

# 工業技術研究院

Industrial Technology  
Research Institute

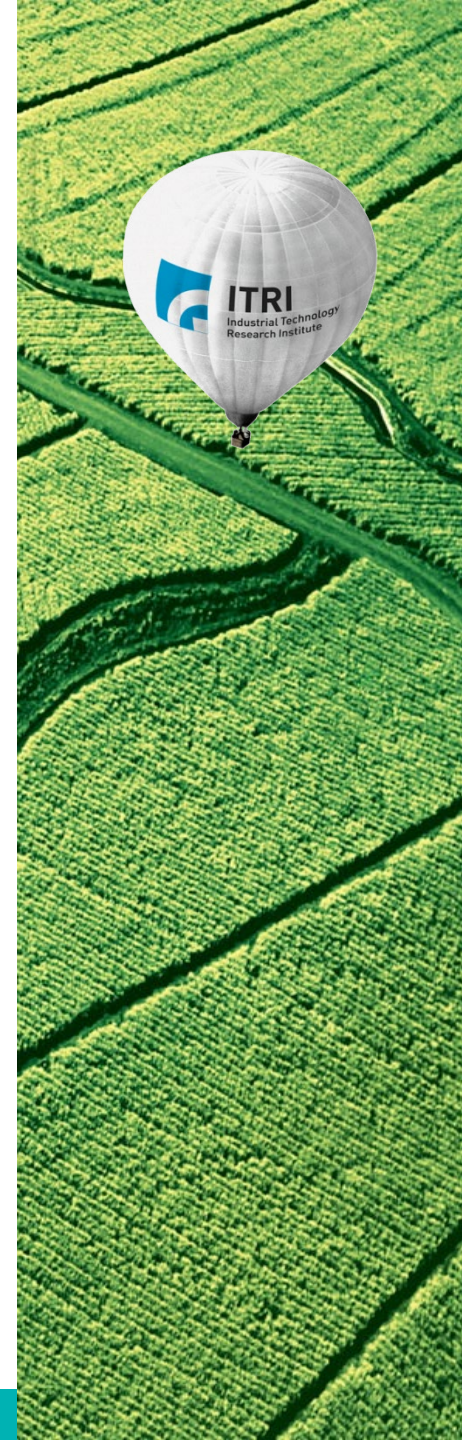
## Bamboo industry technology and innovative biochar materials

科技竹產業與創新生物炭材料

李士畦 中分院副執行長

S.C LEE, ICRC/ITRI

2024.04.20

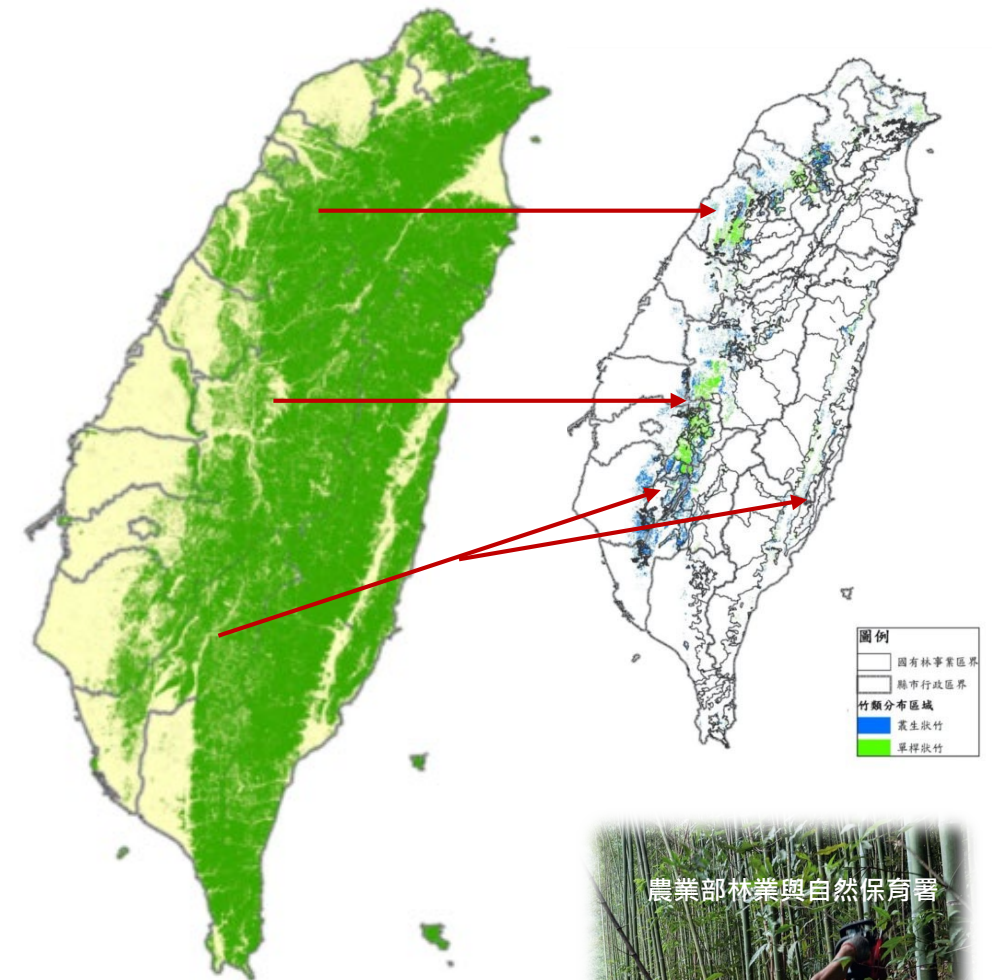


# Bamboo Resource in Taiwan

- Area of Taiwan : 3.59 Mha
- Area of Forest : 2.20 Mha(61%)
  - (1) Natural Forest : 73 %
  - (2) Artificial Forest : 20 %
  - (3) Bamboo : 10-20% (~180,000 ha)

18 genus ; 58 species

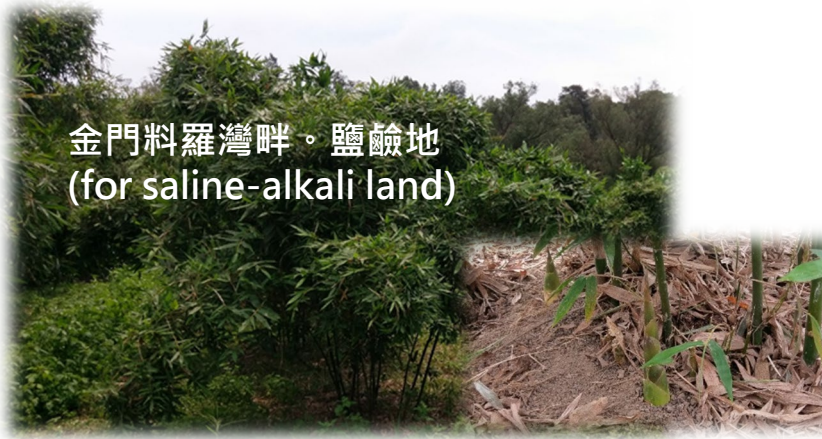
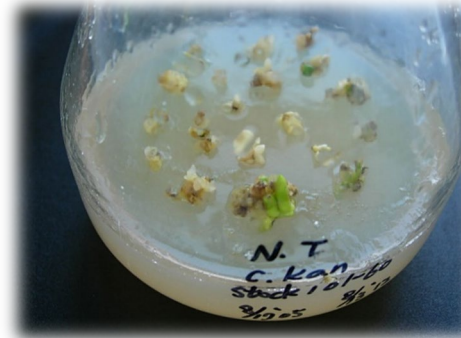
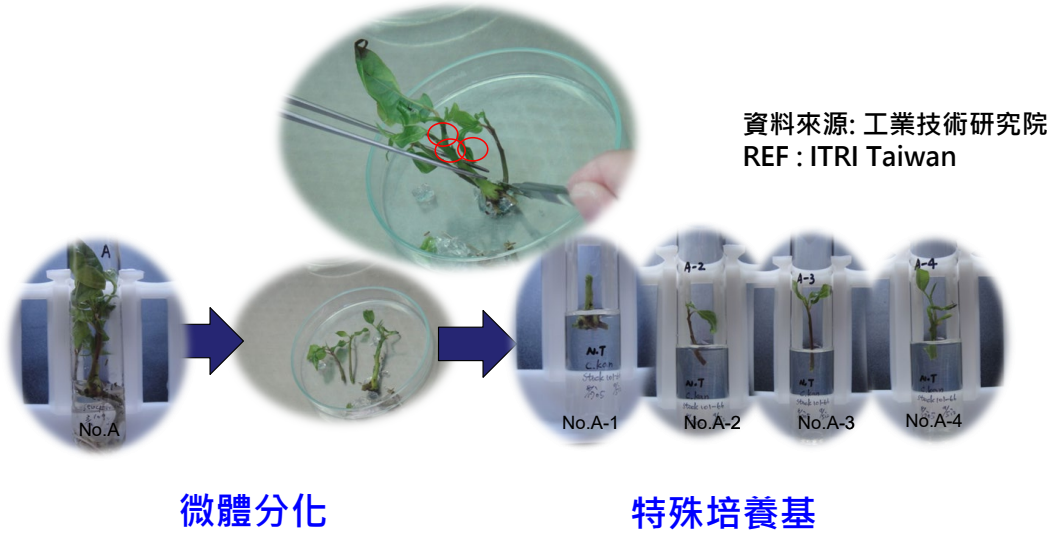
**makino bamboo**(桂), **ma bamboo**(麻),  
**green bamboo**(綠), thorny bamboo,  
**moso bamboo** (孟宗) and long-branch bamboo



