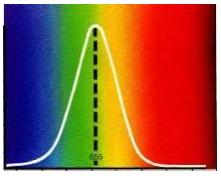
農漁畜牧LED應用跨產業交流講座

LED應用於植物照明

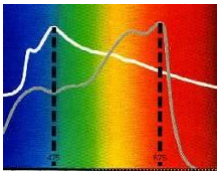
方 煒
台大生機系教授

工研院 2012/08/29

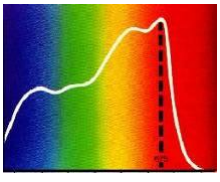
Different Response curves



Lux

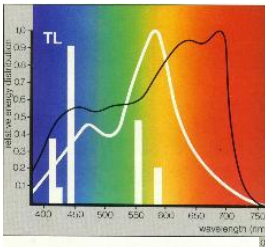


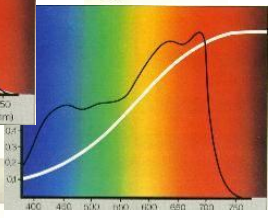
W/m^2

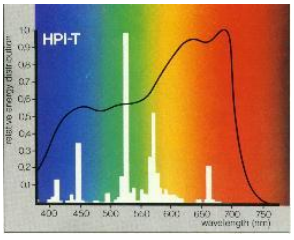


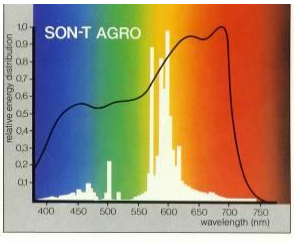
μmol/m$^2_2$/s

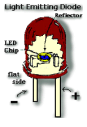
太陽之外的光源





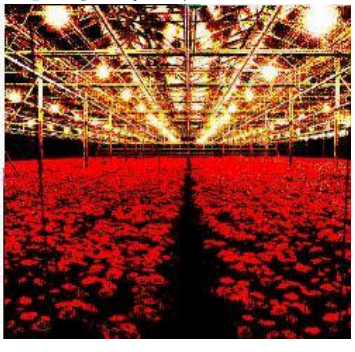






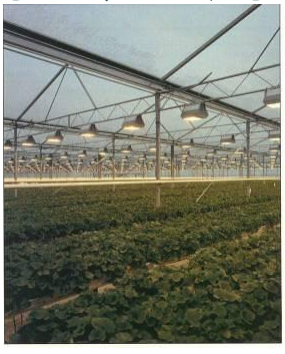
光的不同應用

光週期調控



photoperiodism

光合作用補光

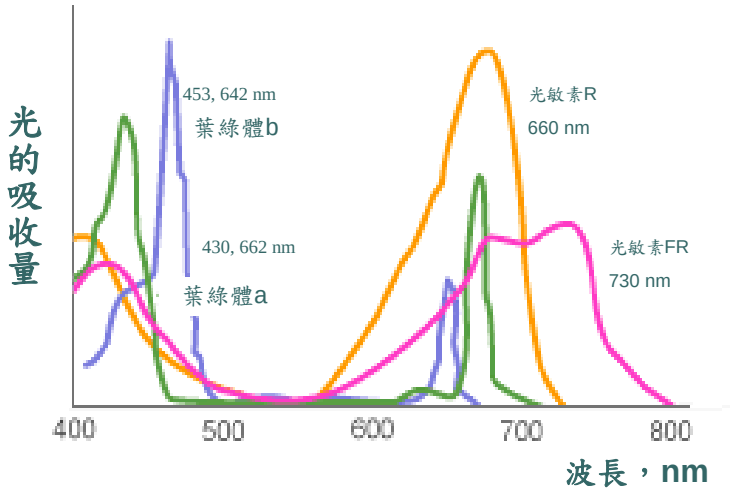


photosynthesis

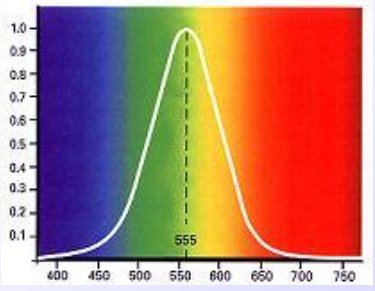
光質影響

photomorphogenesis

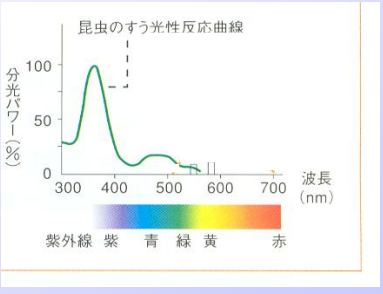
葉綠體a,b 與光敏素R, FR吸收光譜



人與昆蟲對光的敏感度不同

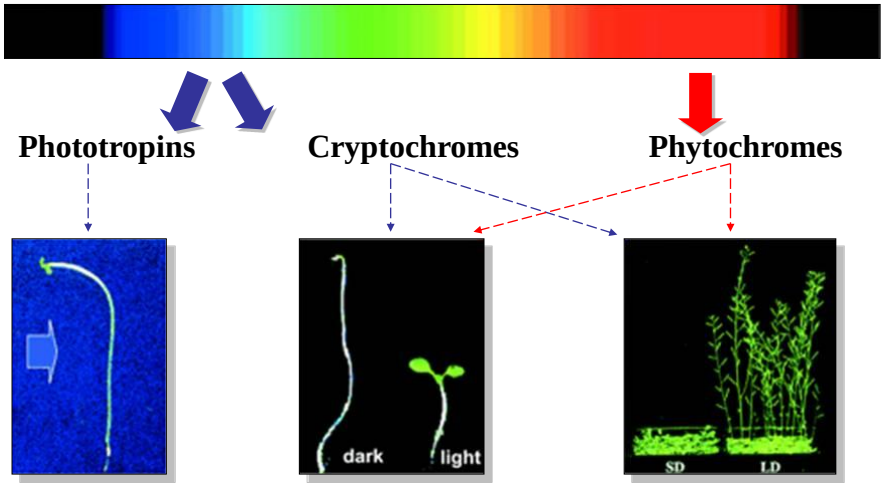


人眼的敏感度曲線



昆蟲眼睛的敏感度曲線

Photomorphogenesis 光形態發生



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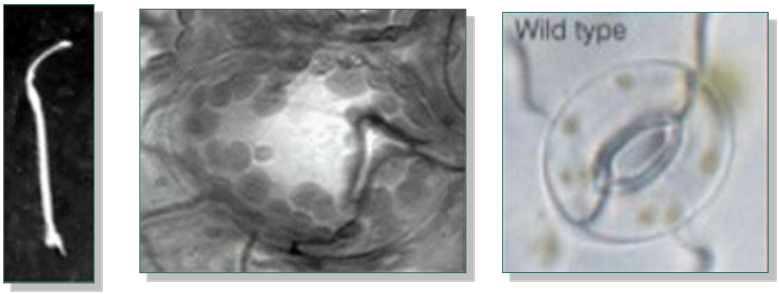
Blue Light

Photoreceptor : phototropins (flavin-containing)



向光性　　葉綠體移動　　氣孔開閉

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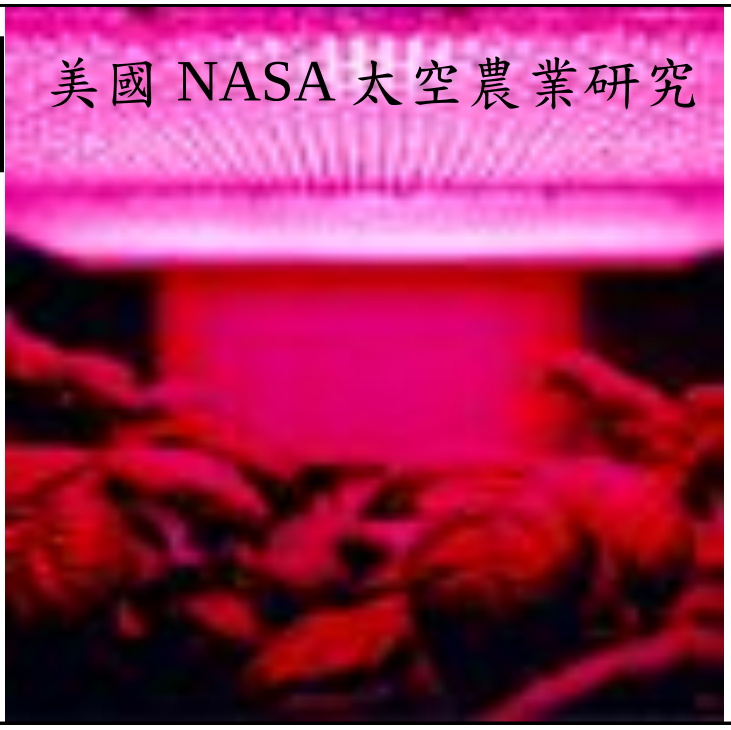
美國 NASA 太空農業研究



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LED 做為園藝照明人工光源

- 組織培養人工光源
- 植物生長箱人工光源

- 短期葉菜類立體化栽培人工光源

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組織培養室

使用燈管，以冷氣散熱

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量產規模組織培養室

使用燈管

以冷氣散熱

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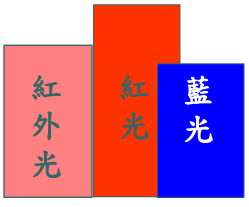
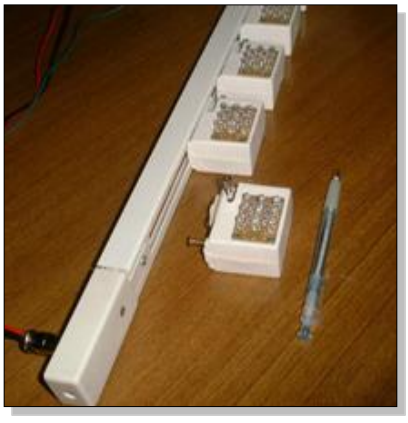
光量，光質，給光頻率與工作比可調



