

Environmentally friendly and sustainable bamboo straw production – An example for organizations to produce products made of bamboo in Cambodia



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1. Introduction

The following advisory report was developed by Ann-Cathrin Joest, while she interned at the Cambodian Child's Dream Organization (CCDO) in Siem Reap, 2016 as part of her studies at the Windesheim Honours College in the Netherlands. CCDO desired the involvement of youth in an extracurricular activity in order to strengthen their practical skills. Currently a large amount of waste enters the environment which leads to environmental pollution and a threat to the human health. To diminish this issue, CCDO thought about the production of bamboo straws while using organic material throughout the entire production process.

This advisory report lists environmental needs that are important for the production of bamboo straws such as organic fertilizer, irrigation and barriers to avoid the spread of bamboo roots. The advisory report also lists two propagation methods that were advised by experts, literature and observations. Organizations are advised to experiment with different bamboo propagation techniques. However, the goal should be to get familiar with one propagation technique and then apply other propagation techniques.

While the advisory report focuses on the sustainable production of bamboo straws, it is possible to produce other bamboo products. However, for any products that are produced from bamboo it is crucial that bamboo is not exploited.

Lastly, all information in this advisory report are based on scientific literature, observations and international experts in bamboo propagation. The research and more information that led to this advisory report can be requested by the author.

2. Summary

To ensure the sustainable production of bamboo straws, bamboo can be propagated by using segments or offsets. A bamboo segment is a part of a bamboo culm that consists of one internode and two nodes. Bamboo offsets consists of a bamboo culm with roots attached. For successful propagation with either, the bamboo needs to be one year or older. The age of the bamboo can be identified based on its color; dark green bamboo serves as an indicator for bamboo that is one year old.

The bamboo segment can be multiplied through the method of proliferation. Proliferation consists of a process that divides the bamboo segment in the middle. This process separates two bamboo nodes in which rhizomes and roots develop into culms. Bamboo offsets can be divided with a sharp tool, while bamboo rhizomes should not be damaged. It is possible to develop culms suitable for the production of bamboo straws after three to four months with either propagation method.

While bamboo can be planted in any type of soil, it should be planted in nutrient soil as the bamboo is more likely to grow faster. It is also possible to apply natural fertilizer such as bat or cow dung or urin as it contributes to faster growth.

Bamboo should be watered every first or second day during the dry season. During the rainy season, bamboo does not need to be watered, but possible flooding should be controlled since this can lead to destruction of the bamboo. If needed land can be raised through extra soil.

Since bamboo roots can quickly spread, it is important to build bamboo barriers at least 60 cm in the ground. To control bamboo, it is helpful to produce bamboo in sections. The bamboo barriers should be built around these sections. These can consist of locally available bamboo. Further, fences should be built around the bamboo planting area if there is a risk of wild animals who could eat the growing bamboo.

Human resources in the bamboo straw production process can include youth, teachers, women other and management. However human resources have to be identified by organizations. Due to the author's focus on the social aspect of the bamboo production, organization may consider human resources that can benefit from skills learned during this production process the most.

Bamboo straws can be produced by cutting the bamboo culms in circular movements. Circular movements are important to prevent the bamboo from splitting. The drying process takes three to four days, which can be done before or after cutting it. Then the bamboo edges need to be sanded. Afterwards, the bamboo needs to be boiled in a vinegar and water solution and then dried again. Lastly, the inside of the bamboo can be cleaned with a stick.

Possible bamboo packaging and cards include palm tree leaf packages and banana fiber cards that are produced locally. The author of this advisory report initiated a local bamboo packaging competition

with youth. To involve other locals in packaging or other environmental friendly ideas, their participation is suggested. However, by using natural resources it is important that their exploitation does not take place.

Lastly, the advisory report contains a planning that is targeted to organizations that have not yet started with a production of bamboo products. This can be adjusted depending on the needs of the organization. The planning is divided into four phases. While a budget of 174 dollars was suggested for CCDO, this may vary due to different resource availability by different organizations.

3. Project Implementation Plan

The following project implementation plan lists processes related to the production of bamboo straws. These include environmental needs, sustainable bamboo propagation techniques, a bamboo straw production description and legal aspects. By following methods and opportunities related to these processes a circular bamboo straw production takes place.

