanna baccifera (Roxb.) Kurz	South subtropics and tropics
Schizostachyum funghomii McClure	South subtropics and tropics
Bambusa sinospinosa McClure	South subtropics and tropics
B.lapidea McClure	South subtropics and tropics
B.arundinacea (Retz.)Willd	South subtropics and tropics
B.tulda Roxb.	South subtropics and tropics
Dendrocalamus farinosus (Keng et Keng f.) Chia et H.L. Fung	South subtropics
Dendrocalamopsis Daii Keng f.	South subtropics
Phyllostachys glauca McClure	South subtropics
Ph. heterocycla var. *pubescens* (Mazel) Ohwi	South subtropics
Ph. nigra var. *henonis* (Bean) Stapf ex Rendle	South subtropics
Pleioblastus maculates (McCl.)Chu et Chao	South subtropics
Phyllostachys aureosulcata McClure	South subtropics

According to the China Weather Bureau climate standard (1966), middle subtropics and south subtropics have the following characteristics:

** Middle subtropics: 240-300 days at cumulative temperature: from 5000°-5300° to 6000°-6500°, average temperature in coldest month: 4°-10°, coldest temperature extremes yearly: -10° to –5°.*

***South subtropics: 300-365 days at cumulative temperature: 6500°-8000°, average temperature in coldest month: 10°-15°, coldest temperature extremes yearly: -5° to 2°. Or 300-350 days at cumulative temperature: 6000°-7500°, average temperature in coldest month: 10°-15°, coldest temperature extremes yearly: -2° to 2°.*

2.2 Cultivating existing bamboo stands for pulp and paper

2.2.1 Adjusting the structure of bamboo stands

The density is very important for bamboo stand cultivation for pulp and paper. If the density of the standing culms is too high and the rhizomes and roots are too dense, air circulation and light are low in the stand, which will influence growth. On the other side, fewer bamboo culms mean less bamboo shoots. According to the results of our trial, the optimum density is different for different species of bamboo. There are 750-900 clumps

of bamboo per ha in the sympodial stand with 6 cm DBH, and 15 standing culms in every clump; 450-600 clumps per ha in the stand of medium-tall sympodial bamboo, and above 15 culms in every clump. On the other hand, the ratio of the standing culms of different age must be considered when determining the density of the bamboo stand. The rate of 1, 2, and 3-year-old culms is equal in high-yielding bamboo stands for pulp and paper. But the rate of 1-2 year-old and 3-4 year-old bamboo culms is about equal in Moso bamboo stands. If the amount of bamboo culms is too low, their number should be increased by keeping shoots for culm production or by cutting selectively. In general, a rational density and rate of different culms is the basis of high-yielding bamboo stands for pulp and paper.

2.2.2 Rational culm harvesting

Culm harvesting is an important means to regulate bamboo stand structure and to obtain material for pulp- and papermaking. Timing and method of cutting can affect bamboo stand managing although the harvesting throughout the year will cater to paper and pulp making factories' continuous demand. The output of bamboo stands can decrease if the structure is upset due to unreasonable harvesting. There are two optimal harvesting seasons: in winter and the season after the new culms have grown. There are several important aspects. Firstly, the culm should not be cut when the shoots appear. Secondly, the age of the culm to be cut should be four years or older. The number of culms cut should be less than the number of new culms produced that year. During the growing season the cut ends sometimes exude sap and this, and associated pests and diseases, can be can be controlled by buning the cut ends of the stumps with a blowtorch.

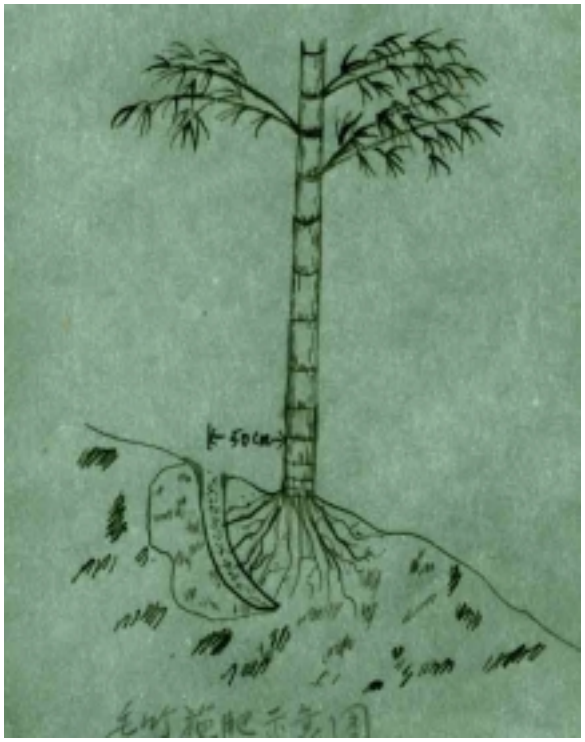

Figure 1: Fertilizing in Moso stand

2.2.3 Fertilization of bamboo stands for pulp and paper

Fertilization is important in high-yielding bamboo stands for pulp and paper because of the short harvesting cycle and high yield. Organic, chemical and compound fertilizers can be applied. Organic fertilizers and chemical fertilizers can be applied concurrently. Fertilizers are applied 1-2 times a year. The fertilization method differs between sympodial and monopodial bamboo stands. In sympodial bamboo stands, organic fertilizer is usually applied in winter and autumn although it can be used all year round and the chemical fertilizer is usually applied from April to June. The following steps