方等2001中華民國專利
方等2002 、2003美國專利
方等2001中國專利

LED 種苗栽培（第一代）

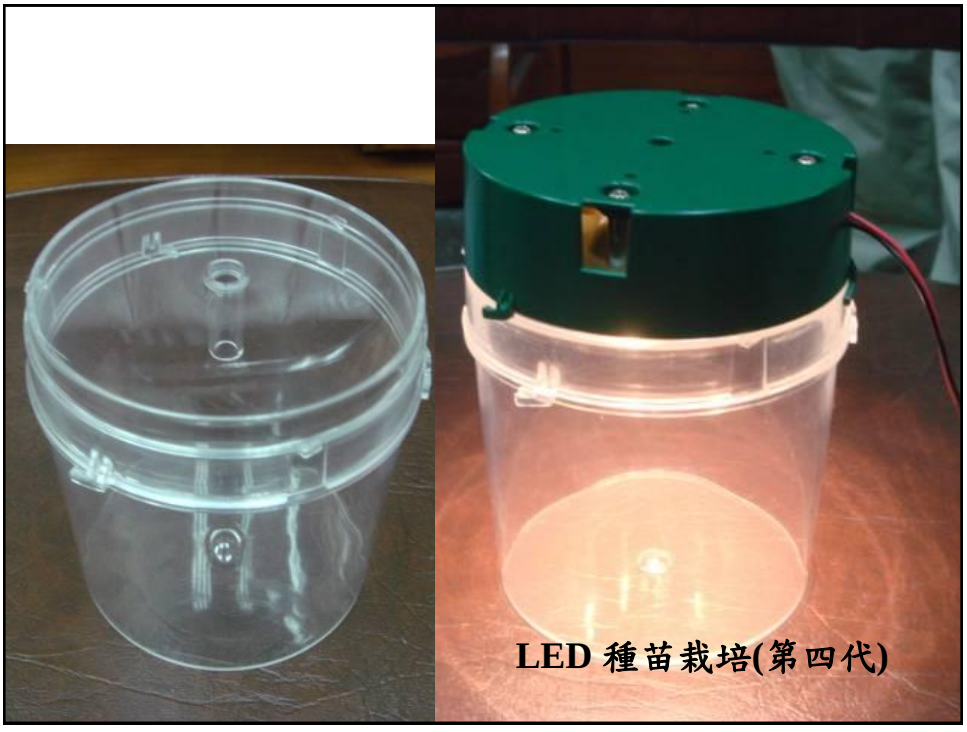
光量、光質、頻率與工作比可調
線上量測頻率、工作比消耗功率與電流




LED 種苗栽培(第二代)


LED 種苗栽培(第二代)


LED 種苗栽培(第三代)


LED 種苗栽培(第四代)

E Light in action

Cool White | Warm White | 6R | 1B1G8R | 1B9R | 6B

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Horti-Fair, 2008

E Light on TC cart 1/3

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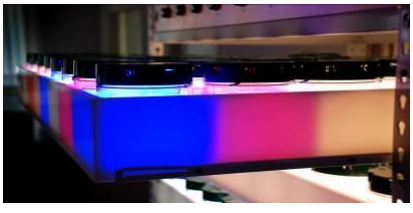
Horti-Fair, 2008

A closer look 2/3



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Horti-Fair, 2008

A closer look 3/3

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Horti-Fair, 2008

Uniform distribution of *E Light* compare with other LED light bench

E Light

Others

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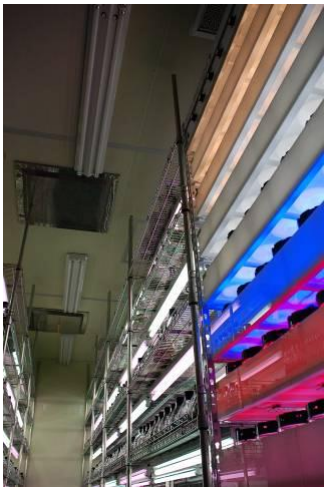
Horti-Fair, 2008

TC lab of the National Natural Science Museum, Taiwan



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植物工廠相關設備

◆ LED植物組織培養系統

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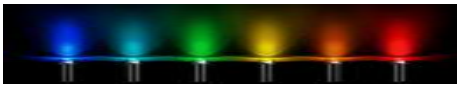
Horti-Fair, 2008

光葉 (*I Light*)



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陳與方 2007 中華民國專利

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Specifications

- Voltage: 100 ~ 240 V
- Power: 1 W

- Electricity fee
  - 0.0048 US$ per 24 hours
  - Assuming 0.2 US$ / kW.hr

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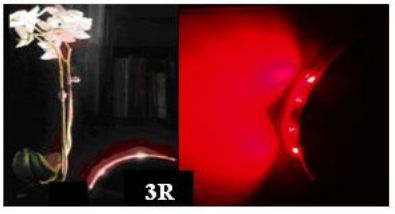
At present, 4 colors are available



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FOUR STAR GREENHOUSE
BANK OF THE WEST
ELLEGAARD A/S7
ATLAS MANUFACTURING INC.
PROGREEN EXPO
FINE AGROCHEMICALS

Finally ··· My favorite product

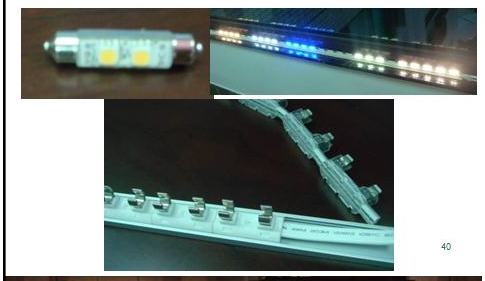
Usually it's a machine or greenhouse innovation, or perhaps some ingenious packaging. But this year it's a silly little light (three LED lights, actually in one of four colors), shaped like a leaf, and intended to be used to illuminate your indoor houseplants. It's both functional and stylish—the light actually helps the plants survive indoors. And it looks cool! Just as lighting your outdoor plants does. It's called the "I-Light, from Nano Bio Light Technology in Taiwan, and the initial estimated wholesale cost is about $35 a pair. You can see how it lights up that orchid that's sitting next to the inventor, Dr. Fang. E-mail him at info@nano-wave.com.tw. It's brand new, and barely on the market, so I don't know how hard or easy it will be to find, but I'd buy a pair or two for my house!

See you next time,

Chris Beytes
Editor & Publisher
GrowerTalks & Green Profit

http://www.ballpublishing.com/growertalks/CurrentNewsletter.aspx

Detachable LED light (2006)
雙頭燈



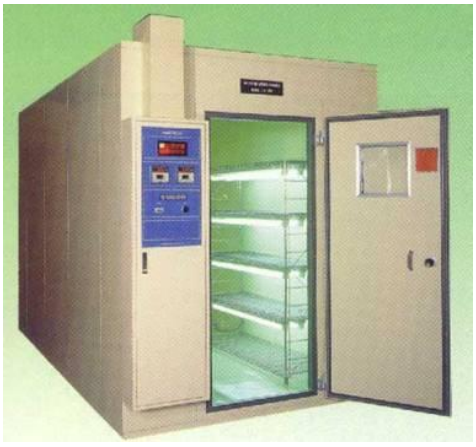
實例：LED 果樹補光(枇杷)

實例：LED 果樹補光(枇杷)

實例：LED 果樹補光(枇杷)

實例：LED 果樹補光(枇杷)

植物生長箱



使用燈管，以冷氣散熱

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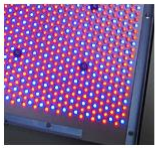
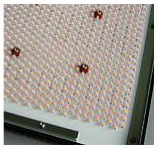
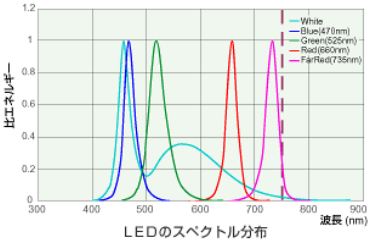
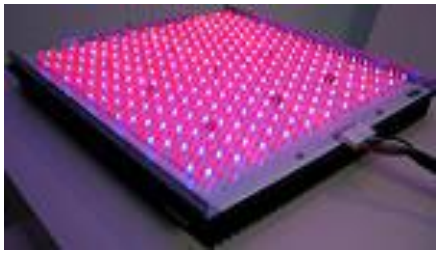
LED植物生長箱光盤







LEDのスペクトル分布



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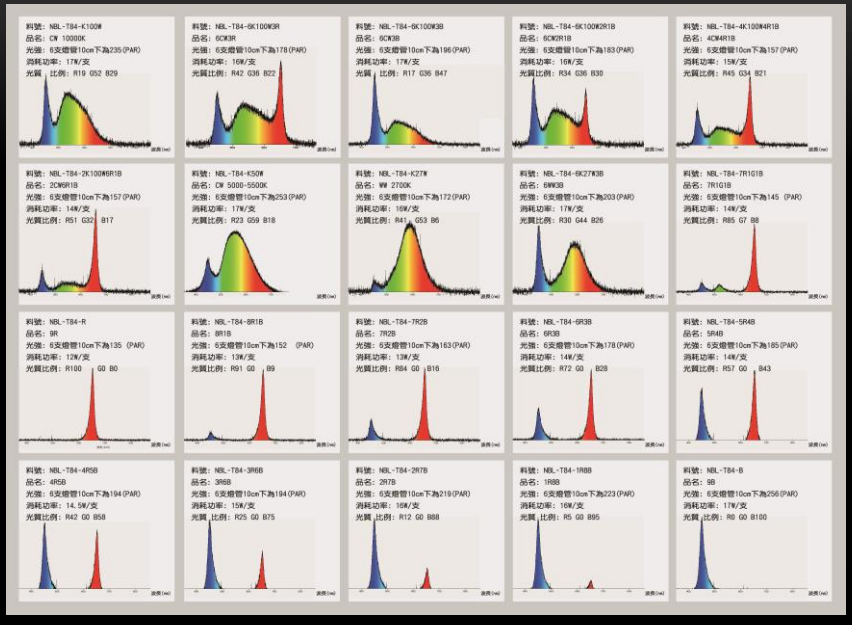
- Trichromatic – RED, BLUE, FAR-RED
- RED, FAR-RED
- RED, BLUE
- BLUE ONLY
- Pulsating LEDs