3.1 Bamboo Structure

Before applying bamboo management techniques, it is advised that the organizations get familiar with the bamboo’s structure. Therefore, the following section contains a description of the bamboo’s structure.

Bamboo can be characterized by its jointed stem which is referred to as a culm.

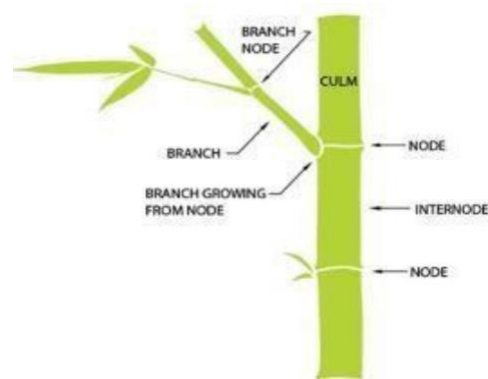
Mostly, culms are hollow, but there are also solid culms.

Every new segment of a culm is beginning and ending with a “solid joint called a node. (...) Nodes are characterized by a swelling encircling the ends of the culm segment, “(Bamboo Botanicals, 2016). Each of the segments inside the nodes are called internodes.

Branches only grow from the nodes. These branches are similar to the culm as they are “segmented with nodes and internodes, “(Bamboo Botanicals,

2016). Figure 1 represents the bamboo’s structure.

Figure 1: Bamboo Structure



Source: Bamboo Botanicals (2016)

Organizations that are looking for the production of bamboo straws are advised to look for hollow bamboo. The hollower, the better.

3.2 Bamboo Age

Bamboo should be older than one year if used to propagate. The age of the bamboo can be recognized by its color as demonstrated in figure 2 (inbar, n.d.). Bamboo that is one year old is dark green. However, the color of bamboo might still vary depending on the species (inbar, n.d.). Once bamboo is propagating it is advised to keep track

Figure 2: Bamboo age and related colors

Internode color			
Age category:	< 1 year	1 - 2 years	> 2 years
			
	Emerald or dark green.	Green.	Turning into yellow.

Source: inbar (n.d.)

of the growth time by marking the bamboo or by keeping records.

3.3 Environmental Needs

The following section describes environmental needs that are required for the sustainable production of bamboo. All processes are eco-friendly which allows the production of bamboo straws while minimizing waste and environmental damage. Environmental needs relate to soil, fertilizer, irrigation, and bamboo barriers. These needs regard differences between the rainy and dry season.

3.3.1 Soil

Bamboo is resilient and can grow in different types of soil. The more fertile the soil, the faster the bamboo's growth. Bamboo can be propagated in any type of soil. Soil that is used for gardening purposes is very useful. If bamboo is planted in fertile soil it will grow faster than in other soil such as clay sand. Clay sand is naturally available in Cambodia. Therefore, other organizations need to identify the type of soil that is locally available for bamboo propagation.

3.3.2 Fertilizer

While fertilizer provides nutrients that enable faster growth of bamboo, fertilizer is not essential for the bamboo's growth. Due to the intention to produce bamboo sustainably, it is assumed that there is a need to anticipate the rate of the bamboo's growth. Therefore, it is advised to utilize natural fertilizer for the propagation of bamboo. Fertilizer should also be applied if the leaves turn yellow. This symbolizes a lack of nutrients.

Natural and locally available fertilizer include cow dung, bat dung or urin. Fertilizer can be applied once or twice a week. It is important that not too much fertilizer is applied as this may lead to the bamboo's destruction. Local farmers can be contacted for more information.

3.3.3 Irrigation and land use

During the *dry season* bamboo can be watered once or twice a day. If it is watered less the growth might slow down. The bamboo should also be watered when it shows symptoms such as hanging bamboo leaves. It is important to keep the soil wet so that the plant can absorb enough water for growing. But if too much water is provided, more than the plant needs, the root will be rotten and the plant will die. Figure 3 shows an image of an overwatered bamboo sprout.

Bamboo does not need to be watered in the *rainy season*. However, it is important to prevent the overwatering of bamboo. This could happen due to flooding. In order to protect

the bamboo from overwatering it is advised to higher land with soil. Planting areas might also be selected in which the land is not at risk of flooding.

