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Using the recycled bamboo chips (*Bambusa blumeana*) to develop horticultural media boards

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Abstract

Thorny bamboo (*Bambusa blumeana*) is widely distributed in southwestern Taiwan and is currently rarely used. Bamboo remaining materials that are not profitable for industrial use or processing now, but they can upgrade and reuse for rising demand for foliage plant cultivation and horticultural planting were growing after COVID-19. It needs a gluing formula, and the chips, remaining materials of the bamboo are developed to be glued to make a gardening media board. It is not only solving the problems of available natural gardening materials in horticultural market, decreasing the excessive exploitation of conserved plants (*Cyathea lepifera*), wood board is prone to mold, epiphytic fungi, etc., it also follows the government's "reduce" and "recycle" net-zero carbon emission strategies and agricultural resource recycling goals and improves the resource efficiency and making it useful at all stages of the product life cycle. The gluing formula contained a small amount of synthetic resin, which effectively reduced the degradation rate of the board products and provided a simple carbon preservation solution. Besides, the synthetic resin used in the formula glue does not contain environmental hormones and is environmental friendly. At the end of the board product's life, it can be easily decomposed into small pieces and used as soil covering to increase soil carbon sequestration. If used as fuel, it will not emit harmful gases.

Keywords: Circular agriculture, carbon sequestration, bamboo chips

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1. Introduction

The horticultural media board product developed in this study using bamboo chips or waste and adding glue materials to press it. The horticultural media board can plant foliage plants and take advantage due to bamboo as a carbon-negative material recently. The board products made of bamboo recycling materials have weather resistance, and heavy usages of bamboo. It can also be regarded as a simple and effective way to utilize mass bamboo materials and accelerate carbon sequestration benefits via bamboo forest adequate management. This new developed process extended existing production equipment and technology from another industry, which not only assists the transformation of traditional industries, but also creates new opportunities for Taiwan's bamboo industry.

Recycling the Remaining Material of Bamboo

The main material is thorny bamboo (*Bambusa blumeana*) which is abundant in southwestern Taiwan. Thorny bamboo mainly grows in the hilly areas of southwestern Taiwan. It is a representative plant in the monsoon climate with drought and few rainfalls in winter. Especially there is limestone mountainous areas with poor water retention capacity and barren land, making it difficult for humans to use it for other purposes, however, thorny bamboo is the most dominant plant. In the past, thorny bamboo was an important source of material for housing, instruments. At present, thorny bamboo is mostly buy by fish man to make of frame for raising oyster in nearshore area. Since this bamboo culm needs straight shape, so it may cut and process to remove the bottom and tail, thus generating a lot of waste materials. However, this kind of waste is collected and transported by environmental protection companies or handled by processors themselves, final way is incinerated.

Because bamboo grows quickly and is low-cost. Taiwan Forestry Research Institute has studied the carbon sequestration capabilities of four main bamboo species in Taiwan: Moso bamboo, Makino bamboo, Ma bamboo, and Thorny bamboo, it had found that the carbon sequestration capability of bamboo was significantly better than ordinary forest trees (Lin, 2018). Thus bamboo is also known as a carbon-negative material. Bamboo material is a very advantage and current topics in the market. It is also an important substitute for wood pulp. Therefore, environmentally friendly bamboo fiber-related products on the market are often innovate. On the one hand, according to the TFRI studied by Agricultural Media, the carbon sequestration ability of bamboo will decrease when bamboo aging, so proper harvesting is necessary. "Bamboo is different from ordinary trees. It grows fast, strong reproduction, short growth period, and easy renewal methods. Its properties can be put to good management." On the other hand,

the processing plants that use Thorny bamboo will eventually produce a large amount of bamboo scraps and branches of the Thorny bamboo grove. Since the processing process is mainly cutting, the remaining materials will be generated, which is quite suitable for application in the target product of this study and has the cost advantage of resource reuse. It can be mixed with biomass materials in different proportions, and a glue adhesive can be used as a glue between biomass materials and bamboo chips. A self-made cultivation medium template can be used to press and mold the cultivation board (Xu, 2009).

In recent years, the planting of foliage plants has become popular, and ornamental plants such as ferns and vines are often planted on boards. This study selected planting boards as the main product to develop to solve the problems related to common wood-derived horticultural planting boards currently on the market. After cutting the bamboo waste into bamboo chips, we had developed a formula glue mixed with biomass materials and a small amount of melamine resin. The horticultural cultivation materials will be synthesized with high temperature and high pressure glue through a semi-automatic machine. We hope to solve the current problem through the development of this material. Problems with commonly used natural source planting boards on the market.