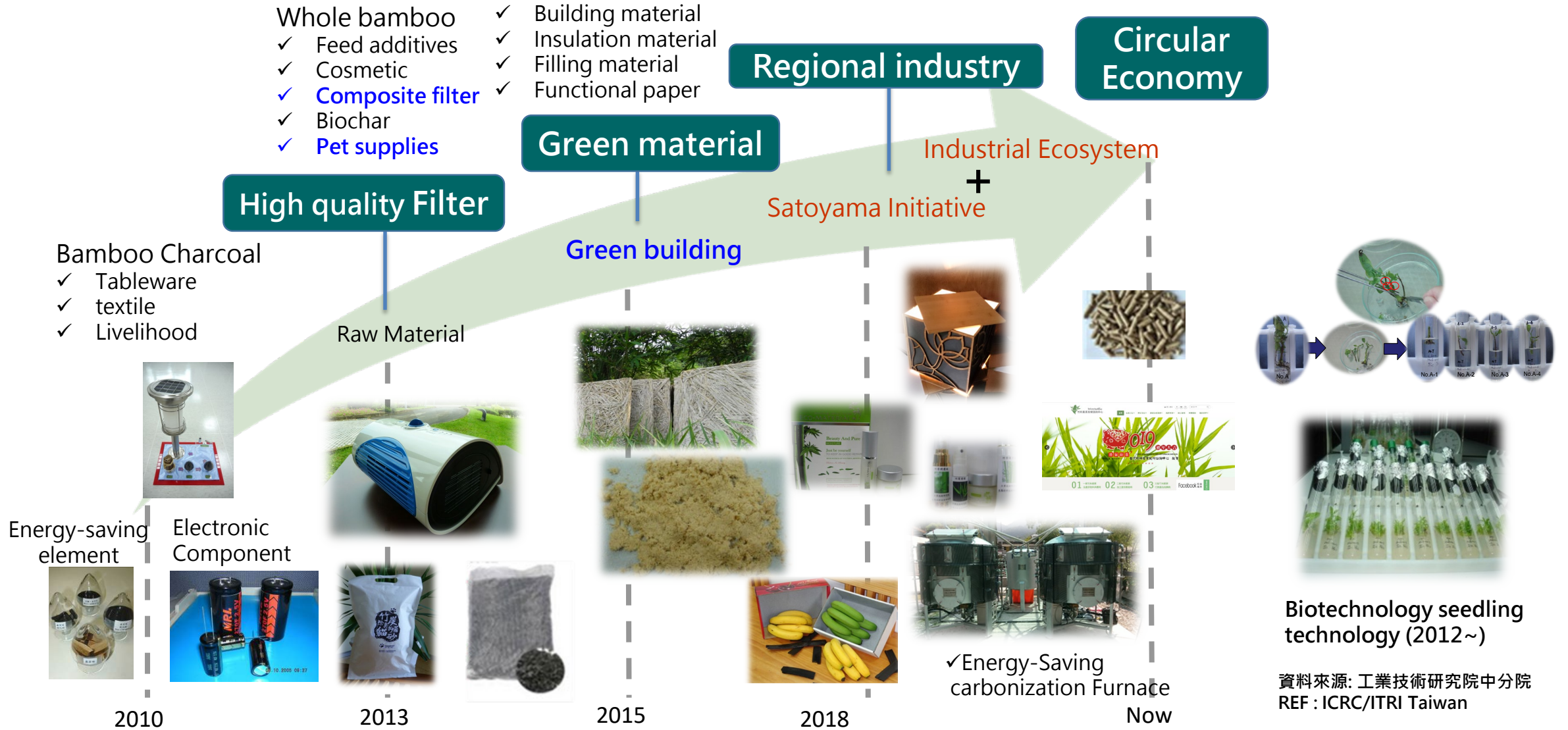
第四次森林調查成果



## 生物技術苗之抗鹽烏腳綠竹，兼具鹽地防風林及綠竹筍生產 (中研院+工研院)



# TBI in ITRI, Taiwan (2012 later)



# TBI in ITRI : Extraction tech. based

Fresh bamboo (Green)



竹萃取液



防護  
噴液

Skin protection  
spray

抗菌  
過敏



抗過敏測試

Allergy skin tests

Antibacterial and skin clinical testing

動物  
實驗



寵物清潔用品

Pet cleaning supplies



竹醋液

Bamboo vinegar

竹炭製程產生的衍伸物

洗潔精

清潔  
殺菌



抗菌測試

臨床  
實驗



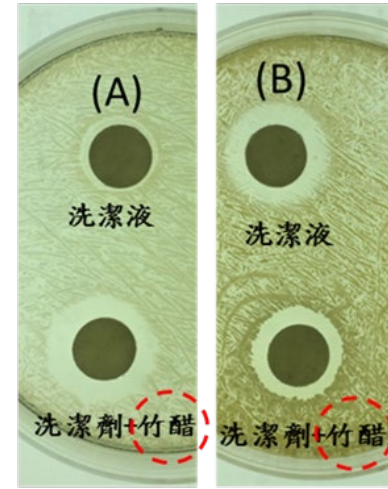
皮膚測試

鮮竹產品的發展以萃取技術為基礎

資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency

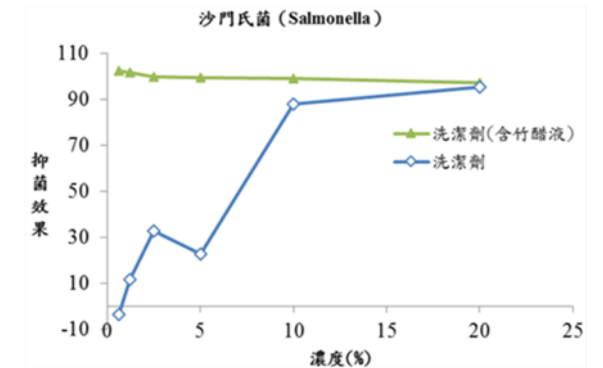
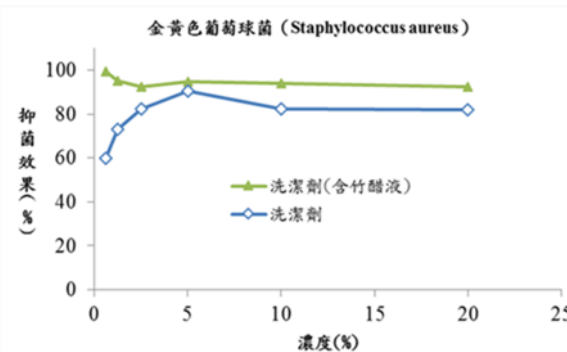


# TBI in ITRI : Pet products: such as Skin protection spray



(A)沙門氏菌 (*Salmonella*)  
(B)金黃色葡萄球菌 (*Staphylococcus aureus*)

A formula containing **bamboo vinegar** has an inhibitory effect on two types of bacteria that cause skin diseases



資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF: ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency



# TBI in ITRI : Pet products: such as cat litter

The number of times the cat peed and used bamboo charcoal litter.

貓咪編號	貓咪排尿次數/天	使用竹炭貓砂次數/天
A(3歲)	3~4	0
B(5歲)	3~4	3
C(2歲)	3~4	2
D(2歲)	3~4	0
E(4歲)	3~4	0
F(1歲)	3~4	2
成貓平均	3.5	1.2
G(4月)	3~4	3
H(5月)	3~4	3
I(5月)	3~4	2
J(3月)	3~4	3
K(3月)	3~4	2
L(3月)	3~4	2
M(3月)	3~4	2
N(6月)	3~4	3
O(7月)	3~4	2
P(2月)	3~4	0
幼貓平均	3.5	2.2

貓砂種類	吸水率%	吸水後形狀	更換頻率	
A市售貓砂	礦砂	134	泥狀	3~4天/kg
B市售貓砂	水晶砂	116	固體	6~7天/kg
竹炭貓砂	竹炭水晶砂	107	固體	8~9天/kg



資料來源: 工研院中分院、農業部林業保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency



# TBI in ITRI : Defibrillation material technology



✓絲狀竹材  
filamentous bamboo material



裁切



✓纖維狀竹材  
fibrous bamboo material



Cutting process

physical process



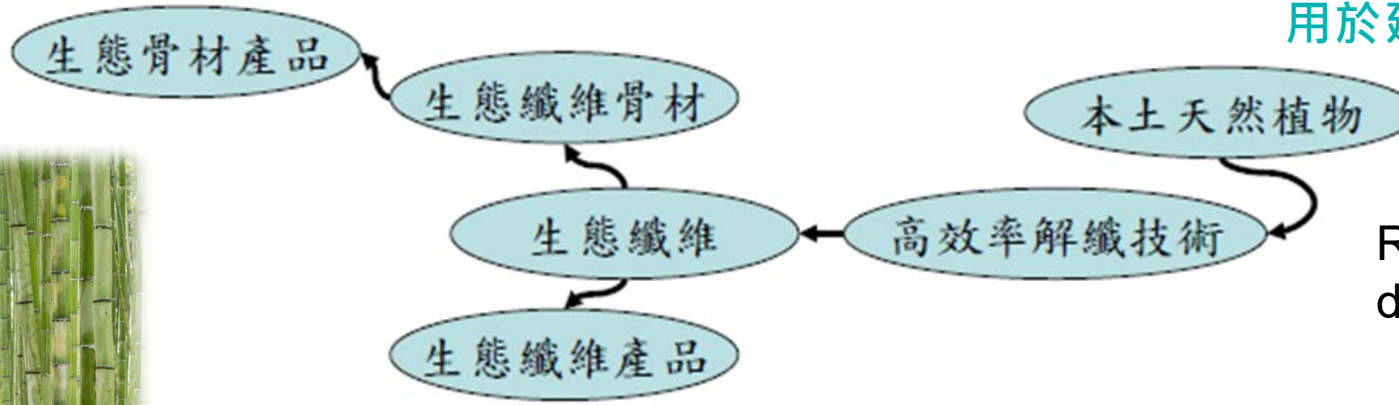
資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
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# TBI in ITRI : Functional building materials