Figure 3: Overwatered plant



Source: Joest (2016)

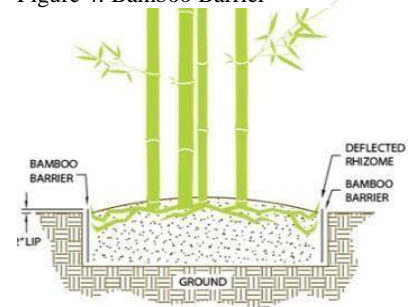
3.3.4 Bamboo barrier and fence

It is important to build a barrier around the area where the bamboo is propagated to avoid the spread of its roots to unwanted areas. If no barrier is put into place, the bamboo can destroy other plants that grow nearby. To avoid the spread of bamboo roots, it is advised to insert bamboo branches into the ground. Through this method, bamboo roots cannot spread as the barriers don't allow them to.

It is advised to stick branches 60 centimeters in the ground. Barriers will also aid in the prevention of soil erosion during the rainy season (Meyer, 1981) as shown in figure 4. There is a risk that wild animals can enter the bamboo propagation area.

Therefore, it is important to build a fence around the area where the bamboo is propagating. The fence can be built from locally grown bamboo. Organizations may identify locally available resources that can be used to build the bamboo barriers.

Figure 4: Bamboo Barrier



Source: Bamboo Botanicals (2016)

3.4 Bamboo Propagation

The following section contains a description about bamboo propagation by using culm segments and offsets. By following these bamboo propagation methods, the sustainable production of bamboo straws can take place. Although there are multiple propagation techniques (Ahlawat, Hardasan & Hedge, 2002), these methods were most commonly suggested by experts, literature and observations.

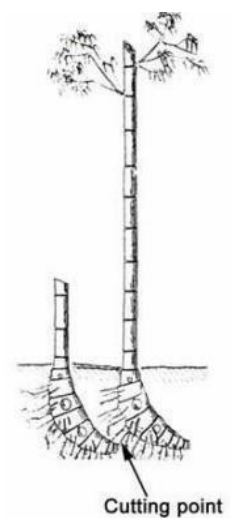
Organizations are advised to experiment with these bamboo propagation methods with the species that is selected for the production of bamboo straws.

3.4.1 Bamboo offset propagation

One of the most common propagation methods is offset propagation. This method includes the division of bamboo rhizomes (Kigomo, 2007). These should be separated while preventing the rhizomes from being injured as shown in figure 5. Kigomo (2007) stresses the immediate planting of the offsets. Once divided and planted, the rhizomes will develop shoots or further rhizomes that turn into culms (Bamboo Botanicals, 2016).

This method has a high success rate because the bamboo offset already developed a "complete plant system that is being transplanted," (Schröder, 2011). The further growth of the bamboo and the amount of culms that develop depends on the bamboo species.

Figure 5: Bamboo offsets



Source: Kigomo (2007)

3.4.2 Bamboo segment propagation

According to Nijugana and Kigomo (2008), a culm that is used for propagation should grow between 15 and 45 centimeters from the ground. From this culm, a segment should be selected that has at least

Figure 6: Bamboo segment with nodes

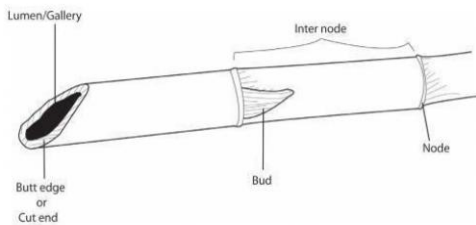


Figure 1: A bamboo cutting

Source: Kigomo (2007)

two nodes and two buds as shown in figure 6. Once a bamboo segment is selected, a sharp knife or saw can be used to cut the bamboo. When cutting the bamboo it is important that the segments do not split. Once the bamboo segment is selected, a sharp hole should be cut in the internode of the segment.

Afterwards, the bamboo should be filled with water. Once the bamboo is filled with water it needs to be sealed with wax, tape or other material. Then, the bamboo has to be covered in soil as shown in figure 7 (Nijugana & Kigomo, 2008 and Roadrunner, 2006).

When planting the segment it is important that the buds are located to the side and the holes are located upwards. If the buds are faced downwards, the emerging shoots might be choked which can lead to the segment's destruction. Once the bamboo is planted, sprouts will develop from the nodes which will then develop into culms (Bamboo Botanicals, 2016).