20種光譜圖



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家庭與社區內LED 蔬菜栽培系統

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層架式 LED 水耕蔬菜栽培系統

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台北花卉博覽會 - 未來館

植物工廠家電化

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台北花卉博覽會 - 爭豔館

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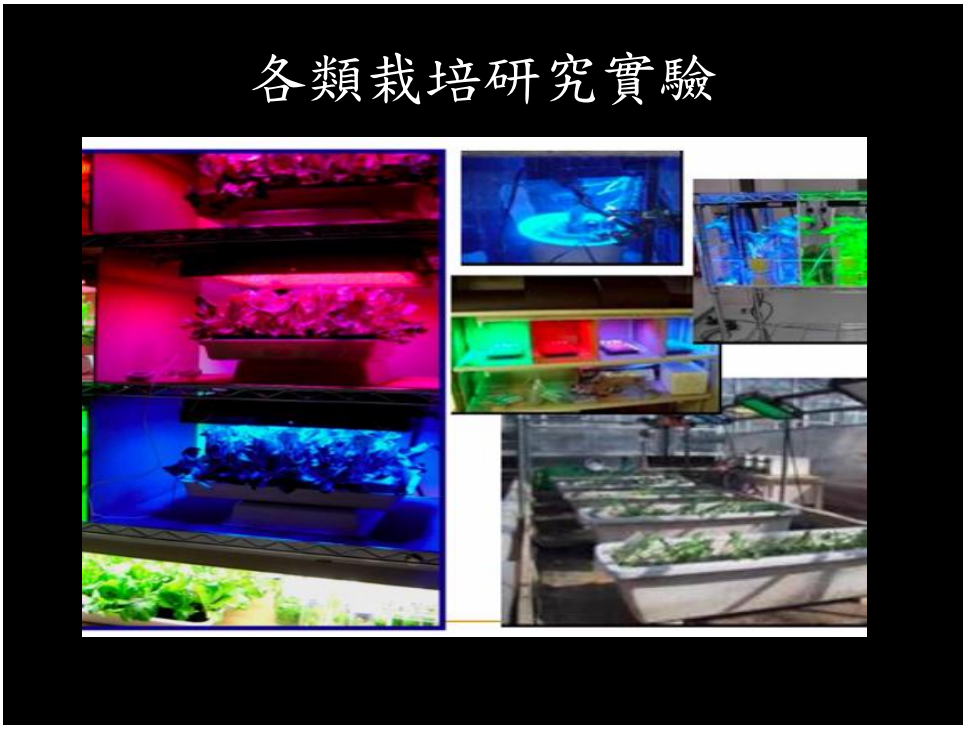
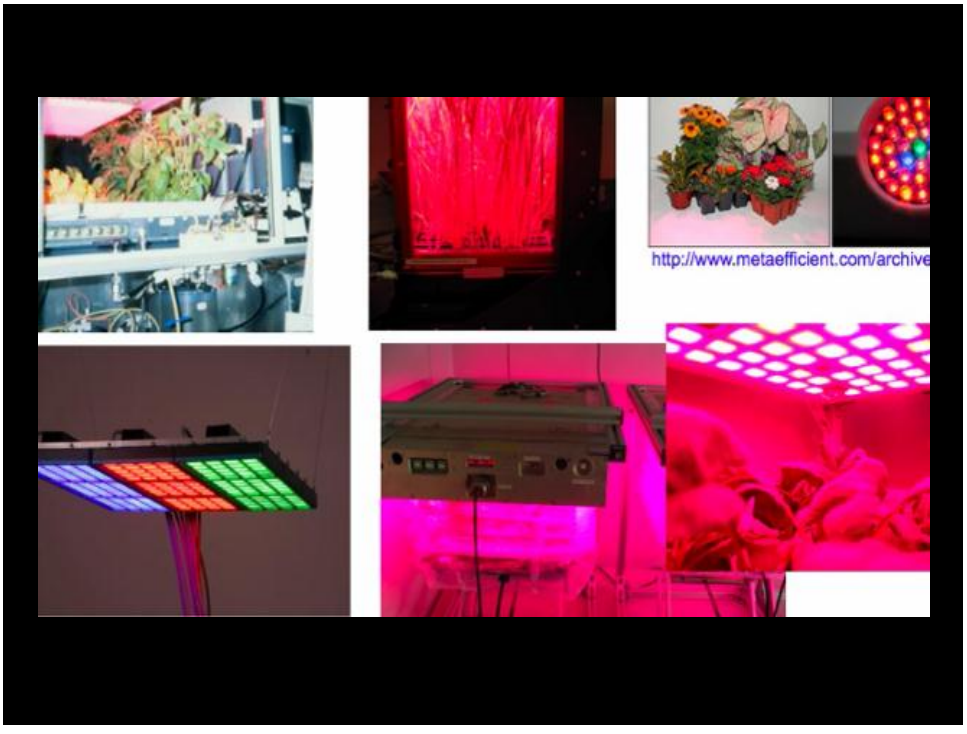
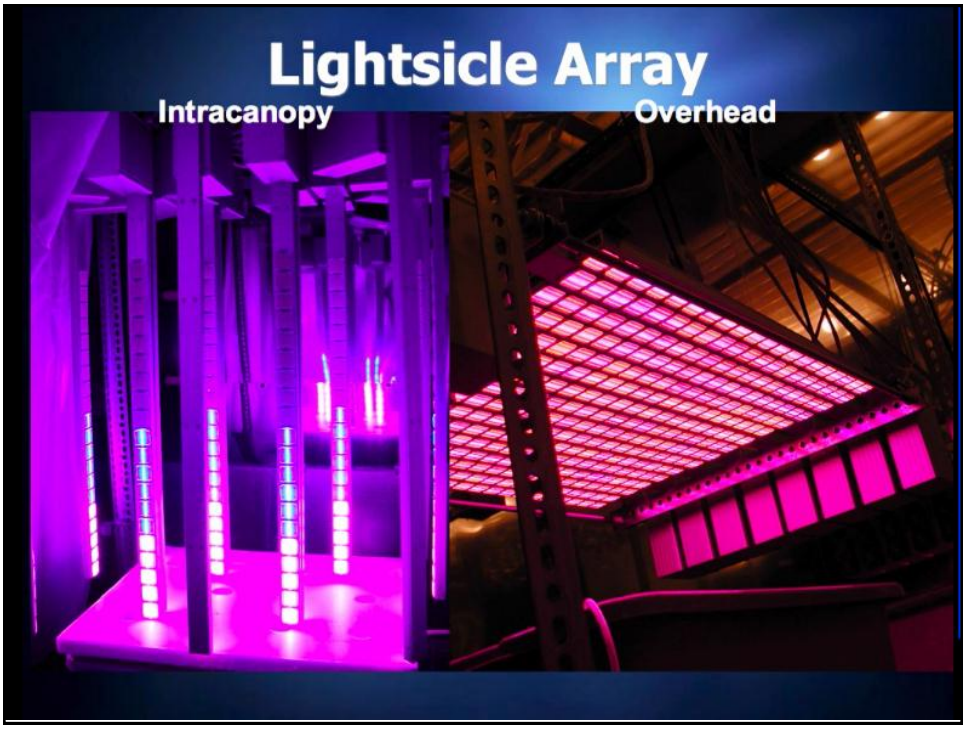
家庭農場

Nano Bio Light 45

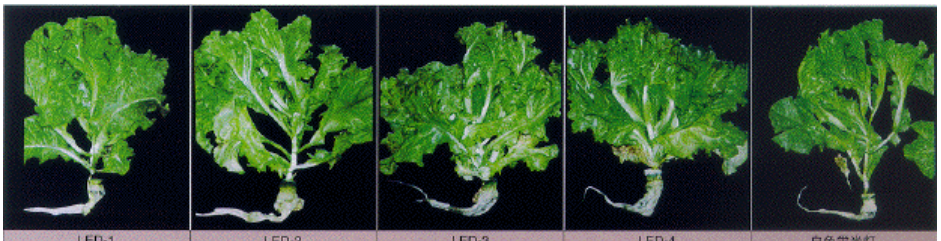

SOFR3SH植物工廠區
SOFR3SH
太 平 洋 鮮 活
47


各類栽培研究實驗


http://www.metaefficient.com/archive


Lightsicle Array
Intracanopy
Overhead

LED應用在蔬菜栽培的研究



LED-1	LED-2	LED-3	LED-4	白色蛍光灯
全光量 80	100	100	100	50
赤色／青色光 72／8	95／5	92／8	90／10	

試験区	LED-1	LED-2	LED-3	LED-4	白色蛍光灯
地上部新鮮重（g／株）	31.1 ±6.2	61.8 ±12.5	80.9 ±14.4	82.7 ±16.9	35.7±8.4
地上部乾重 （g／株）	0.9±0.2	1.8 ±0.4	2.4 ±0.4	2.5 ±0.5	1.2±0.3
草丈 （cm）	32±3	29 ±2	25 ±1	24 ±3	30±2
根部乾重 （mg／株）	188±20	244 ±49	298 ±48	342 ±68	211±42

※栽培日数34日、値は22株の平均値±標準偏差。

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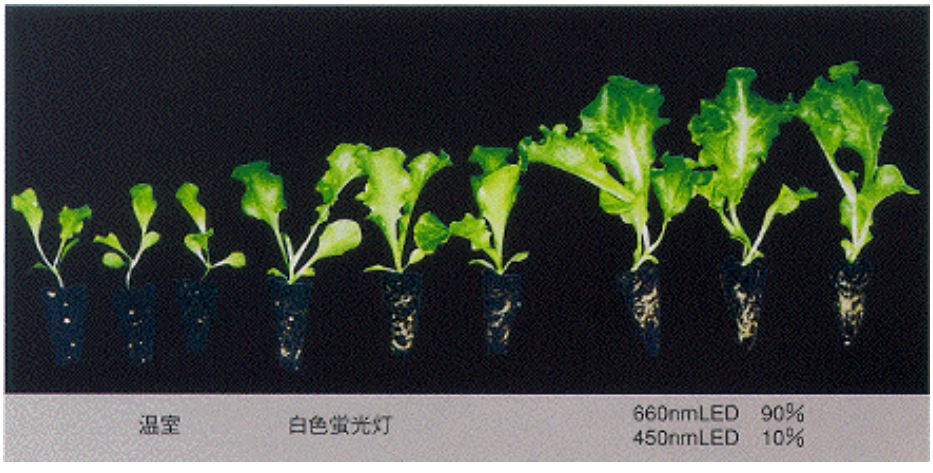
紅藍光比例9:1最佳