2. Materials and Methods

Taiwan's bamboo production is abundant, with a wide variety of species and unique antibacterial properties. This article took thorny bamboo that is abundant in southwestern Taiwan as an example. This bamboo is mostly used for oyster frame and agricultural branches, and is used in various products developed in this research. The product is used in the horticulture industry. In addition to helping to reduce costs, planting board type products can also contribute to solving the problem of excessive exploitation of Common Free Fern (Cyathea lepifera). Therefore, we were tried to develop technology for making bamboo into horticulture materials. The Material Selection and Suitable Gluing Formula was as follows:

2.1. Natural material selection and production process establishment

First, we selected bamboo culms which with porous fiber water-retaining properties, and with the same degree of maturity. After crushing and subdividing, the bamboo fragments are softened to facilitate pressure forming. Conduct molding tests through raw materials of different sizes, and determine the final feasible size based on the feasibility of product molding. The bamboo chip size (5mm) suitable for product use will be studied to facilitate good fluidity in the mold during subsequent pressure

molding, as well as good breathability and water retention properties of the finished product.

i. Bamboo fragmentation and subdivision (Figure 1): Cracked and decomposed the selected bamboo into small pieces to facilitate the softening of the bamboo.

ii. Moisture content condition control: adjust the bamboo processing volume and moisture content of each treatment, and control the moisture content of the bamboo chips to 15% before testing

iii. Media pressing and forming: Use a press to press the orchid cultivation media with a pressure of 175 kg/cm2 for 3 minutes to form an rectangular board with a size of 200mm×150mm×15mm (Figure 2, 3).

iv. Property measurement: Compare the properties of the completed samples with currently commercially bamboo products or Common Free Fern, including analysis of water retention capacity, ventilation porosity, overall density, etc.

v. Comparison of various types of gardening board and planting material products: Compare the self-pressed gardening board, commercially solid wood splicing board and Common Free Fern.

vi. Comparison of cultivation characteristics of bamboo gardening boards: Compare the manufacturing process parameters and properties of self-pressed bamboo gardening boards and green bamboo gardening boards developed by Taoyuan District Agricultural Research and Extension Station.

thorny bamboo cut into pieces

thorny bamboo coarse screening and cutting

Finely sieved and cut	Cut to orchid board specifications

Figure 1. Bamboo fragmentation and subdivision

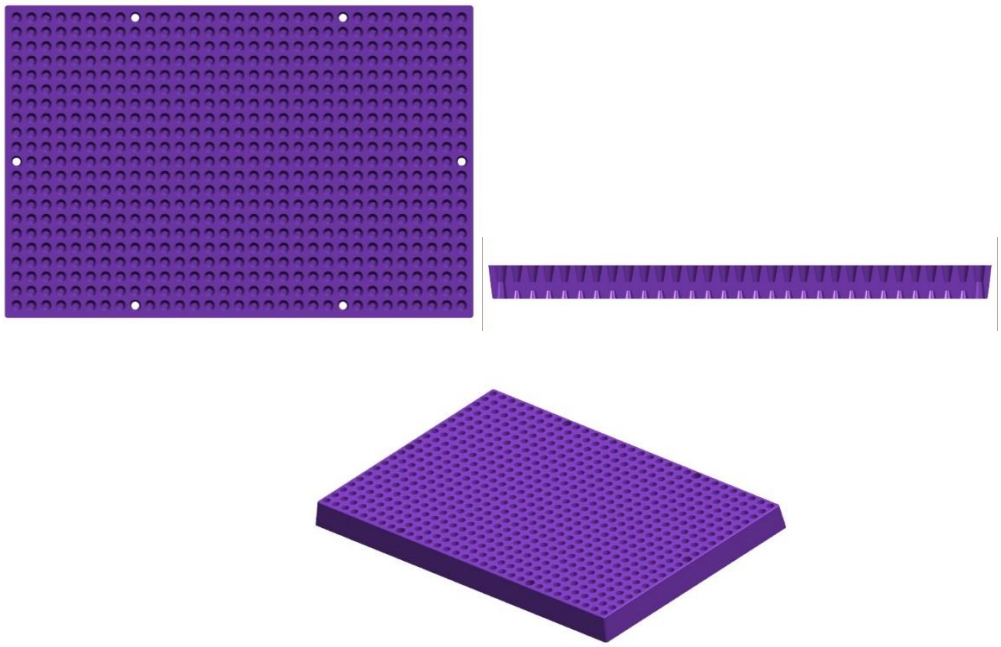

Figure 2. Template design drawing

Figure 3. Thorny bamboo gardening board mold

2.2. Gardening materials product molding process design

The board was designed with concave and convex points to consider heat conduction and product aesthetic issues during molding. This design can also retain water through the surface tension of water flowing, which was helpful for plant growth and climbing. The regular alignment of these concave and convex points also contributes to the aesthetic effect of the board when in use (in the leaf viewing club, plant friends often discuss whether the moss ball is round or not, whether the fishing line winding technique is neat, or even aligned and symmetrical aesthetics), while considering the convenience for users of all ages. The holes can be penetrated with simple hand tools without the need for power tools. The penetrated holes are convenient for hanging single products or splicing them to expand the planting contact area and combined into unique shapes.