According to Banik (1995, p.35), "culm segment cuttings sprout within a week after planting and root between 45-90 days."

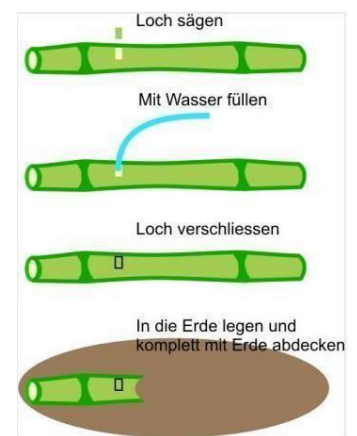
3.4.3 Proliferation

A bamboo segment should produce shoots on its nodes. Proliferation is used as a method that separates the bamboo segment (Nijugana & Kigomo, 2008). The segment should be divided in the center of the internode because this separates the growing sprouts and roots on either side as shown in figure 8 (Nijugana & Kigomo).

By dividing the internode as shown in figure 8, the new bamboo sprouts can be planted separately. They can be separated by using a tool such as a saw or a sharp knife. After the separation of the bamboo at its internode, the separated segments should be planted (Nijugana & Kigomo, 2008).

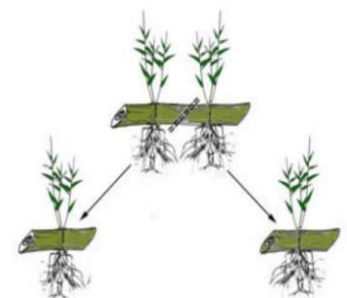
Bamboo is able to reproduce asexually, therefore no other techniques needs to be applied for the bamboo's propagation once it is divided (Banik, 1985).

Figure 7: Segment preparation



Source: Roadrunner (2006)

Figure 8: Internode separation

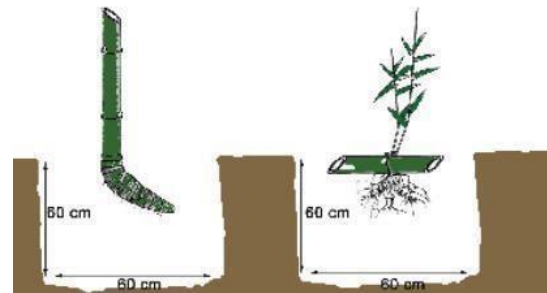


Source: Nijugana & Kigomo (2008)

3.4.4 Planting Requirements

Depending on the size of the bamboo, the bamboo stem cutting or rhizome offset can be planted between 10 and 40 centimeters deep in the ground as shown in figure 10. After the plant is put into the ground, it needs to be covered with soil (Kigomo, 2007). It is also possible to create pits of 60 cm x 60 cm. Generally, 60cm x 60 cm are more than sufficient. In the pit, compost or farmyard manure can be added (see figure 9).

Figure 9: Planting holes and requirements



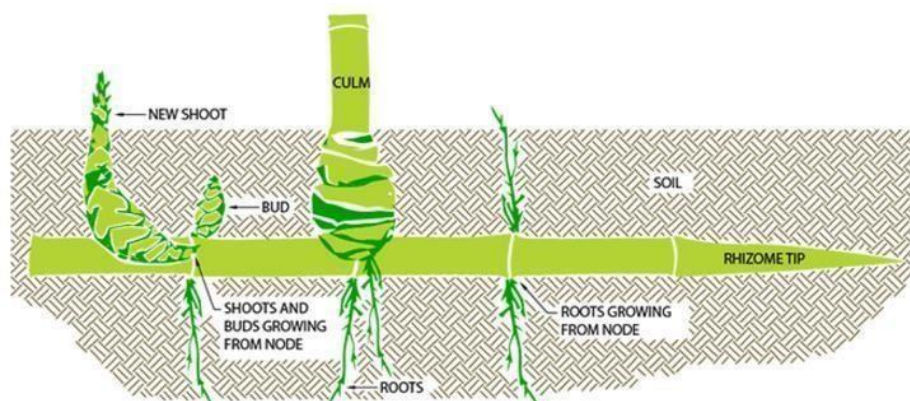
Source: Nijugana and Kigomo (2008)

Because there are different opinion about the planting requirements, organizations are advised to define best practices as suggested (Christmann, 2000). Once these are defined, planting requirements can be followed consecutively.