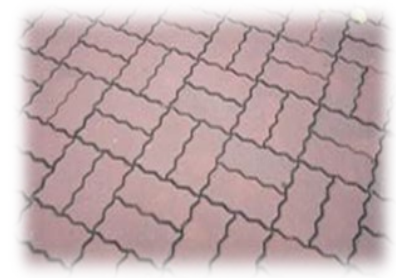
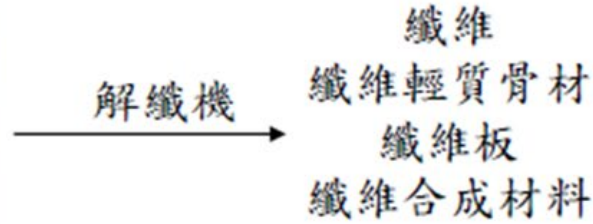
用於建築裝修板材的竹解纖原料



Raw materials for building decoration panels



Physically destroy fibers



纖維/纖維骨材開發產品

資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
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Lightweight materials that can be used for decoration



# TBI in ITRI : Cement board and Fiber board

Short fiber bamboo material combined with starch glue developed by ITRI

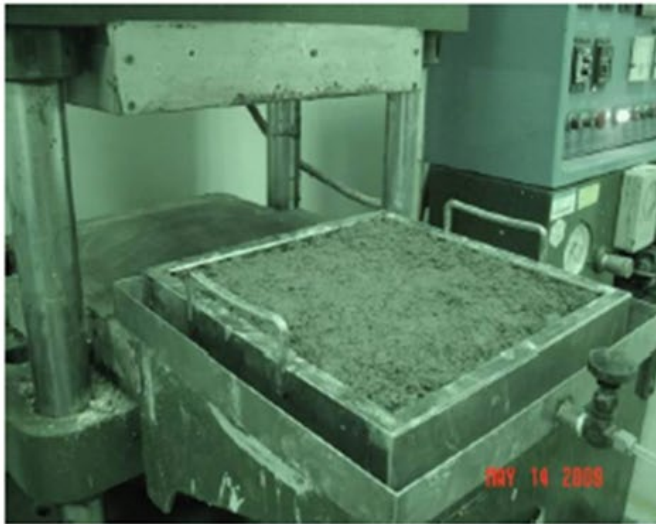
採用短纖竹材為原料，竹纖維經過風乾、篩除異物等處理，膠料採用工研院開發之澱粉膠。



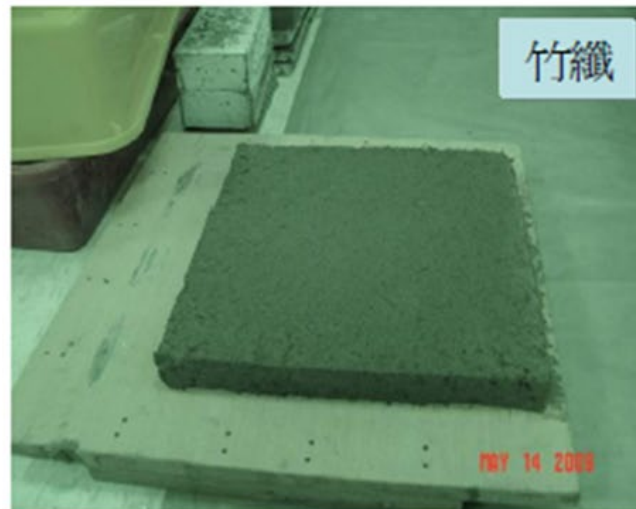
竹絲纖維板



竹纖水泥板



1.調料入模



2.壓製成型

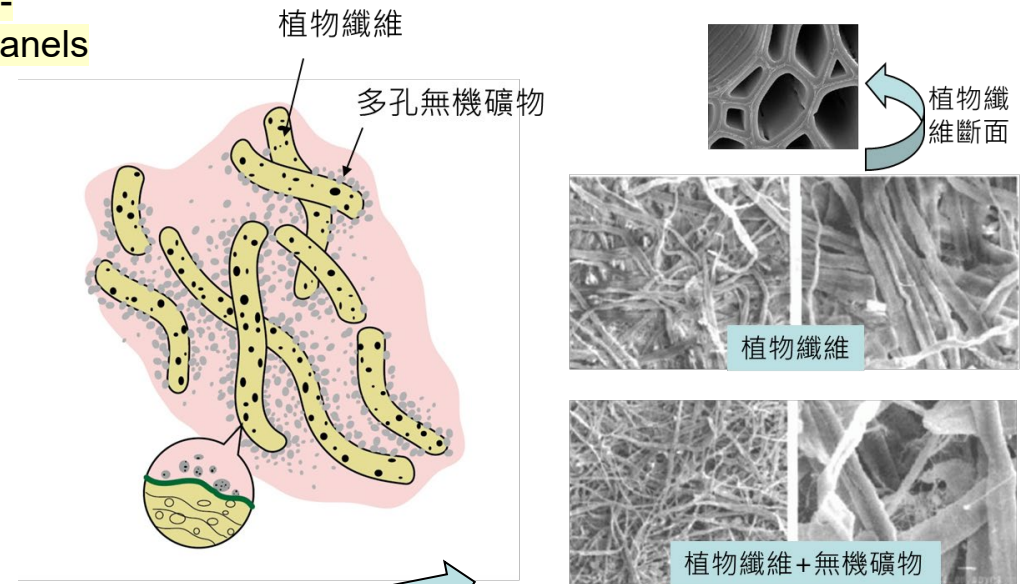
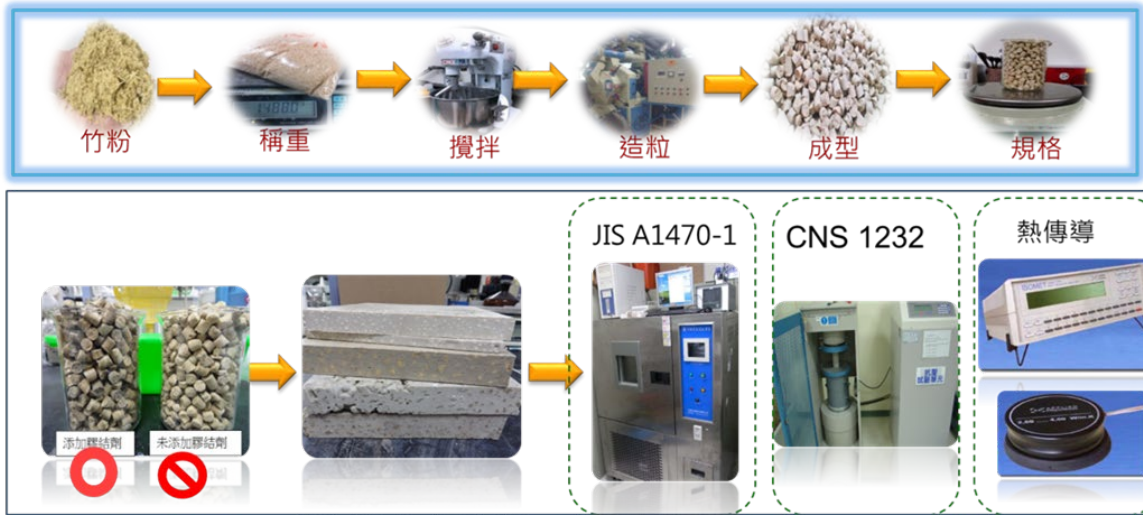


資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
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## 竹粒料隔熱材料及高效率調濕板材

Thermal insulation and high-efficiency humidity control panels



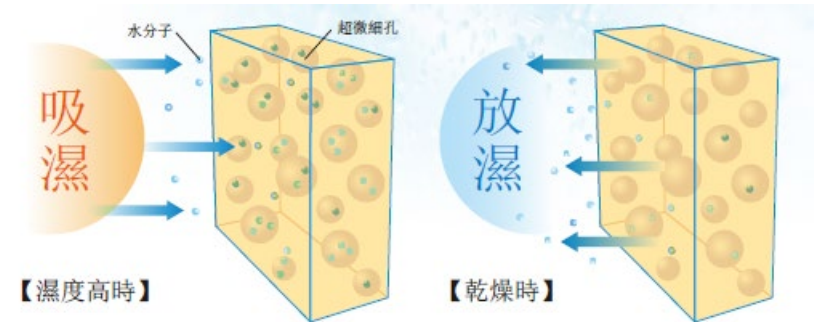
Bamboo fiber + Porous inorganic minerals

### 製程配方



抗壓強度達177-188kgf/cm<sup>2</sup>  
吸濕量達143.10mg/cm<sup>2</sup>  
放濕量達96.55mg/cm<sup>2</sup>  
熱傳導係數小於0.76W/m.K

Compressive strength  
Moisture absorption capacity  
Humidity release capacity  
Thermal conductivity