2.3. Thorny bamboo gardening board material formulation process

Adjust the ratio of raw material processing volume and glue dosage, explore using melamine resin as the base, or adding suitable biomass materials (such as starch) to make glue, and study adjusting the ratio based on the degree of plant suitability and the simplicity of the process. Add more than 70% of bamboo chips to different proportions of synthetic resin (melamine resin, etc.), and preheat it through a high-frequency machine to understand the solidification effect. This can be a preliminary observation to see whether it can be mass-produced smoothly, so as to find ways to shape bamboo gardening materials. Optimum conditions (as shown in Figure 4: Production process of thorny bamboo gardening boards)

Weighing materials (Bamboo chip)　Weighing materials (Resin powde

Mix　Boxing

Compaction　Put into mold

Heating and pressurizing　Forming

Remove burrs　Finished product

Figure 4. Production process of thorny bamboo gardening boards

2.4. Physicochemical properties test of thorny bamboo gardening board material

In addition to its ventilation and water-retaining properties, bamboo is also relatively resistant to corrosion and acidification, making it a good horticultural medium if possible. When planting plants, the cultivation medium plays an extremely important role, so the physical and chemical properties of the medium are very important (Wang Caiyi, 1990). The physical properties include (1) water retention (2) air-filled porosity (3) overall density, and the chemical properties include (1) pH (2) Electrical conductivity, which are described below (Table 1 Physical and chemical properties of chrysanthemum gardening board):

Table 1. Physical and chemical properties of wormwood gardening board

Test item samples	Thorny bamboo gardening board	Remarks (sample shape)
Moisture content	8.75(0.16)	
Water capacity (%)	31.5±0.3	lumpy
pH (25℃)	6.46(0.03)	lumpy
EC (ms/cm)	3.65(0.03)	lumpy
CEC (m.e/100g)	20.08(1.38)	
Air-filled porosity (%)	4.62±0.23	lumpy
Overall density (g/cm^3)	0.83±0.05	lumpy
Water retention capacity(%)	26.49±1.39	lumpy

Note:

1. Measurements where the test value is lower than the method detection limit (MDL) are expressed as N.D, and the method detection limit is indicated.
2. When the test value is lower than the lowest concentration of the calibration line but higher than the MDL concentration, it is expressed as <the lowest concentration value of the calibration line.

3. Results and discussion

Currently, commercially available planting boards are made of natural and plastic materials. Natural materials often have problems such as heavy weight (ceramic material), high carbon emissions (cement material), conservation (snake wood material), and epiphytic fungi (wood material). Therefore, Planting boards made of plastic/synthetic resin still have a much higher market share than other materials due to their light weight, durability, and easy maintenance. In addition to common pots, in response to the growth of the foliage plant market, there are also many plants on the Taiwan market. Plastic planting boards of different shapes have also begun to appear and are selling well overseas, and some plant friends are printing on the boards. However, in the wave of plastic reduction, even gardening materials made of plastic must face corporate social responsibilities and consider the environmental value of products.

In this study, we have observed the plants grown status on the thorny bamboo gardening boards:

i. Production of thorny bamboo gardening board cultivation medium board (150×200×15 mm)

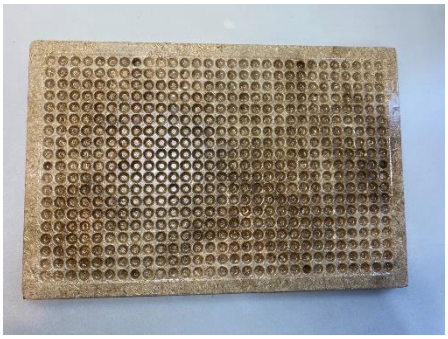

Figure 5. Thorny bamboo Gardening Board

ii. Thorny bamboo gardening board cultivation test (as shown in Figure 6)

Figure 6. The cultivation test of thorny bamboo gardening boards

iii. Comparison of various gardening board products

Comparisons were made with various standard gardening plate cultivation media in terms of properties, including weather resistance, environmental friendliness and recycling (see Table 2).