3.4.5 Development of bamboo culms

The growth habit of propagating bamboo varies between bamboo species. Bamboo can be running bamboo but also clumping bamboo. In both cases, the bamboo develops automatically culms from rhizomes that grow underground as shown in figure 11 (Bamboo Botanicals, 2016).

Figure 11: Running bamboo

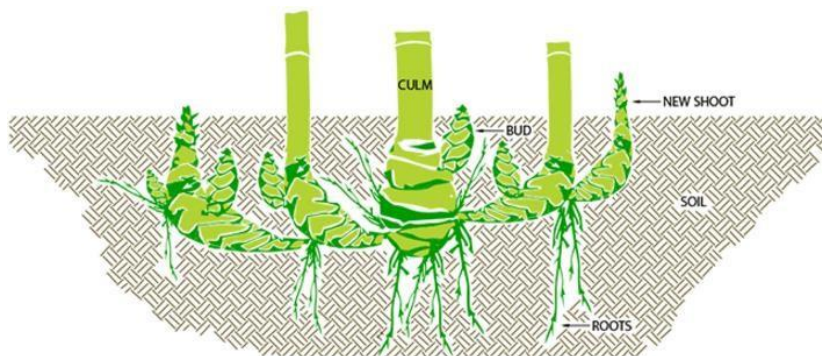


Source: Bamboo Botanicals (2016)

Running bamboo has rhizomes that run horizontally under the ground. New buds and roots emerge from the nodes of the rhizomes. Most buds remain dormant but may develop into a new culm or it may develop into another new rhizome. Any new rhizomes will also run horizontally underground and produce more new culms and rhizomes. This growth behaviour gives the bamboo a 'running' habit as shown in figure 10 (Bamboo Botanicals, 2016, Running Bamboo, para. 1). Running bamboo can be identified by its collection of independent single culms that spread over the entire area of the plot.

Clumping bamboo has rhizomes that grow upwards and that envelop into a new culm. New rhizomes emerge from buds on an existing rhizome and so forth as shown in figure 11. This accumulative effect causes a slow growth around the perimeter. This growth behavior gives the bamboo a 'clumping' habit. Its predictable growth behavior makes it easier to maintain without having to apply containment methods that a running bamboo may need (Bamboo Botanicals, 2016, para 3.). Clumping bamboo can be identified by its cluster of bamboo culms.

Figure 11: Clumping bamboo

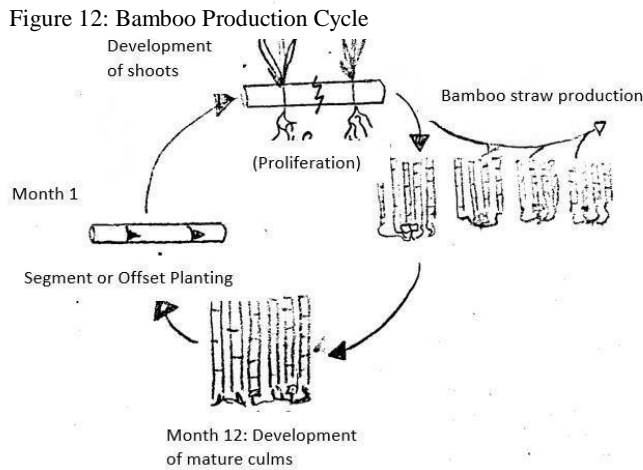


Source: Bamboo Botanicals (2016)

Due different needs related to the maintenance of bamboo as explained by Bamboo Botanicals (2016), organizations should identify if the bamboo species consists of running or clumping bamboo.

Independent from the bamboo species, bamboo has the ability to reproduce by itself (Bamboo Botanicals, 2016) through which the development of multiple culms is noted. These can either be used for the production of bamboo straws or further propagation. Though the amount of culms are difficult to identify as there are different species, the bamboo's ability to reproduce by itself may enable the cyclic production of bamboo straws. Hence, it is advised to take notes on the amount of developing culms during a one year period.