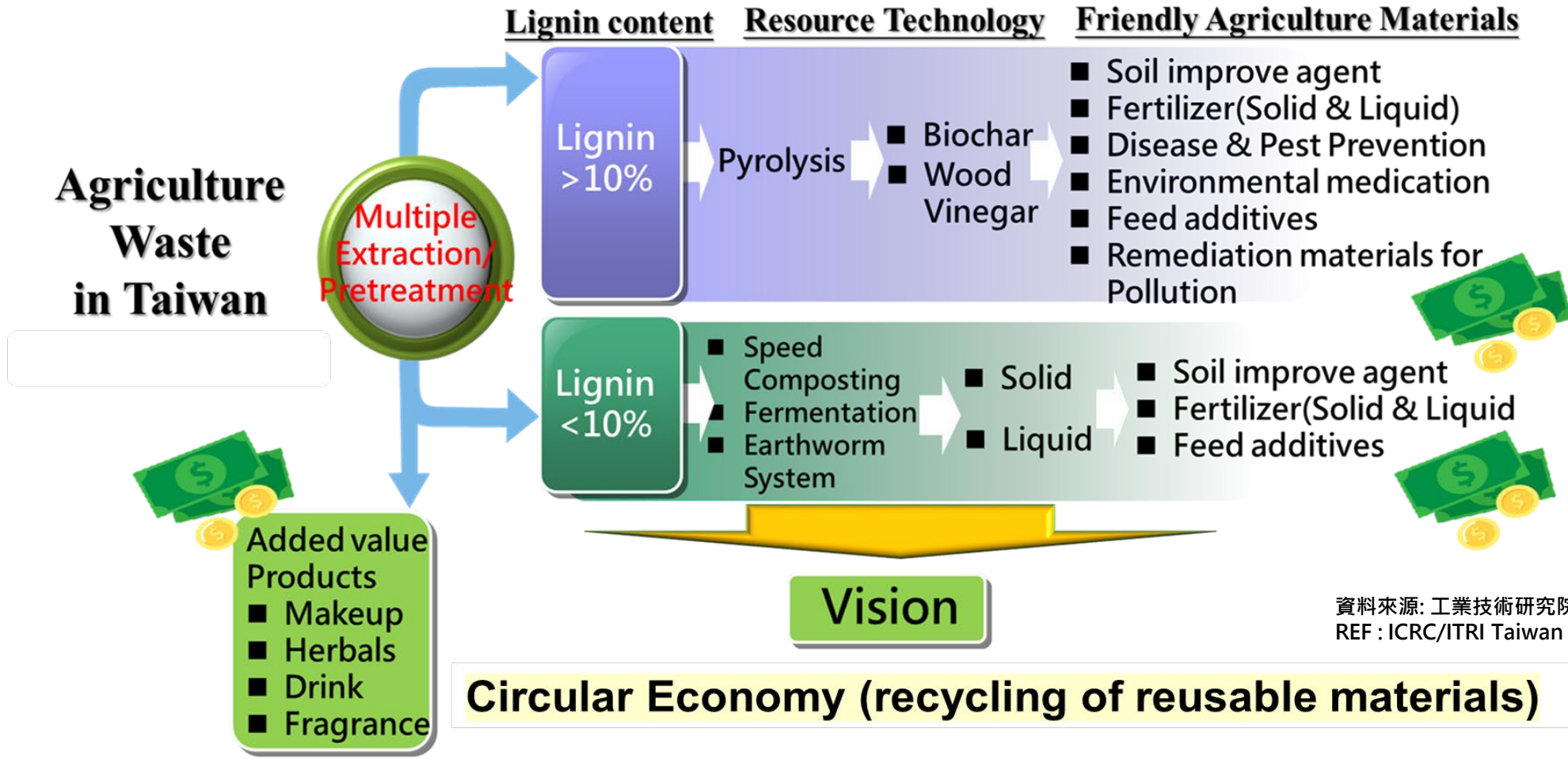


Absorbs moisture when humidity is high  
Releases moisture when humidity is low

資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency

# TBI in ITRI : Overview of biomass utilization

Technical classification and products of biomass utilization



資料來源: 工業技術研究院中分院  
REF : ICRC/ITRI Taiwan

Biochar is charcoal that is produced by pyrolysis of biomass, yet in the absence of oxygen, and is used as a soil ameliorant for both carbon sequestration and soil health benefits.

# TBI in ITRI : Policy Support

Basic technology



- ◆ Energy-saving biochar equipment (Lee, 2018)
- ◆ Database of different types of biochar properties

Since 1999



Increase the use value of barren land

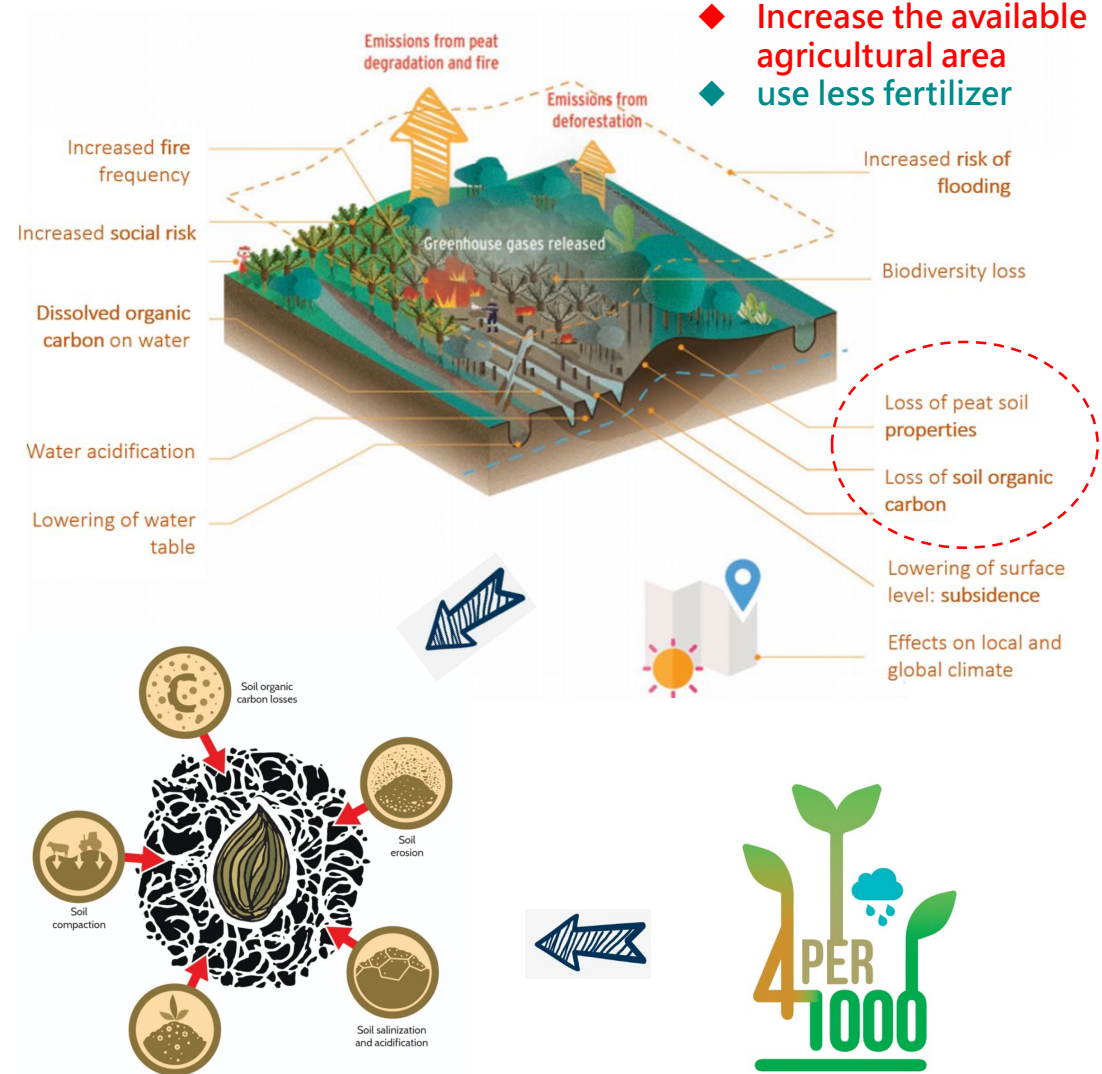
National Policy : National Master Plan for Net Zero Carbon Emissions by NBSs (~2050)



Farm or farmer organization

Key issue : Combining agricultural and forestry surplus materials with microbial technology

Functional Biochar



Reference: Recarbonizing Global Soils: A Technical Manual of Recommended Management Practices, FAO/UN, 2021



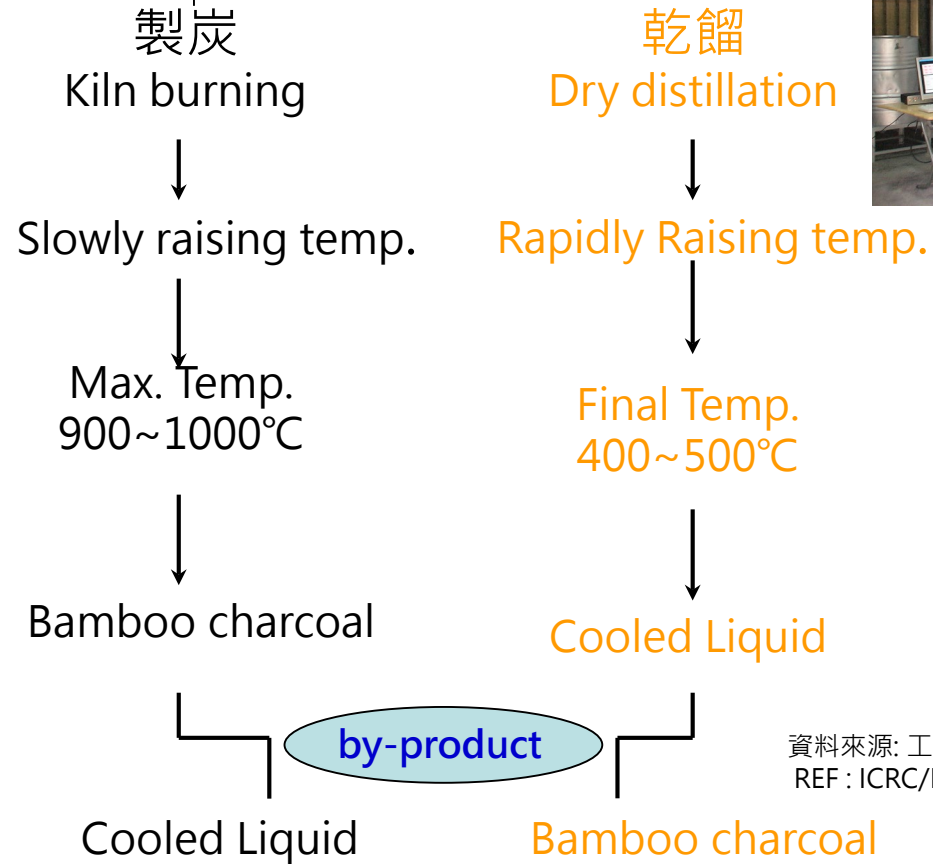
# TBI in ITRI : Biochar Production Equipment