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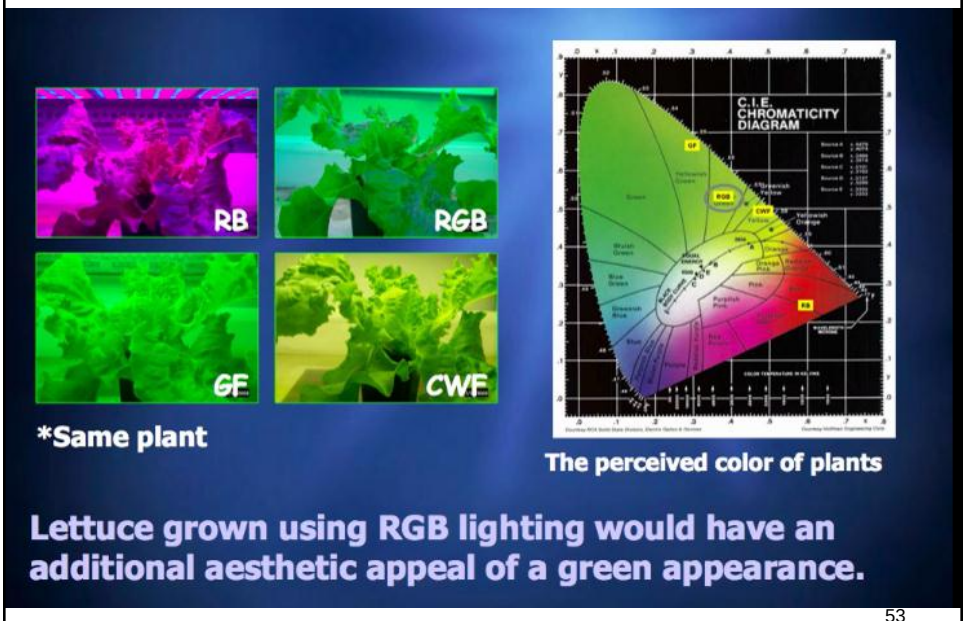

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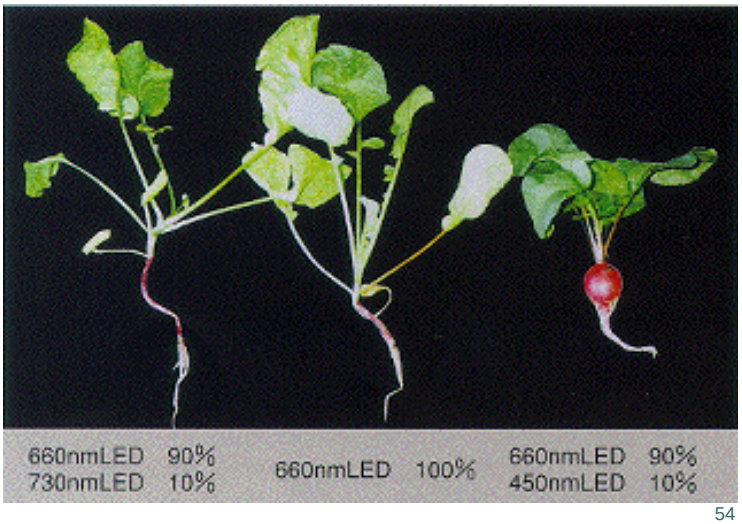
缺藍光，影響地下部形成



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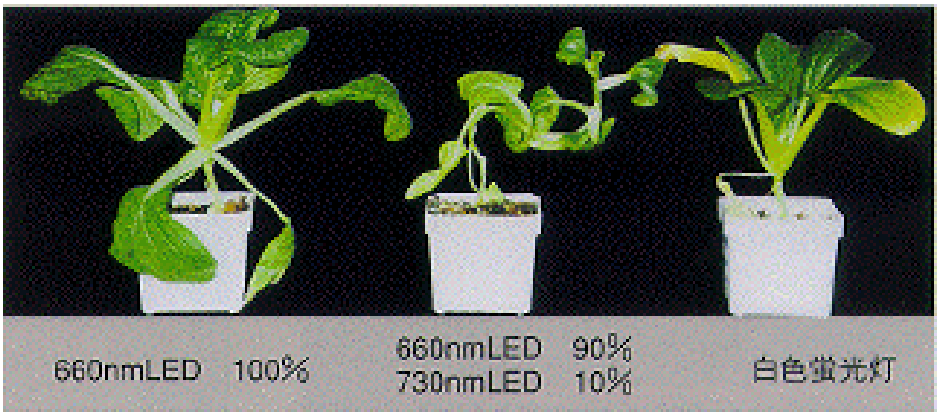
缺藍光，地上部纖細



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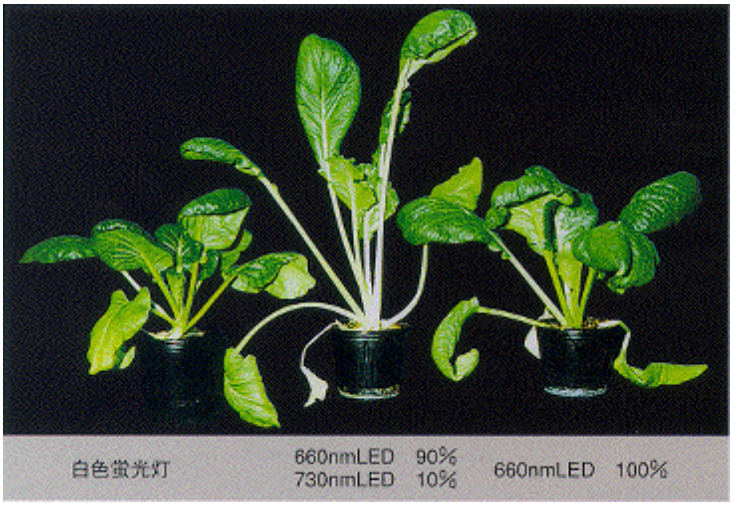
缺藍光，卻有紅外光，更纖細



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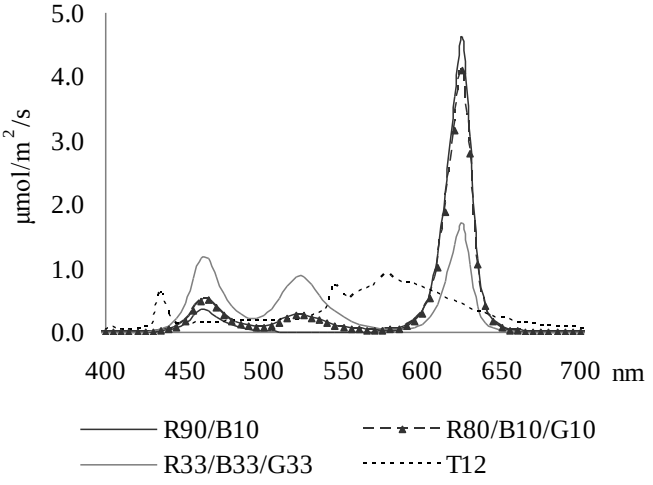
LED蔬菜栽培



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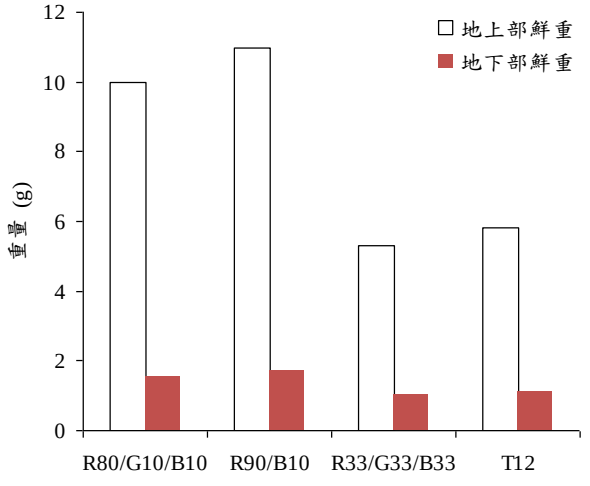
葉萵苣14天之重量比較



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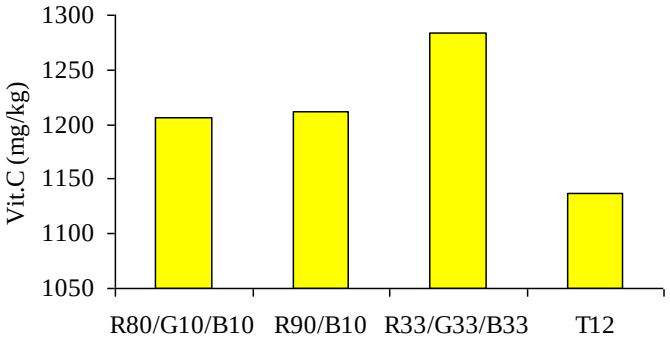
萵苣維他命C含量之比較

- LED栽培之萵苣維他命C含量均較T12栽培者含量高，尤其以等比例混光之白光最顯著



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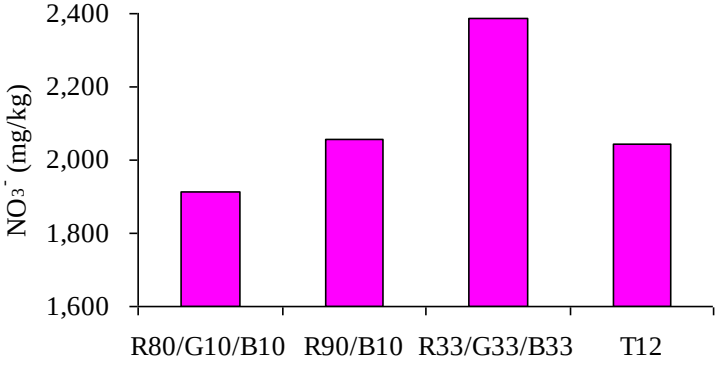
萵苣硝酸鹽含量之比較