3.5. Sustainable production of bamboo



Source: Own data set

Bamboo propagation is successful when the bamboo is at least one year old. The model shown in figure 12 visualizes a yearly bamboo growth process which includes the propagation of a single bamboo segment. This model can be adapted to other propagation methods such as offset propagation. If bamboo propagation through offsets is used, the method of proliferation does not apply. Further, the multiplication and sustainable production of bamboo straws is explained through this model.

The propagation process of bamboo starts with the planting of a segment. Once it has produced shoots and roots it can be divided (proliferation) (Njugana & Kigomo, 2008). Once divided, the separated segments will develop to mature culms that can be propagated after one year (12 month) of growth. However, there is no definitive information on the amount of bamboo culms that are produced from a bamboo segment. This is because the amount of developing bamboo culms depends on the species and the environment.

Culms should be cut for the production of bamboo straws after three to four months of growth. However, the specific time to harvest the bamboo needs to be determined as the growth estimations were provided for a different species. It is important that not all culms are cut as some need to develop for one year before they are cut again for further propagation. The amount of culms to be cut depends on the desired amount of bamboo straws.

Since bamboo reproduces asexually (Bamboo Botanicals, 2016), it is assumed that the model can be adapted to any method which allows the cyclic production of bamboo straws.

3.6 Selection of bamboo species

Bamboo should be selected that is hollow. In addition to that, the internodes of the bamboo should not be small. It is important that at least one bamboo straw can be produced. There are species with a small internode length. This species is not suggested for the production of bamboo straws.

3.7 Bamboo Straw Production

Once organization identified a bamboo species, they need to define the age of the bamboo culm that is most suitable. While cutting the bamboo, it is important to not split it. Therefore, it is advised to use a sharp knife or saw. Different techniques and methods may be used to produce bamboo straws. One important step is that the bamboo straws need to be dried between three to four days as shown in figure 13.

This can be done before or after cutting it. As the bamboo needs to be cut into the desired size, two types of cutting

Figure 13: Dry bamboo cutting in light color and freshly cut bamboo in dark green color



Source: Joest (2016)

material and methods applied for this purpose. An electronic cutting machine can be used as demonstrated in Figure 14 and secondly, a hand saw can be used. Either way, it is crucial to ensure that the bamboo does not split during the cutting process. Therefore, it should be cut while rotating the bamboo.

As it is safer to use an electrical saw to cut the bamboo with instead of a handsaw an electrical saw should be purchased as shown in figure 14. Once the bamboo is cut into the size of a bamboo straw, it is important to sand down the edges. Therefore, it is possible to use a machine as shown in Figure 15 or sand paper.

Figure 14: Bamboo Cutting Machine



Source: Joest (2016)

Figure 15: Bamboo Sanding Machine



Source: Joest (2016)

Due to the simplicity of this machine, it is advised to also purchase it. In order to finalize the bamboo straw, it is important to clean the inside of it. Therefore, a smaller item such as a chopstick can be inserted. Lastly, the bamboo should be boiled in a vinegar and water solution; it should be washed with water afterwards.

3.8 Environmentally friendly bamboo packaging and cards

The following sections contain a description of environmentally friendly alternatives to plastic packaging and conventional paper cards.

3.8.1 Bamboo Straw Package

The study leading to the advisory report was developed based on the importance to minimize waste. Therefore, the usage of palm leaf packages is suggested. Examples of palm leaf packages that were produced by youth of a seventh grade during a school competition in a rural region of Siem Reap are shown in figure 16.¹

When utilizing material such as palm leaves it is important that the material is used in a way that no exploitation of palm trees takes place. Therefore, organizations are advised to look into growth patterns of palm trees and the usability of palm leaves for long term packaging.

3.8.2 Bamboo Cards

For the sale of the bamboo straws, it is important to develop cards that include a description of the supporting organization, the cause and how to reuse them. To follow the principles of an environmentally friendly production process, cards can be produced that are made from banana fiber². However, there are also other possibilities to make organic paper. Organizations that are not located in Siem Reap, are advised to search in the internet for instructions to make these cards or to purchase organic cards if available. Producing environmentally friendly banana cards can be done by a social enterprise if resources are available.

Figure 16: Palm Leaf Packages



Source: Joest (2016)

² This YouTube video explains a production process of organic paper: https://www.youtube.com/watch?v=I_4kZRUCw9g

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