Since 1999



## Process of BC



Since 2010



資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency

# TBI in ITRI : Biochar Production Equipment



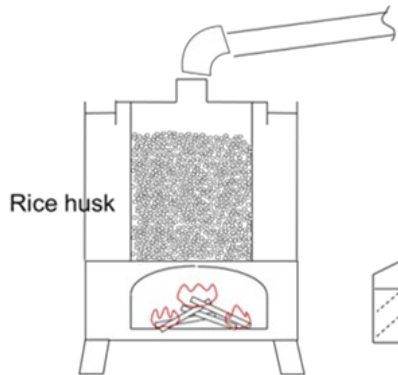
資料來源: 工業技術研究院中分院  
REF : ICRC/ITRI Taiwan



高階應用  
(high value materials)



量化應用 (Large amount of material used)



資料來源: 工業技術研究院中分院  
REF : ICRC/ITRI Taiwan

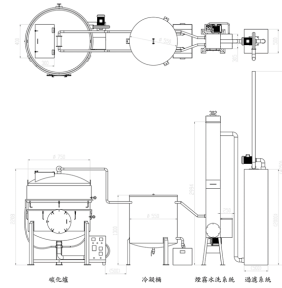


- ✓ 目前常用的簡易窯，面臨批次質量再現性、排煙處理或無熱能回收，炭收時間較長之挑戰。  
Simple carbonization equipment still have the disadvantages of poor reproducibility of carbon yield and quality, no exhaust gas treatment or heat energy recovery, and long operating time.
- ✓ 傳統機械設備以電力或重油間接加熱，窯體大、組合不易且能源耗用相對明顯。製造成本也相對較高。  
Traditional equipment uses electricity or heavy oil for indirect heating, which requires large tank volume and energy consumption. Manufacturing costs are relatively high.



# TBI in ITRI : Biochar Production Equipment

## ITRI's 3E Pyrolysis Furnace for Biomass (Energy-saving, Eco-friendly, Efficient)



ITRI's 3E Furnace	Type ICRC-A	Type ICRC-B	Type ICRC-C
Capacity (Batch)	100 – 150 Kg	150 – 300 Kg	150 – 300 Kg
Yielding rates (Hot water)	200 L/h 45~60 °C for 4 hrs	500 L/h 45~70 °C for 6 hrs	500 L/h 45~70 °C for 6 hrs
Main features	Self-energy sustainable <sup>1</sup> , programmable, equipped with auto-feeding <sup>2</sup> , heat-recovery, exhaust gas treatment and monitoring system, highly efficient for producing biochar and vinegar, easily scalable and space-saving <sup>3</sup> , customizable.		

1. Electricity cost is less than \$2 per batch. 2. No shredder included. For 3 type ICRC-C furnaces, space requirement is around 150 – 200 m<sup>2</sup>.

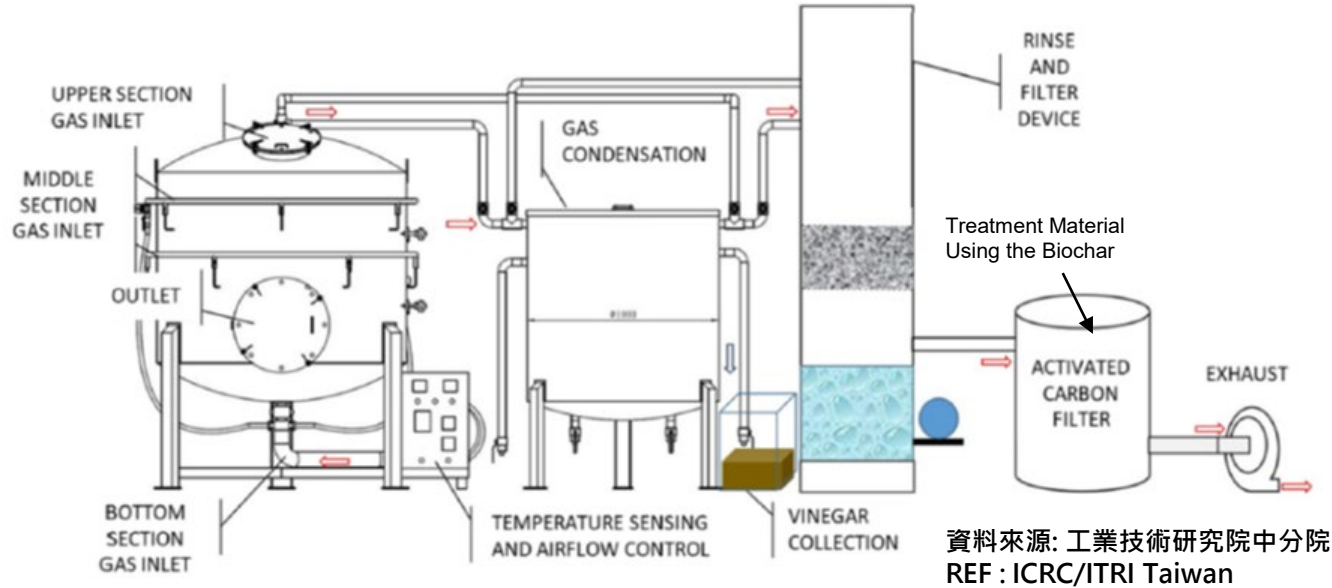
資料來源: 工業技術研究院中分院  
REF : ICRC/ITRI Taiwan





# TBI in ITRI : Biochar Production Equipment

Digitally controlled improved biochar application manufacturing system



Generally, the carbon yield is about 20~30%.  
Vinegar liquid collection rate (weight ratio): 25~40%

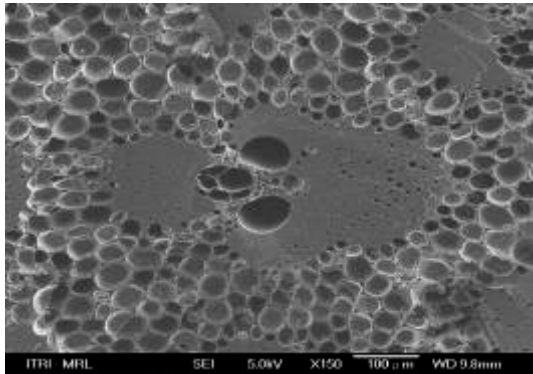




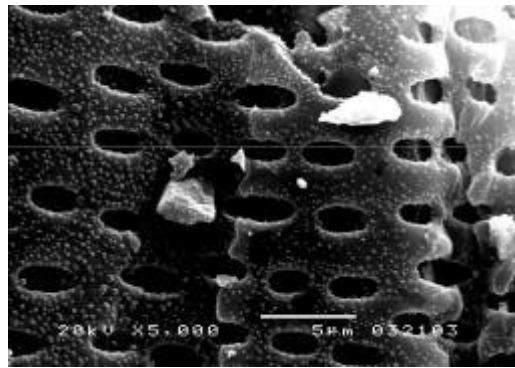
# TBI in ITRI : Functional Biochar Materials

竹炭經活化處理後可產生大量 Micropore · BET值達800 ~ 1,200 m<sup>2</sup>/g

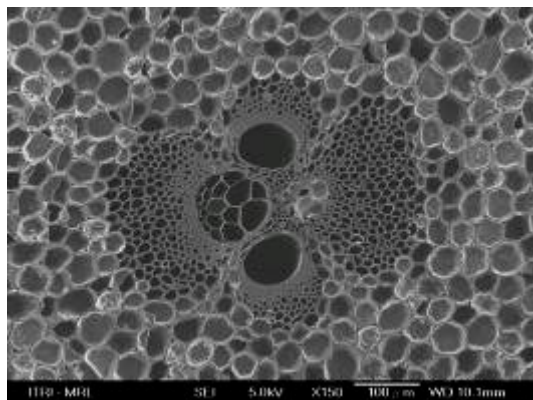
The number of holes near the vascular bundle increases, and the longitudinal section also shows a regular arrangement.



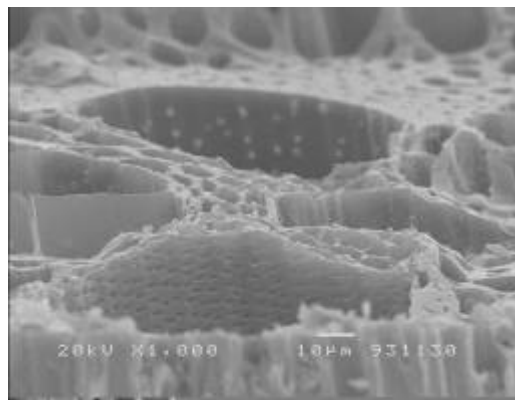
碳化(橫斷面)



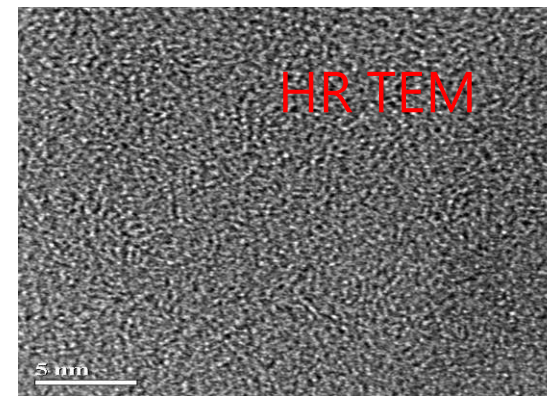
維管束附近的孔數增多，縱切面也呈現規則排列



碳化+賦活處理(橫斷面)



碳化+活化(縱斷面)



Micropore

## Pore size定義

- macropore-  $D > 50 \text{ nm}$
- mesopore-  $50 > D > 2 \text{ nm}$
- micropore  $2 \text{ nm} > D$