- 加強紅光可降低硝酸鹽含量（< 2100 ppm）
- 加入少量綠光可進一步減少硝酸鹽含量（<2000 ppm）



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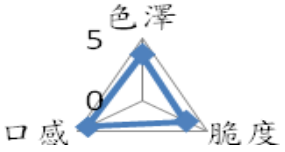
葉萬苣官能品評

(a) R80/G10/B10

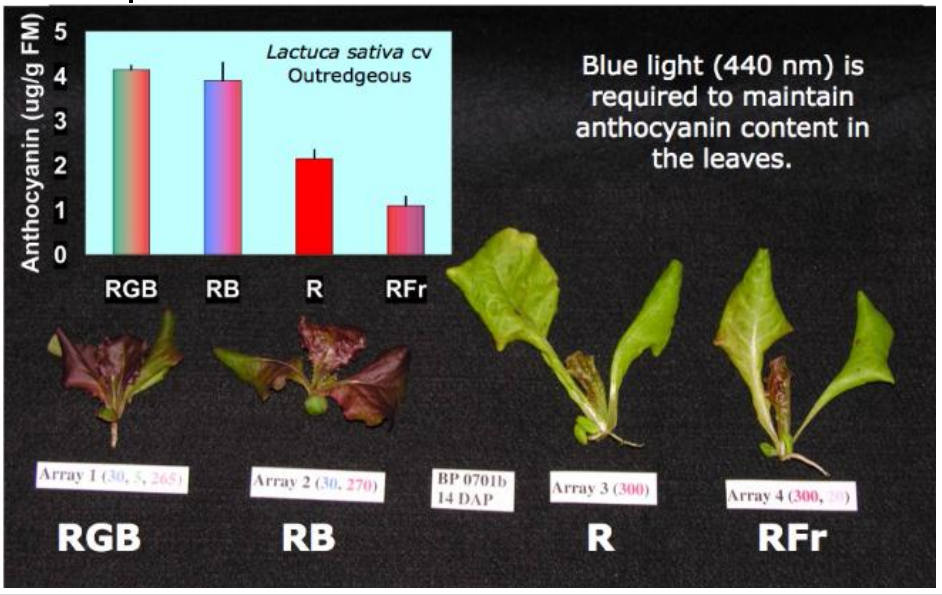


(b) R90/B10

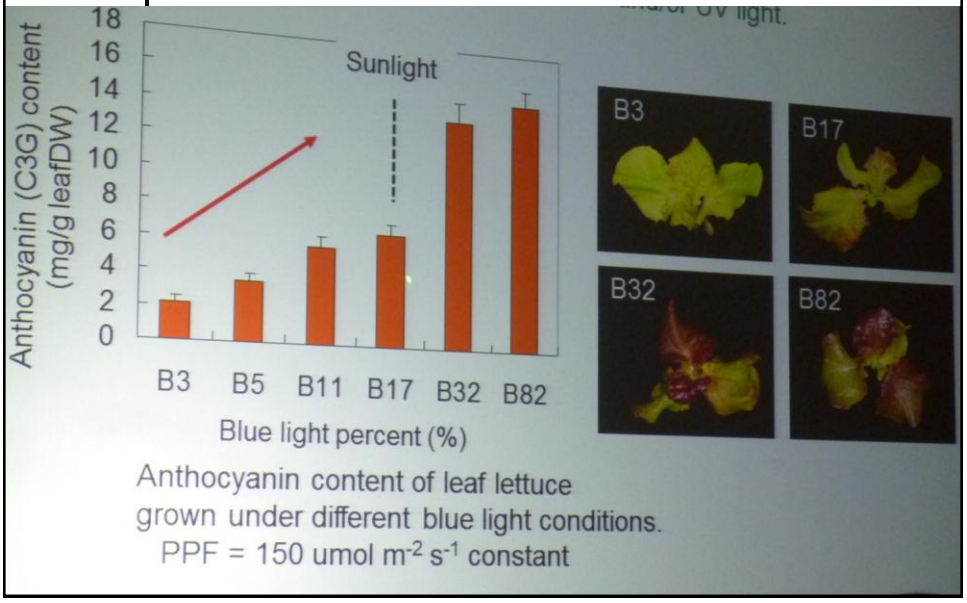
(c) R33/G33/B33

(d) T12

光質影響花青素的形成



藍光影響花青素形成



Anthocyanin content of leaf lettuce grown under different blue light conditions. PPF = 150 umol m^{-2} s^{-1} constant

LED光質對紅橡木萵苣內色素累積 與 抗氧化力之影響

分析項目

鮮重、乾重、葉面積、

花青素、總酚、清除 DPPH 能力、

類胡蘿蔔素、葉綠素、葉黃素、

維他命C (或稱抗壞血酸)

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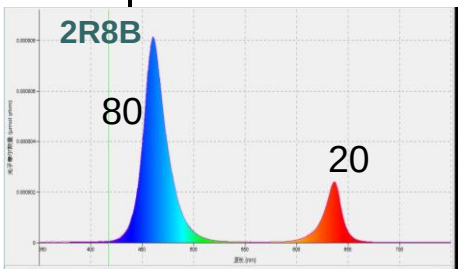
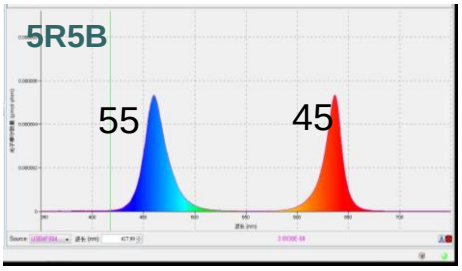
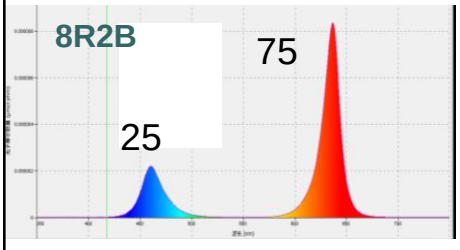
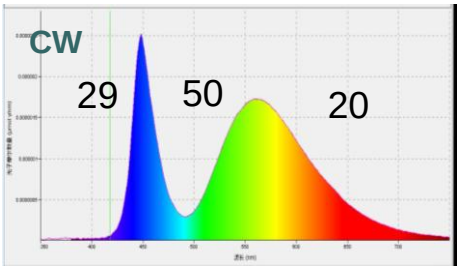
四種LED光源之光譜





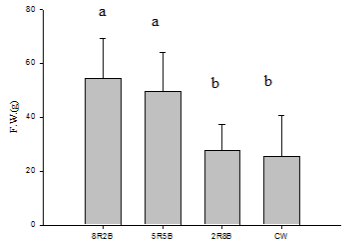




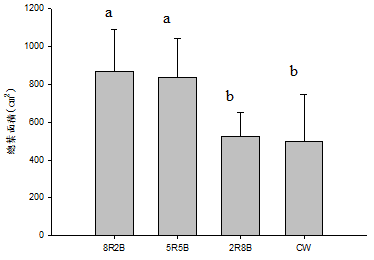
四種LED光源之分光配比

處理	R	G	B
2R8B	20	0	80
5R5B	45	0	55
8R2B	75	0	25
CW	20	50	29

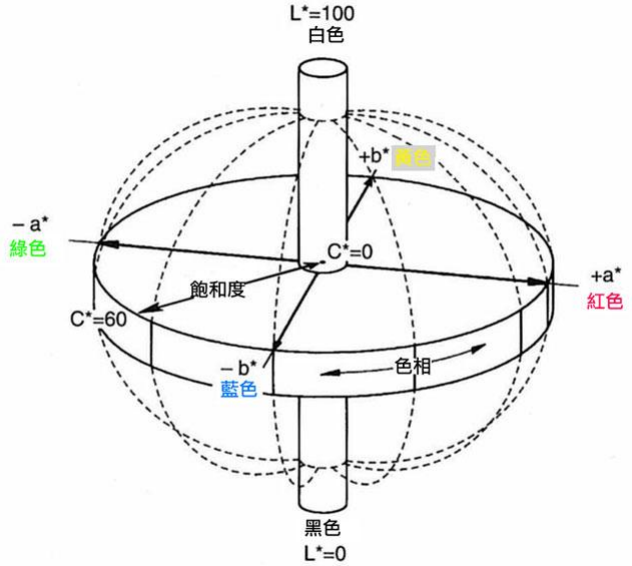
8R2B與5R5B會提高紅橡萵苣鮮重，2R8B與CW會降低萵苣鮮重，藍光比例增加到80%會抑制萵苣生長



8R2B與5R5B會提高紅橡萵苣葉面積，2R8B與CW會降低萵苣葉面積，藍光比例增加到80%會抑制萵苣生長



處理
8R2B
5R5B
2R8B
CW



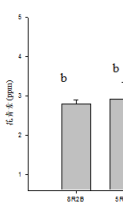
葉片顏色較淡

光比例增加

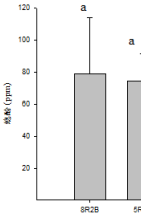
光質對紅橡萬苣葉片色素之影響

處理	葉綠素 a	葉綠素b	a/b	類胡蘿蔔素	葉黃素
8R2B	1.17 b	0.34 b	3.49	0.44 b	8.41 b
5R5B	1.31 a	0.49 a	2.74	0.50 a	11.8 a
2R8B	1.18 b	0.36 b	3.35	0.45 ab	9.87 ab
CW	1.04 c	0.29 b	3.65	0.38 c	8.37 b