Discussion of the results: 1. The durability, weathering physical properties, insect-proof and mildew-proof properties of the thorny bamboo gardening board were higher than those of ordinary boards, the shape can be molded, there are many types of plant upper boards, and the agricultural recycling was high, and the carbon footprint was low.

Table 2. Comparison of various types of gardening board products

Gardening board products	Solid wood or spliced Gardening board	Thorny bamboo gardening board	Natural snake wood
Ingredients	Natural wood (100%)	Thorny bamboo powder (85%) Resin (15%)	Common Free Fern (100%)
Mode of use	Easy to deform and degummed at joints	Stable and non-deforming	Soft and easy to disintegrate
Durability	Poor	Good	Medium
Material source	Imported raw materials	Local raw materials and resins	Imported raw materials (logging prohibited)
Carbon Footprint	Medium	Medium	High

Gardening board products	Solid wood or spliced Gardening board	Thorny bamboo gardening board	Natural snake wood
Environmental friendliness	Medium	Medium	Low
Water retention	Medium	Medium	Good
Weathering speed	Medium	Low	Medium
physical strength	Medium	High	Low
Insect repellent	Low	High	Medium
Mildew resistance	Low	High	Medium
overall density	Medium	High	Low
Porosity	Medium	Low	High
Appearance plasticity	Medium	High	Low
Various plant species on the board	Medium	High	Low
Surface integrity	Medium	High	low (increasingly less)
Board operability	High	Low	High
Volume/Weight	Small size, light weight, high handling integrity	Small size, medium weight, high handling integrity	Small size, light weight, medium handling integrity
Environmental protection and reusability	Natural logs	Agricultural recycling	Collection is prohibited, plants was protected
Production method/mass production level	Manual splicing/low	Factory semi-automation/high	Conservation, prohibit to logging
Product selling price	high (there are more fewer to get logs)	low (it can be produced in factories)	high (there are more fewer raw materials)

iv. Comparison of bamboo gardening board products

Comparison of similar bamboo gardening board products in market (see Table 3): Compare with the physical properties, market production surface and applicable attributes of bamboo gardening boards.

Table 3. Comparison of similar bamboo gardening board products

Products	Thorny bamboo Gardening Board	Green Gardening Board
Types of Bamboo	Thorny bamboo	Green Bamboo
Bamboo chip size	0.5 cm	5~10 cm
Moisture content of bamboo chips	15%	13~20%
Pre-processing (sterilization) for plate making	No	Yes
Types of adhesive	melamine formazan resin	epoxy resin glue
Adhesive proportion	15%	8~10%
Hot pressing time	3 minutes (at a pressure of 175 kg/cm^2)	10 minutes (at a pressure of 100 kg/cm^2)

Dimensions	The length, width and thickness of the board are 20 cm × 15 cm × 1.5 cm	The length, width and thickness of the board are 20 cm × 15 cm × 3 cm
Weight	400g-500g	600~800g
pH value	6.46	6.2
EC (electrical conductivity) value	3.65 dS/m	1.2 dS/m

v. The growth status of the plants after installing on thorny bamboo gardening boards

From Figure 9, it can be observed that whether it is rabbit's foot fern, phalaenopsis, fox tail orchid or dendrobium, the root system grown well, the leaves were healthy and dark green, and the new sprout was abundant.

Figure 7. The plant growth status after installing them on the thorny bamboo gardening boards

4. Conclusions

As bamboo aging, its ability to sequester carbon will decrease, so proper harvesting is necessary: "Bamboo is different from ordinary trees. It has the properties of fast growth, easy reproduction, short growth period, and easy renewal. It shall be use wisely." This research has harvested that had not been cut bamboo residues for many years. These residues were sorting or processing (leftovers) to upcycle, and according to the rising needs of horticultural cultivation and the circular economy model of commodities. Using a glue formula containing a small amount of melamine resin base was tailor-made to glue the waste bamboo chips. It can made into cultivation materials, resource efficiency can be improved and used in all stages of the product life cycle. When the horticultural product life ends and becomes unusable, it can be easily broken into small pieces and can be used as a covering material to maintain soil moisture and fertilize the

soil. Since Melamine resin does not produce toxic gases after complete combustion, it can be further used as fuel. The ash after combustion has a high nitrogen content and can be used as fertilizer again, which is expected comply with the goal of circular agriculture.

Conflict of Interest

We hereby confirm that the manuscript has been read and approved by all signed authors and there is no conflict of interest. All regulations of the relevant institutions/research institutes/companies are complied with, including compliance with relevant intellectual property rights to ensure barrier-free publication."

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