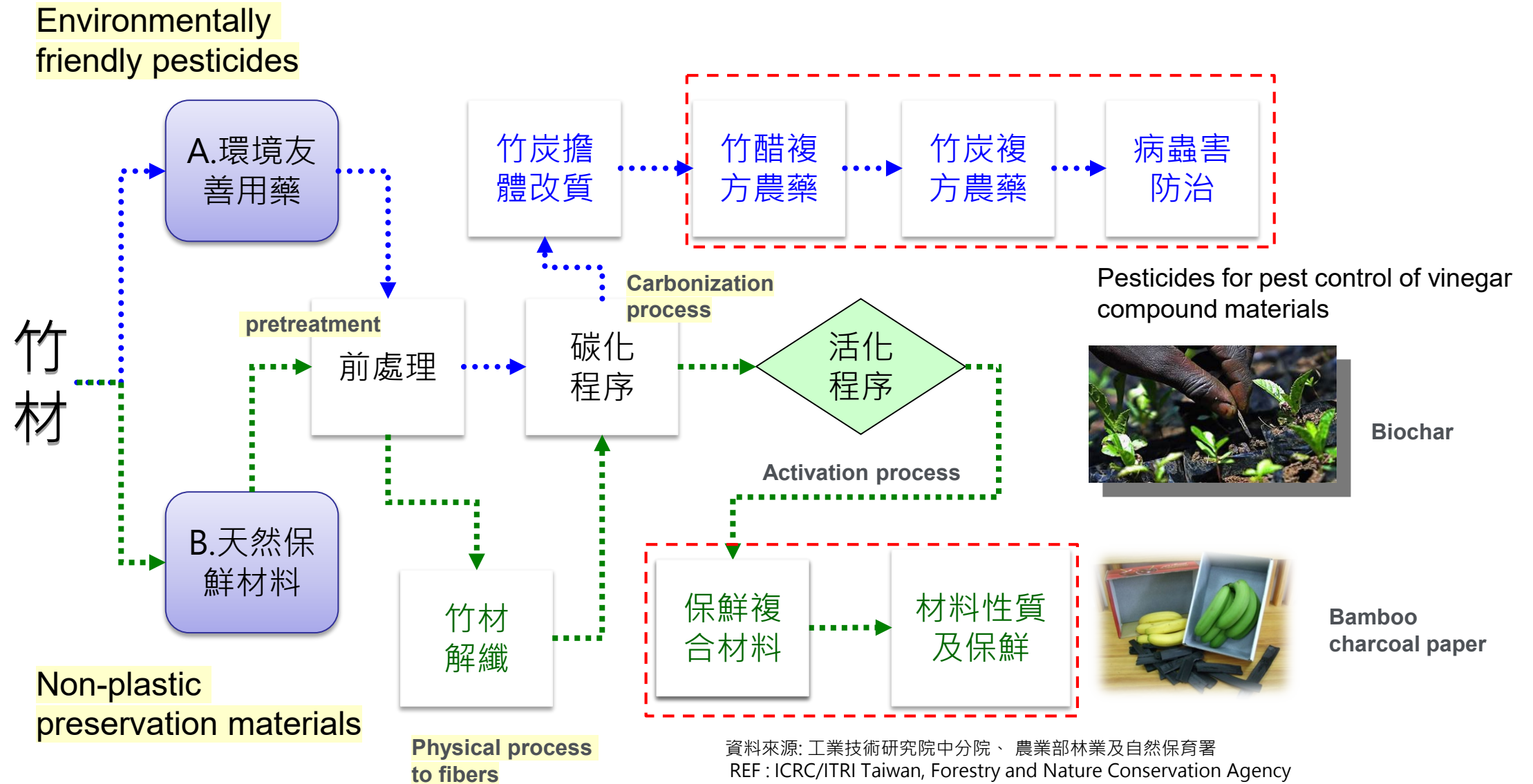
小孔洞有助於保水能力，中大孔洞有助於微生物進駐

Micropores → maintain humidity  
Meso & macro pores → microorganisms

資料來源: 工業技術研究院中分院  
REF : ICRC/ITRI Taiwan

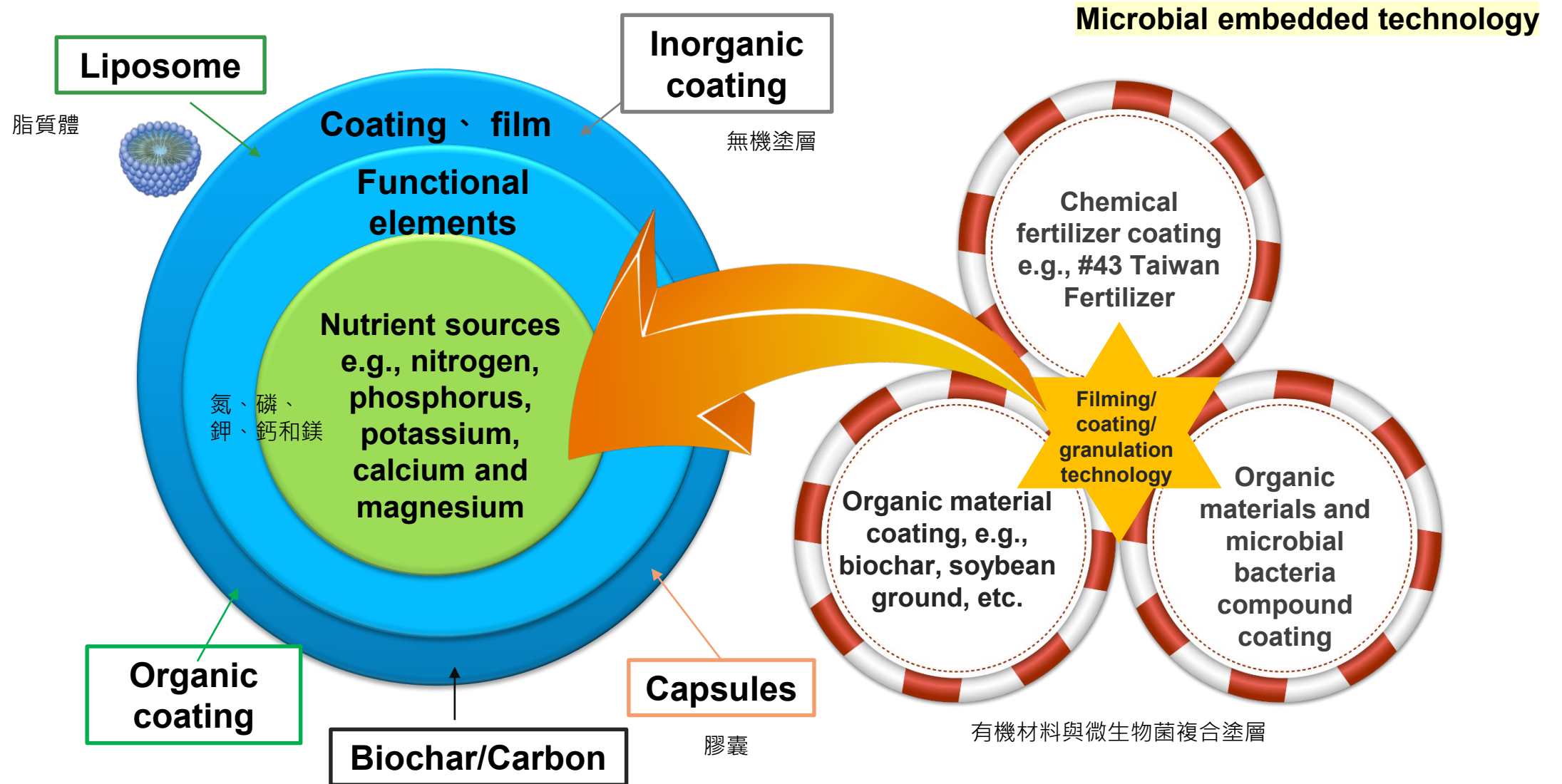


# TBI in ITRI : popular application directions of biochar





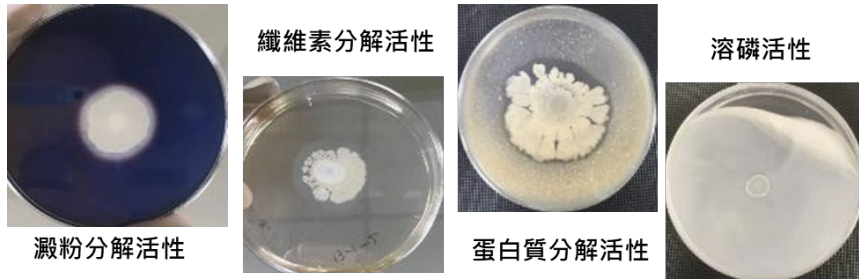
# TBI in ITRI : Functional Biochar Materials



Source : ITRI ICRC (2022)



# TBI in ITRI : Functional Biochar Materials

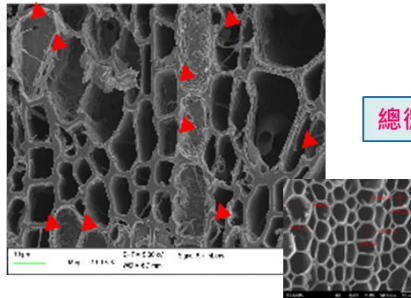


500°C炭化之生物炭攪和有益微生物

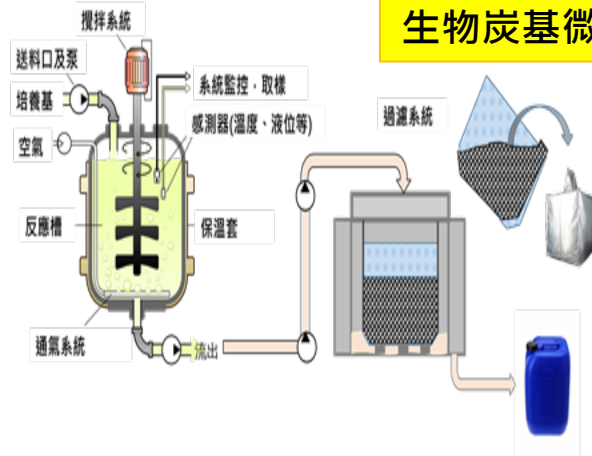
**Microbial embedded technology**

總微生物密度 > 10<sup>8</sup> CFU/g

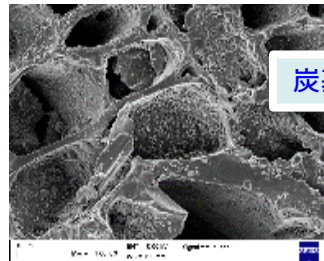
Source : ITRI ICRC (2023)