are required: dig a channel about 10-15cm deep and at 20-30cm distance from the clump, distribute the fertiliser in the channel and then cover it with soil. Amounts required: 750-1,500kg/ha of rapeseed cake fertilizer, (or 1-2kg per clump), 30,000-45,000kg/ha of other organic fertilizers (or 35-50kg per clump), and 350-450kg/ha of chemical fertilizers (urea) (or 0.5-1kg per clump). In monopodial bamboo stands, organic fertilizer can be applied with deep scarification. At first, about 30,000-45,000kg organic fertilizers are distributed per ha and then covered with soil when the soil is scarified. Chemical fertilizers should be applied in channels, which are dug in parallel approximately 2-3m apart and 10cm deep (see Figure 1 and Figure 2). The amount of chemical fertilizer ranges from 300 to 450kg per ha. On the other hand, chemical fertilizers can also be applied in channels dug next to each culm. These channel are about 50cm from the culm and are 10cm deep. Two hundred grammes of fertiliser is applied per culm.

Figure 2: Fertilizing in sympodial bamboo stand

2.2.4 Cultivating and managing techniques of bamboo stand for pulp and paper

The old stumps of bamboo should be cleared timely and soil should be added along the clump in sympodial bamboo stands. In monopodial bamboo stands, the soil should be tilled deeply once in four years and the depth is about 30cm, the old stumps of bamboo and trees should be cleared. If the slope is over 25°, the soil should not be tilled everywhere. On the other side, the soil should be tilled and the grass should be cleared once a year in July or August.

2.3 Establishing a new bamboo plantation

2.3.1 Land preparation

Selection of land and bamboo species: It is very important to select suitable bamboo species to match local site conditions. In general, bamboos prefer sites with warm, moist climate and over 1200 mm of annual precipitation. They require fertile, moist, well-drained, neutral sandy loams (suitable pH 5.8~7.0)

Soil preparation: If the site is covered by dense grasses and shrubs, clearing them will be necessary before soil preparation which should involve completely loosening the soil to a depth of 25~30cm.

Plot preparation: Dig planting holes at fixed intervals (usually 4 - 5 metres apart for large bamboos, or 3m apart for smaller bamboos) 60cm×60cm×40cm in length, width and depth respectively for medium or large bamboos species, and 50cm×50cm×30cm for smaller species.

2.3.2 Planting practices

Planting season: Bamboos are usually planted in winter during dormancy or in April, just before the start of the growing season.

Selecting transplants: Selection of transplants has a direct influence on the plantation quality. We should select 1- to 2-year-old, medium-sized, low branching, healthy, strong offsets for planting. After transplants are dug out, they should be planted as soon as possible. If planting nearby, packaging is unnecessary, but the rhizome buds must not be damaged during transportation. For long distance transportation, the stump should be covered with straw or straw bags so it stays moist on the way.

Planting: For monopodial bamboos, the planting depth is 3-5cm deeper than the depth the offset was dug out from. For sympodial bamboos, the transplant can be planted vertically or at a 45° angle, planting at the same depth it used to grow at. Planting too deeply or too shallowly is unfavorable for its growth. Then fill the hole with soil in layers around the root to keep the root in tight contact with the soil and water it. When planting large-sized bamboos, support is needed to prevent the transplants from falling over.

2.3.3 Tending new plantations

Watering and drainage: The first three to six months after planting are a critical period for transplants to survive and watering is very necessary especially during dry periods. After heavy rainfall, proper drainage might be required.

Shoot and culm protection: Grazing must be prohibited in newly established plantations. During the first three years after planting, the shoots should be retained and well-distributed so as to enhance autotrophic ability of bamboo stands and to close the canopy early.

Weeding and soil loosening: Weeding and soil-loosening (scarification) should be done in summer and once again in winter each year.

Fertilizing: About 150 kg N per hectare as effective component of chemical fertilizer is applied in May or June for sympodial bamboos and in July or August for monopodial bamboos during the first 1-2 years after planting. 350 kg N in chemical fertilizer per hectare are needed in the third year, plus 15-30 tons of organic fertilizer, applied in winter.

Intercropping: Intercropping in newly established bamboo stands not only increases productivity and economic returns, but also increases soil fertility. Crops should not be planted too close to the bamboo plants, as this could negatively effect their growth. Deep rooted crops are not suitable.