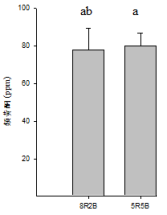
2R8B會提高紅橡萬苣



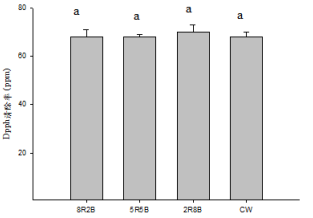
CW會降低總酚的含量



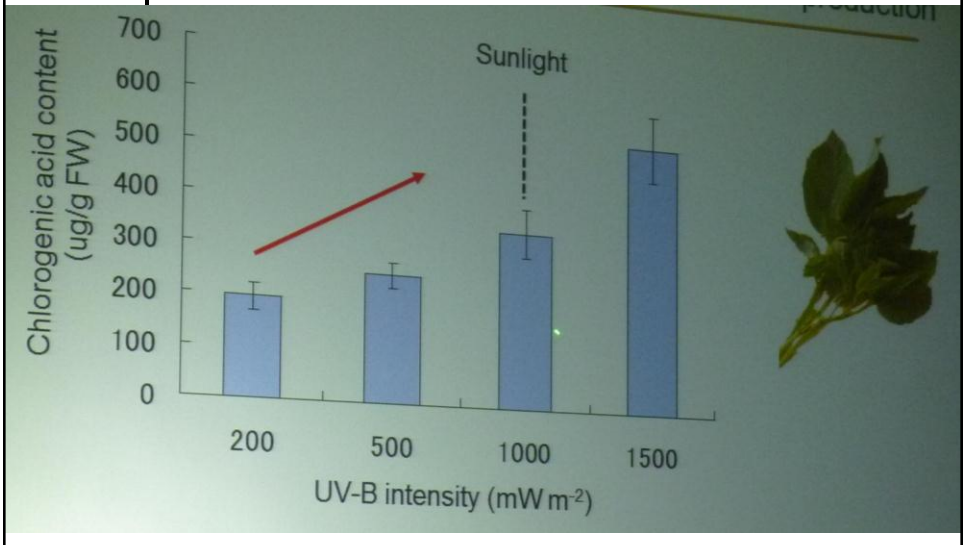
CW有最低的類黃酮含量，



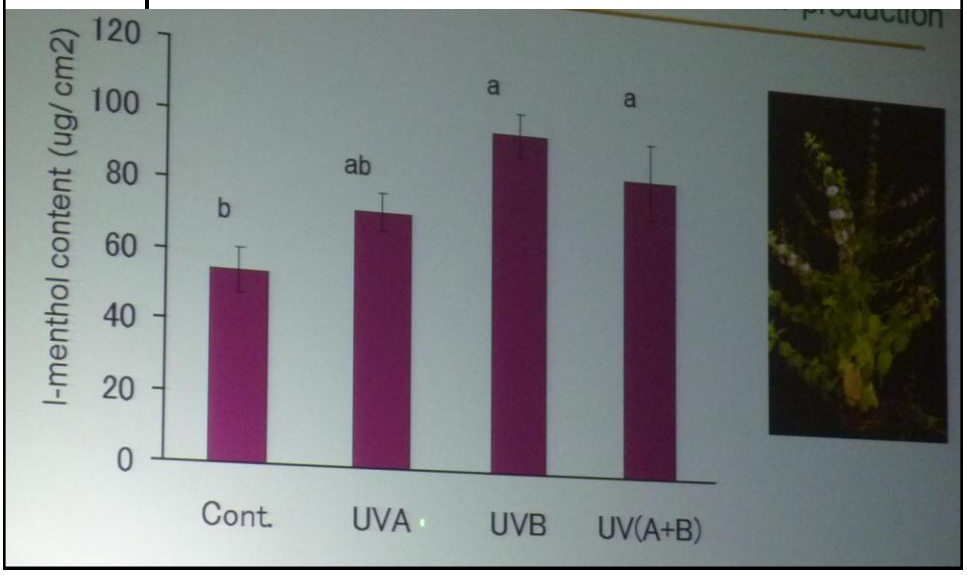
DPPH清除率沒有顯著差異



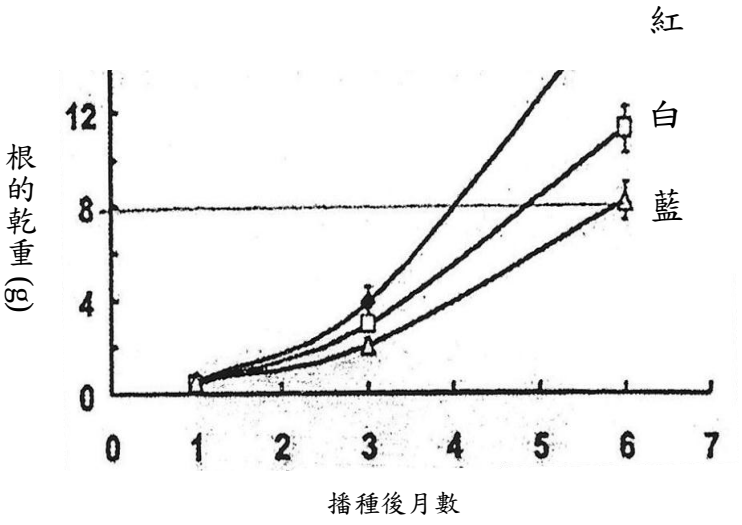
UVB 影響綠原酸產量



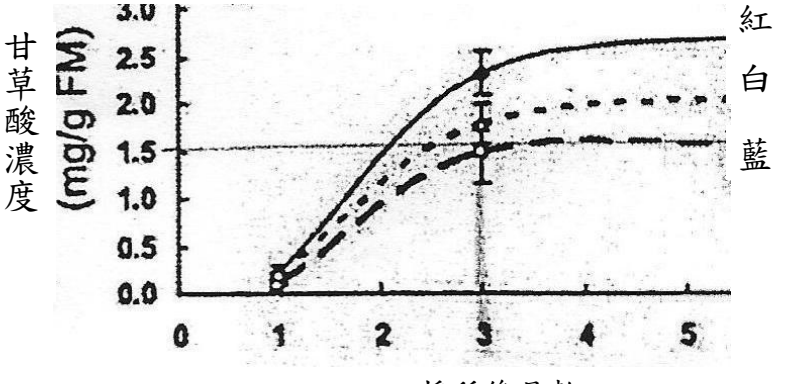
UVB 影響 左旋薄荷 產量



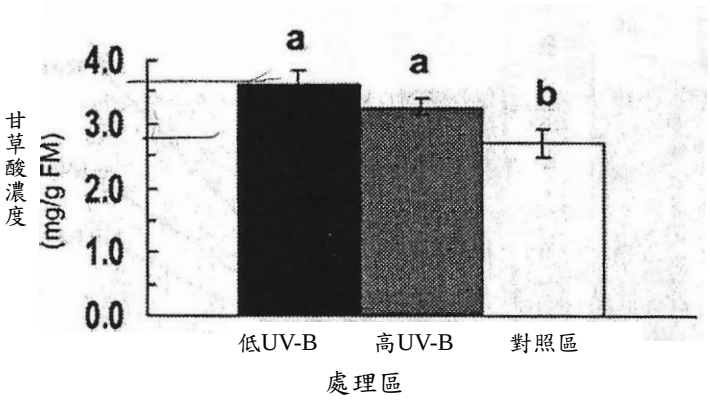
光質對甘草根部乾重的影響



光質對甘草根部甘草酸濃度的影響

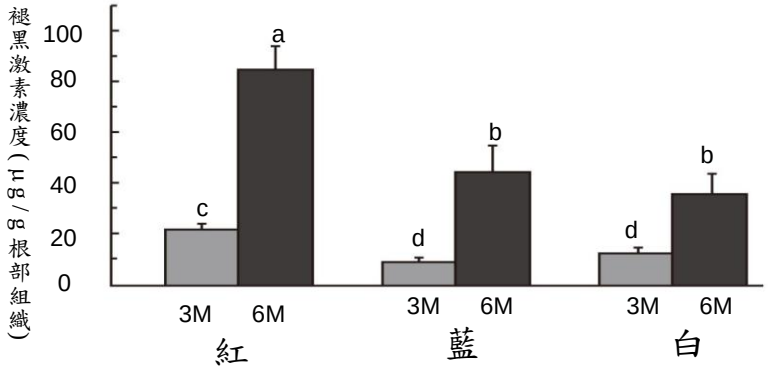


UV-B照射對甘草根部乾草酸濃度的影響



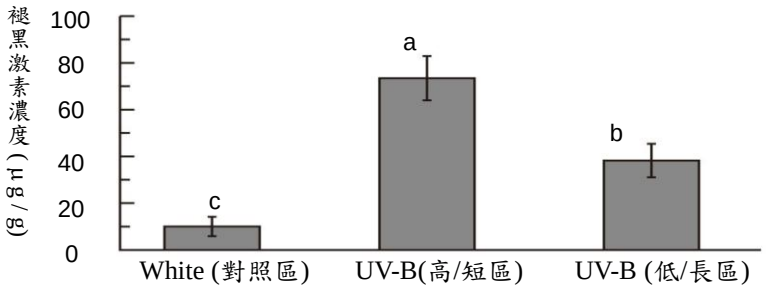
以0.43 Wm^{-2}的低UV-B照射15日 = 6.45 W日 m^{-2}
以1.13 W m^{-2}的高UV-B照射3日 = 3.39 W日 m^{-2}

光質對甘草根部褪黑激素濃度的影響



以紅、藍與白色螢光燈栽培3個月(3M) 或6個月(6M) 的甘草 (Glycyrrhiza uralensis) 根部所含的褪黑激素（melatonin)濃度（μg/g ）。PPF: 300 μmol m^{-2} s^{-1}; 氣溫: 明期28 ℃ /暗期26℃ (Afreen, et al., 2006).