**生物炭基微包覆(埋)設備**



炭基發酵槽主槽與蓋子

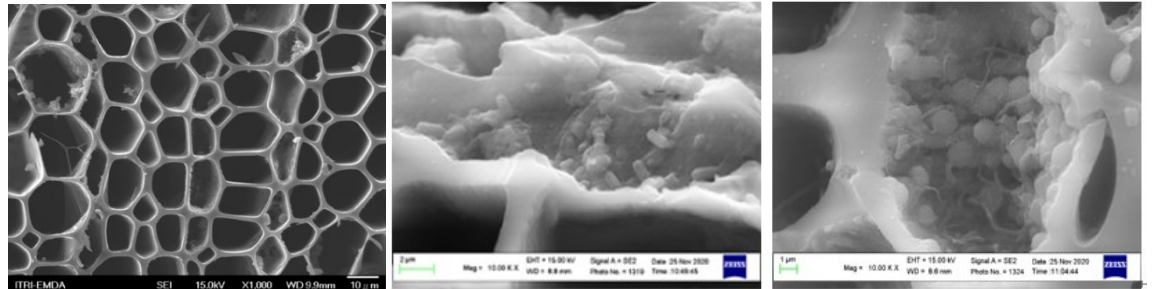


發酵槽內部槽主要部件

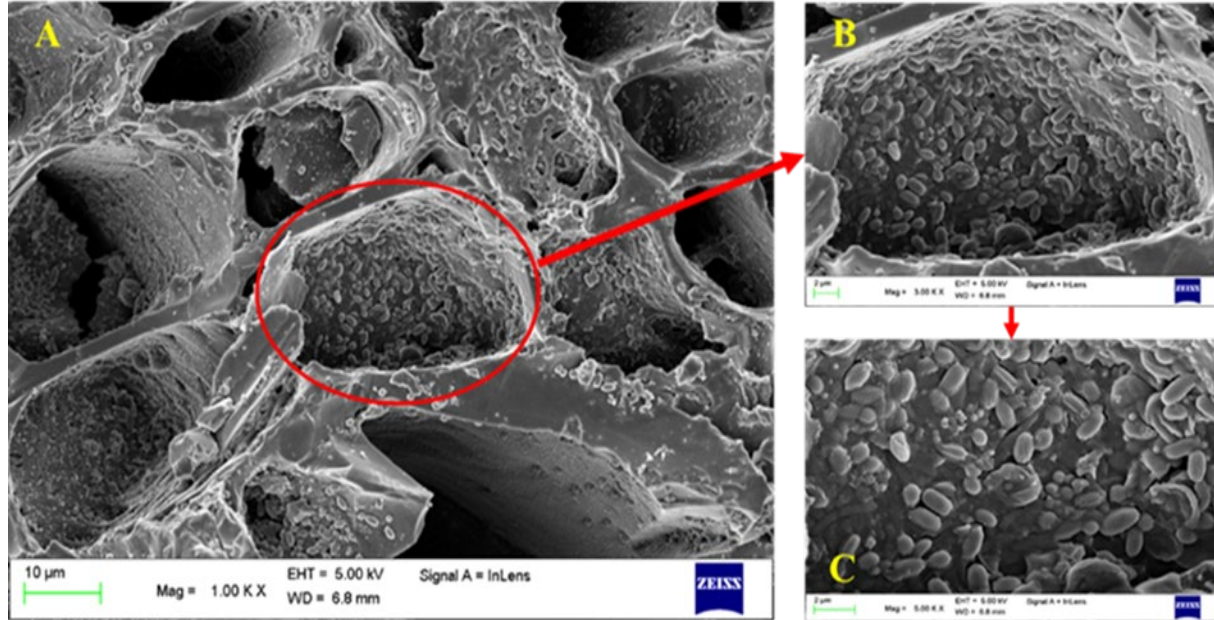
數位客製化生物炭設施製作及生物炭製造設備



材料具多孔性且具備長效載菌效果



- ITRI 已有多年生物炭的開發經驗。
- ITRI中大孔生物炭同時具備高比表與高質傳的特性，可用以包覆大量有益微生物(> 10<sup>8</sup> CFU/g)，製成**具備緩釋功能的機能性土壤添加劑**。



## Microbial embedded technology

- ◆ A is the distribution of bacteria on the surface of the biochar and its pores after magnification of 1,000 times.
- ◆ B is the enlargement of the circle in area A of 3,000 times.
- ◆ C is the case of magnifying 5,000 times.

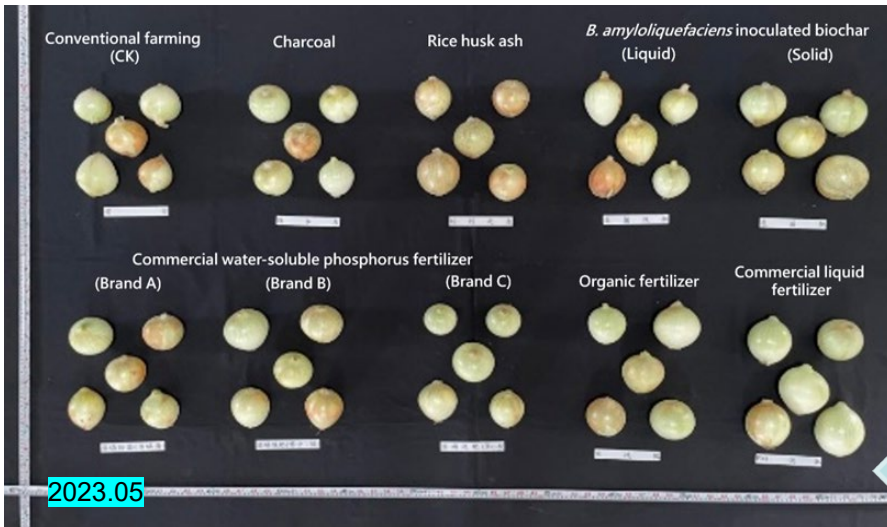
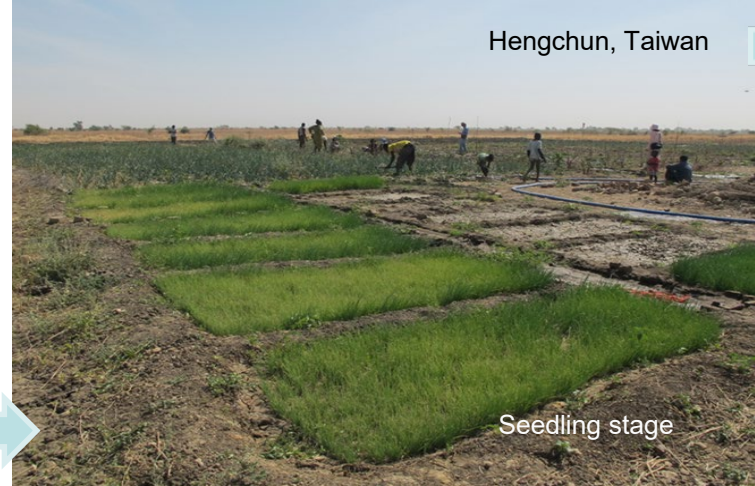
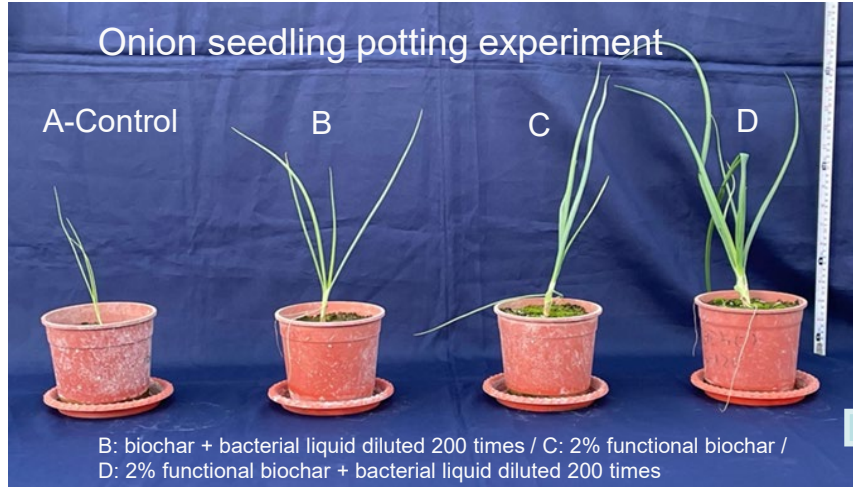
工研院中分院 (2023)

Batch	Strains concent				Cultivation time (days)
	Functional biochar		Liquid byproduct (cultivation medium)		
	CFU/g	STDEV	CFU/mL	STDEV	
1	$1.02 \times 10^9$	$6.56 \times 10^8$	$2.33 \times 10^8$	$8.97 \times 10^7$	7-8
2	$7.58 \times 10^8$	$3.99 \times 10^8$	$2.90 \times 10^8$	$1.02 \times 10^8$	7-8
3	$2.53 \times 10^9$	$2.92 \times 10^8$	$9.40 \times 10^7$	$1.56 \times 10^7$	7-8



Source : ITRI ICRC (2023)

## Large-scale application case of functional biochar: Onion field



Source: HC Farmers Association; ICRC/ITRI (2023.6)