2.4. Inputs

The inputs for bamboo plantation mainly are seedlings, land cost, labour, management and fertilizers. For example, the cost of planting *B. rigida* is about 2,400-3,000 RMB per ha. The price of transplants is about 4-6 RMB per culm, and the total cost is 2,700-4,000 Yuan as 675-900 culms are usually planted per ha. The cost of fertilizers and labour is about 1,200-1,500 RMB per ha and the managing cost is about 1,000 RMB per ha every two years. In general, the total cost of establishing a bamboo plantation is about 7,300-9,500 RMB per ha. Harvesting can begin in the third year after planting, and output in the 5th year can reach 30,000kg of culms and 900kg of bamboo shoots per ha. Assuming a price of 240 Yuan per 1,000kg of culms and 1,000 RMB per 1,000kg of shoots, the output value is 8,100 RMB per ha. This is similar to other sympodial bamboo species. But this technology is not usually adopted for new Moso bamboo stands since it takes 10 years to reach maximum productivity. However, natural bamboo stands or existing low-yield Moso bamboo stands can be developed into high-yielding stands.

Potential Sources of Problems and Needs for Adaptations

The fluctuation of market prices of bamboo culms for pulp and paper production will greatly impact the benefits farmers can derive from bamboo stands. A steady demand for culms is necessary to maintain production. In addition, it is not suitable for bamboo culms to be transported to distant markets due to the high costs of transportation. Moreover, there is little or no income from bamboo in the first two or three years after transforming management for high yields due to the need to restrict culm harvesting adjust the age structure of standing culms to that required for high-yielding stands.

3. Financial evaluation

Tables 2 and 3 show the financial analysis for *B. rigida* and Moso bamboo model stands respectively. High returns from both *B. rigida* and Moso bamboo stands are possible through improved management.

Assumptions in Table: 2. Price of culms is 240 RMB per 1000kg. 2. Fertilizers are applied once a year. 3. Stumps were cleared and soil was added every three years, which needs 15 work-days per ha and the labour cost is 20 RMB/work-day.

Based on the standard of site condition for bamboo stands in China:

Table 2. Financial analysis of *B. rigida* model stand for pulp and paper in Changning, Sichuan province

Site condition class	Output per year before the trial (1000kg/ha)	Average output during 1993-1995 (1000kg/ha)	Output increase (1000kg/ha)	Increase in output (RMB/ha)	Investment			Net increase in output value	Ratio of input to output
					Fertilizer	Tillage	Total cost		
*	15.5	43.67	28.17	6760.8	750	100	850	5910.8	1:7.95
**	15.89	24.81	8.92	2140.8	750	100	850	1290.8	1:2.52
***	7.80	15.59	7.79	1869.6	750	100	850	1019.6	1:2.20

** Site class I: Located down of hillside, with > 50 cm of soil thickness (A + B layer) and well fertility.*
*** Site class II: Located middle of hillside, with 30~50 cm of soil thickness (A + B layer) and middling fertility*
**** Site class III: Located middle-up of hillside, with < 30 cm of soil thickness (A + B layer) and poor fertility*

Table 3. Financial analysis of Moso bamboo model stand for pulp and paper in Anji, Zhejiang province.

		Intensive Management	**Less Intensive Management**
Bamboo culms	Output (1000kg/ha)	32.31	25.74
	Output value (RMB/ha)	12,924	10,296
Bamboo shoots	Output (1000kg/ha)	2.07	1.05
	Output value (RMB/ha)	3,726	1,890
Income from culms and shoots (RMB/ha)		16,650	12,186
Investment per ha (RMB)	a. Shrub and grass clearing	300	300
	b. Scarification	1,500	1,500
	c. Fertilizer and labour	3,030	555
	Total a - c	4,830	2,355
Net output value (RMB/ha)		11,820	9,831

Assumptions: Calculated based on: 1. Market prices are 400 RMB per ton of bamboo culm and 1,800 RMB/ton of shoots. 2. Labour needed: 15 work-days for shrub and grass clearing, 75 work-days for scarification per ha; labour cost s 20 RMB/work-day.

Table 4 shows the cash flow and net present value for a new *B. rigida* plantation. The total investment in the first year is 8,350 RMB/ha. Costs in the second year and third year amount to 1,150 RMB/ha each year, including labour, fertilizer and management costs. Bamboo culms and shoots can be harvested in the fourth year. In the fifth year and thereafter, the total annual output can reach 30 tones of culms and 0.9 ton of bamboo shoots. The labour costs of cutting culms and collecting shoots plus fertilizers and others are 1,980 RMB/ha. The Net Present Values in different year are listed in Table 3. The Internal Rate of Return and the Breakeven Period are 29.7% and 5.98 years, respectively, based on an interest rate of 8%.

Table 4. Cash flow and net present value for a new *B. rigida* plantation (RMB/ha)

Year	Net cash flow value	Net present value	Accumulation of net present value
1	-8,350	-7731	-7,731
2	-1,150	-986	-8,717
3	-1,150	-913	-9,630
4	2,268	1,667	-7,963
5	6,120	4,165	-3,798
6	6,120	3,857	59
7	6,120	3,571	3,629
8	6,120	3,306	6,936
9	6,120	3,062	9,997
10	6,120	2,835	12,832
11	6,120	2,625	15,457
12	6,120	2,430	17,887
13	6,120	2,250	20,138
14	6,120	2,084	22,221
15	6,120	1,929	24,151

APPENDICES

Appendix 1

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