光質對甘草根部褪黑激素濃度的影響



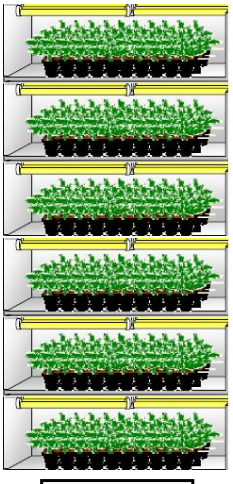
播種3個月後的甘草在①白光（對照區）中栽培15日，②照射白光12日及強烈紫外線3日（3日累積照射量為54.2 W・hr/m^2），高/短區），③照射弱紫外光（UV-B、280-315 nm) 15日（15日累積照射量為103.2 W・hr/m^2，低/長區）後根部所含褪黑激素濃度。

所有處理區的PPF (光合作用光量子通量) 皆為 300 μmol m^{-2} s^{-1}。

植物的生育條件：PPF：300 μmol m^{-2} s^{-1} ，無UV-B照射。相對濕度：65-70%；CO_2 濃度：1000 μmol mol^{-1}；氣溫： 明期28 / 暗期26℃ (Zobayed, et al., 2006).

完全使用人工光的植物工廠

垂直農場



Single layer

multilayer

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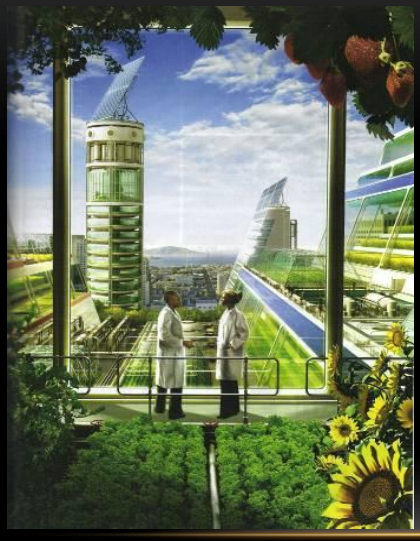
植物工廠的特色



垂直農場：在城市摩天大樓裡種植作物，要比戶外農場栽種還要省水、省燃料，亦能消除農業降雨逕流、提供城市居民更新鮮的食物更大大降低探足跡。

- 定期、定量與定品質的生產，生產成本固定
- 節省水資源
- 『安全、 安心』：
  - 無農藥、無重金屬、低硝酸鹽
- 不受環境限制：
  - 風吹、雨打、日曬、蟲侵
- 使用空間率高：
  - 多層與立體化栽培

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微藻減碳養殖場

火力發電廠所產生的排煙經過脫硫後用來培育藻類，讓藻類吸收CO_2轉化為Biomass並產生氧氣，減少CO_2 的排放量。

微藻可做為健康食材與化妝品等，最終廢棄物也可作為生質能源。

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微藻減碳養殖場

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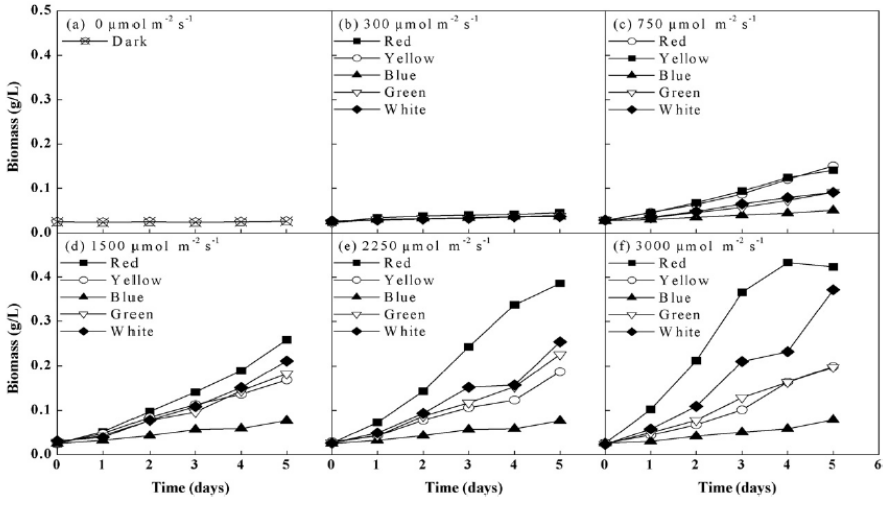
光質對螺旋藻生長的影響



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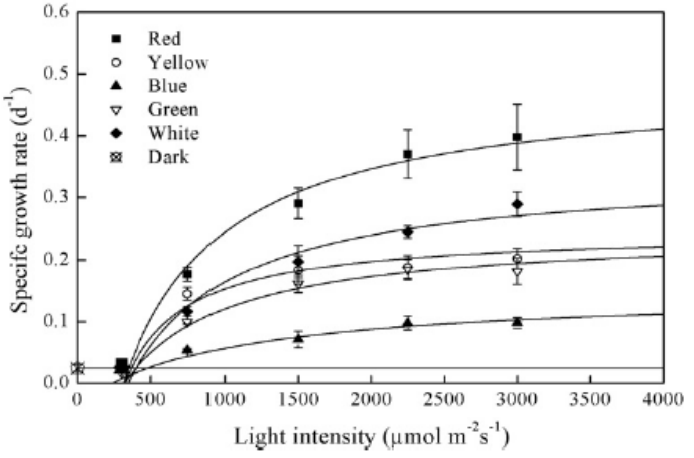
生長模式



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生長模式

$$\mu - \mu_0 = \frac{\mu_{\max}(I - I_0)}{K_s + (I - I_0)}$$

Light sources	μ_{max} (day^{-1})	K_s ($\mu mol\ m^{-2}\ s^{-1}$)	I_0 ($\mu mol\ m^{-2}\ s^{-1}$)
Red	0.44	461.2	391.3
Yellow	0.22	459.4	366.0
Blue	0.12	1460.4	475.6
Green	0.22	781.3	397.1
White	0.32	773.5	398.4

[a] μ_0 was set at 0.02 (day^{-1}) in the fitting.

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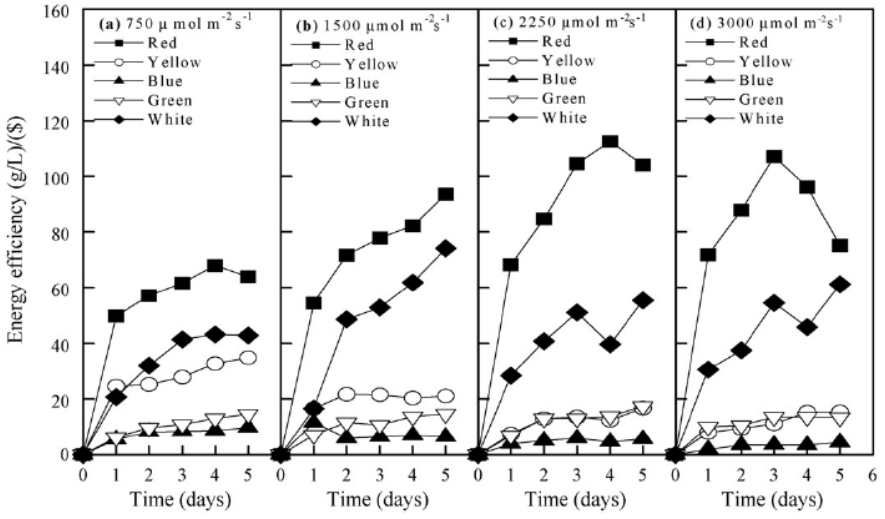
Biomass/耗電成本



植物工廠人工光源的演進

低效率的人工光源　代表

- **低光量**
- **更多廢熱**
- **加大燈具與植物的距離**
- **更多空調能量消耗以移走額外熱能**

植物工廠使用的光源

1. 金屬燈 MH
2. 高壓鈉燈 HPS
3. 螢光燈管 FL（仍是主流）
4. 冷陰極管 CCFL
5. 發光二極體 LED

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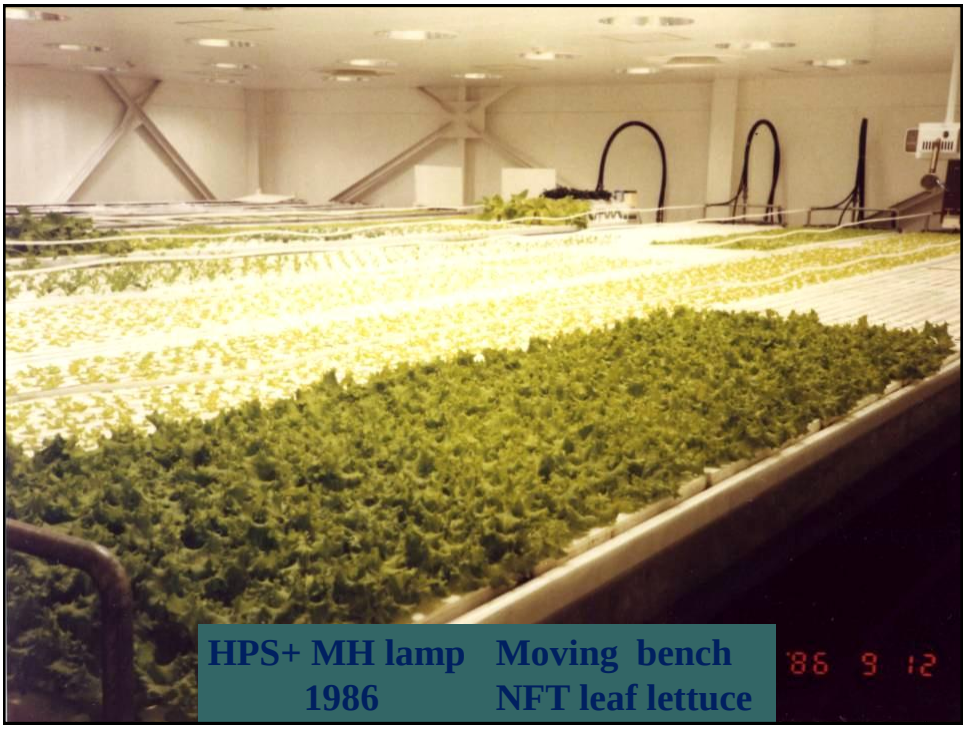
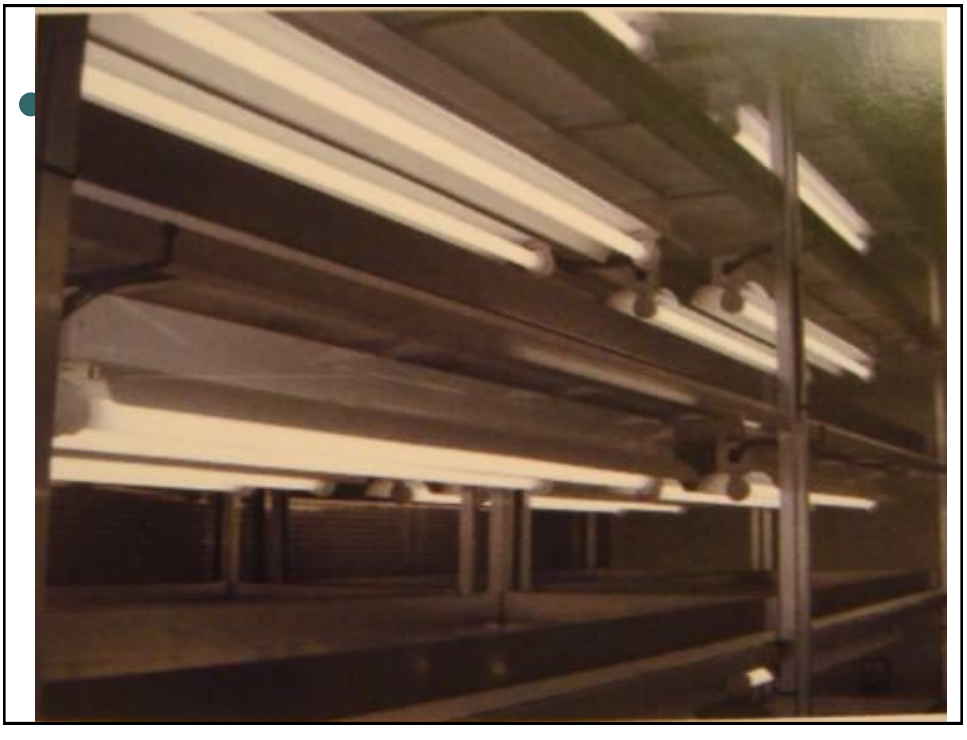