## Large-scale application case of functional biochar: Onion field

	Mean±SD			Grade of onion bulbil (%)		
	Fresh weight (g/plant)	Yield per square meter (kg/m <sup>2</sup> )	Estimated yield (kg/0.1 ha)	Large (>8 cm)	Medium (6-8 cm)	Small (<6 cm)
Conventional agriculture (control)	90.64±47.23 a	2.02±0.10 a	2024.24±98.315 a	0	0	100
Rice husk ash	177.70±66.97 c	4.92±0.08 c	4916.37±77.328 c	7.69	23.08	69.23
Water-soluble phosphorus fertilizer	170.57±58.40 c	4.38±0.09 c	4377.86±89.201 c	3.57	25.00	71.43
Organic fertilizer	178.25±82.93 c	5.05±0.34 c	5050.55±335.15 c	16.13	12.90	70.97
<i>B. amylo.</i> inoculated biochar	291.45±78.57 abc	9.03±0.08 bc	9034.95±75.57 bc	100	0	0
<i>B. amylo.</i> inoculated biochar (Liquid of byproduct)	136.00±66.71 b	3.72±0.10 b	3717.25±101.90 b	3.23 b	6.45 b	90.32 b

Table: SC LEE, Kitamura, etc. (2024)

	Income ratio (%)	Storage diseases (%)	Actual income ratio (%)
Conventional agriculture (control)	100	20.7	100
Mixing of ash and charcoal from rice husk	363	36.0	195
Water-soluble phosphorus fertilizer	322	38.5	220
Organic fertilizer	382	13.8	197
<i>B. amylo.</i> inoculated biochar	897	0	333
<i>B. amylo.</i> inoculated biochar (Liquid of byproduct)	232	6.5	274

Source: HC Farmers Association; ICRC/ITRI (2023.6)



- Full application of functional biochar or its by-products (a mixture of bacterial liquid, suspended biochar and culture medium)
- Also reduce the incidence of storage diseases





# TBI in ITRI : Functional Biochar Materials



NO Biochar

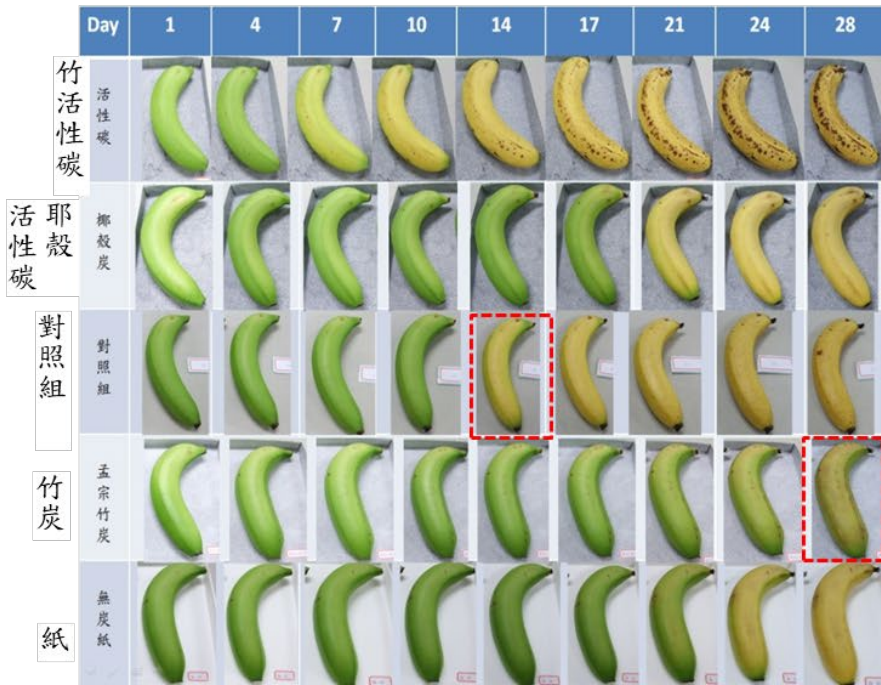


Use Biochar

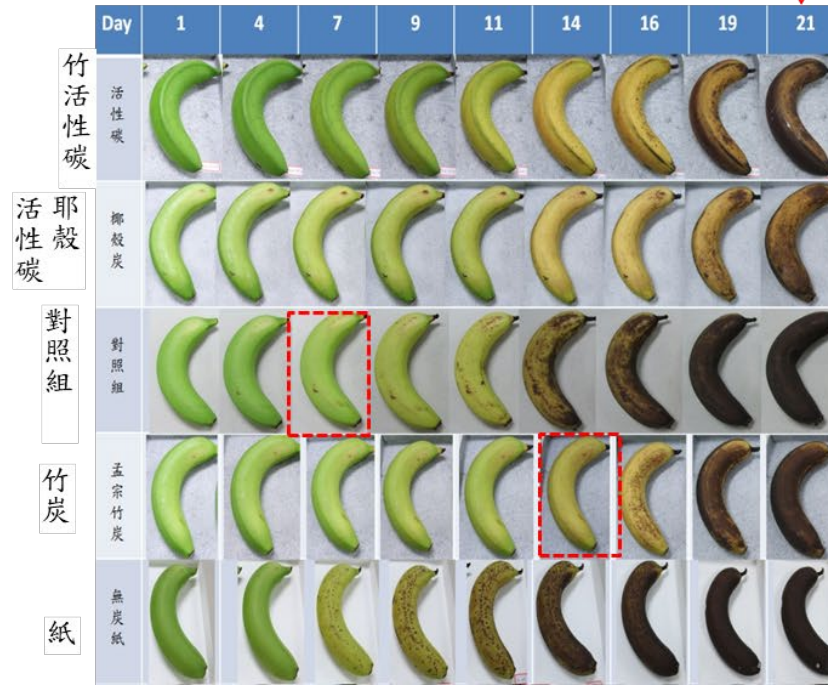
In the three months after planting



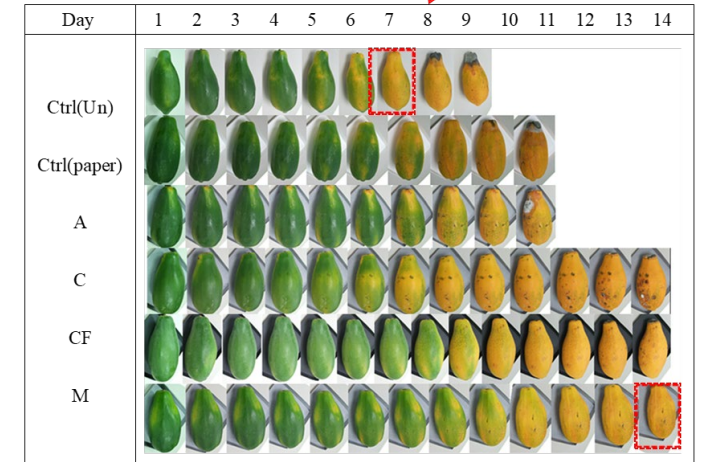
## 未催熟香蕉低溫(15°C)保鮮試驗



## 未催熟香蕉常溫保鮮試驗



## 木瓜常溫保鮮試驗



資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency

It is often used to extend the freshness of climacteric fruits.

## Composite materials used in air purification

### 物理活化



以孟宗竹為原材料



40-100mesh竹炭



浸泡/還原/水洗



浮子流量計設定 L/min	進氣口流量 L/min	出氣口流量 L/min	進出氣比
2.5	2.429	2.344	96%

污染物進口濃度	HCHO (±0.1ppm)	TVOC (±0.3ppm)	CO (10±1ppm)
竹活性炭濾網	74.2%	78.6%	12.3%
複合式濾網 (奈米金銀竹活性炭濾網+幾丁聚醣)	99.0%	84.4%	20.2%
市售抗菌濾網(LPA)	3.0%	2.7%	1.0%
市售活性炭濾網(Honeywell CPZ)	30.3%	10.8%	6.9%

資料來源: 工業技術研究院中分院、農業部林業及自然保育署  
REF : ICRC/ITRI Taiwan, Forestry and Nature Conservation Agency

實場測試濾網對於生物氣膠去除效果

生物氣膠	Bacteria (2000-4000 CFU/m <sup>3</sup> )	Fungi (2000-8000 CFU/m <sup>3</sup> )
竹活性炭濾網	52.7±3.9%	41.3±3.7%
複合式濾網 (奈米金銀竹活性炭濾網+幾丁聚醣)	66.1±12.4%	87.2±11.9%
市售抗菌濾網(LPA)	74.4±2.9%	65.3±0.8%

### 風速測試

Formaldehyde and VOC

- 抗菌率
- CO轉換率
- VOC/甲醛吸附性



Adsorption capacity is increased

### Chitosan-bound

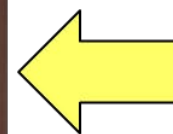
塗佈幾丁聚醣  
增加接觸面積



複合竹活性炭濾網



奈米金銀竹活性炭濾網



## Nano Silver Bamboo Activated Carbon Filter Material



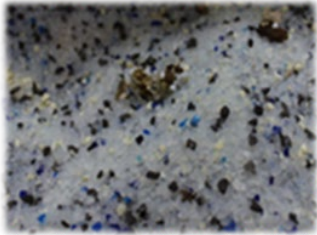


# TBI in ITRI : Present and the Future

## Carbon Negative Material Technology



Materials for people's livelihood



Green building decoration materials

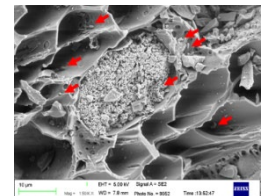
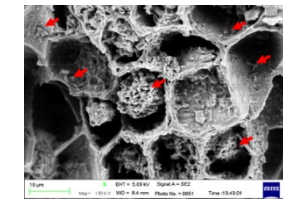


Traditional agricultural applications



Eco-Friendly Pesticides

Functional bamboo biochar



- 竹子二氧化碳吸存能力較一般林木高約 3 ~ 6 倍、接近熱帶林木的 1.5 ~ 2 倍

The carbon dioxide absorption capacity of bamboo is about 3 to 6 times higher than that of ordinary forest trees, and close to 1.5 to 2 times that of tropical forest trees.



工業技術研究院  
Industrial Technology  
Research Institute

Thank  
You

*Thank You for Your Attention*



竹材產業技術諮詢中心

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