HPS lamp **Layered bench (3 layer):1 layer = 1 m**
1991 **NFT leaf lettuce**

Lamp jackets to remove heat from HPS lamp




Fluorescent lamp Multi-layer(10)
2004 NFT leaf lettuce

Fluorescent lamp Multi-layer(7):1 layer = 38cm
2007 NFT leaf lettuce

LED蔬菜工廠

- 植物栽培用光源爲改良型水冷式紅色LED（660 nm）。
- 以薄膜水耕法(NFT)栽培生菜、芹菜等葉菜
- 產能：5900株/日，150萬株/年。

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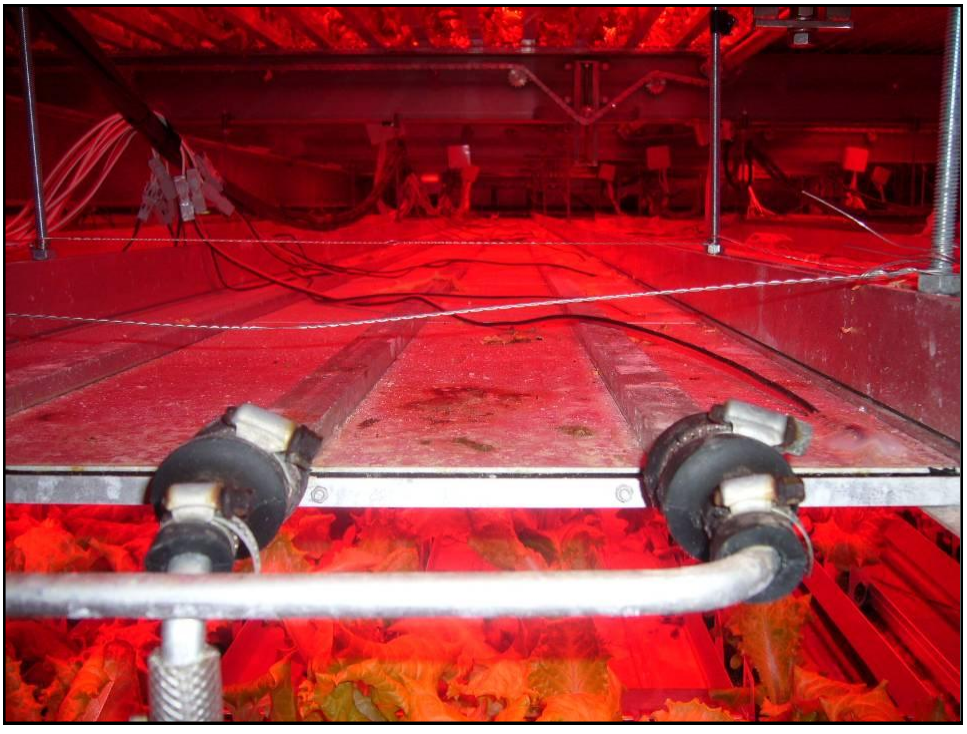
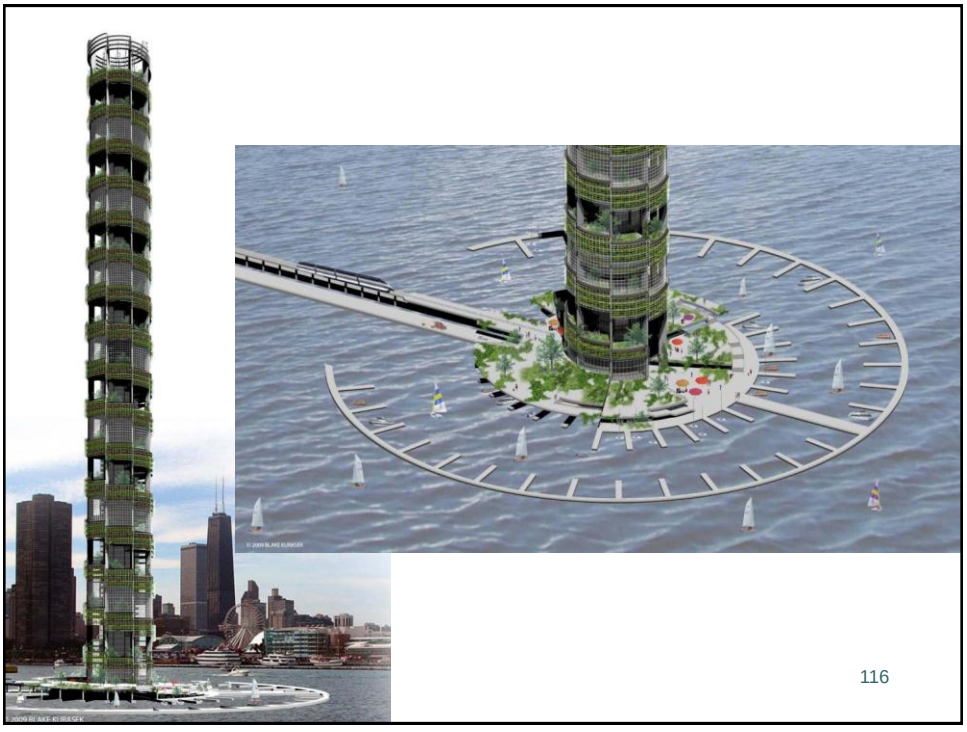
栽培區

栽培區

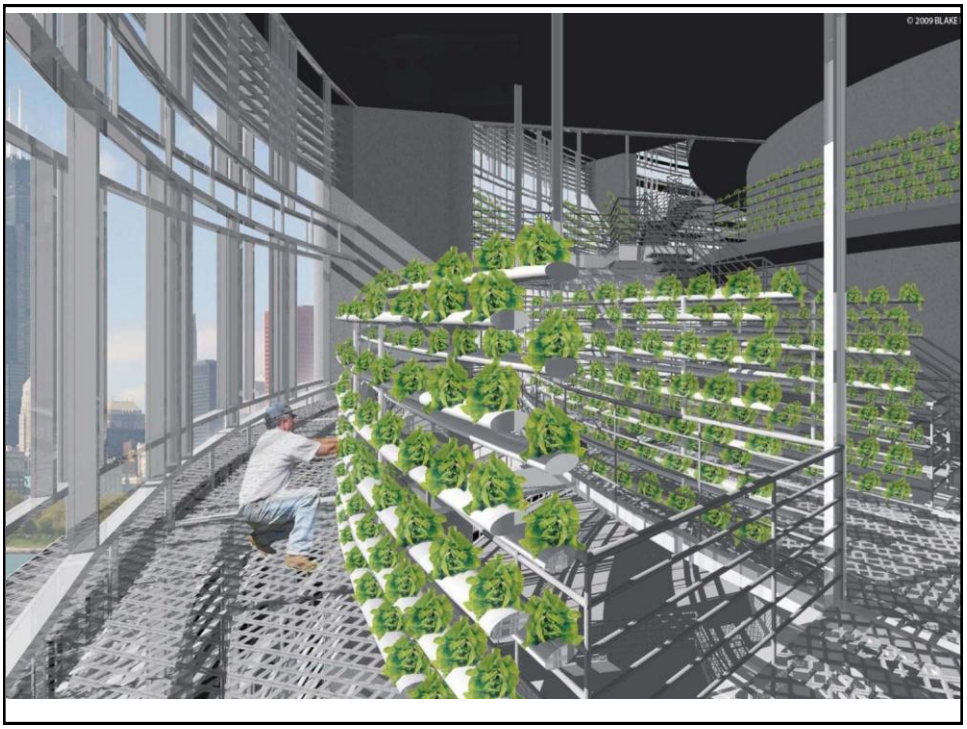
Commercial lettuce production using red LEDs
Cultivation area: 800 m^2 in 169 m^2 building (multi-layered system)
Production capacity: 1.5 million lettuce heads per year

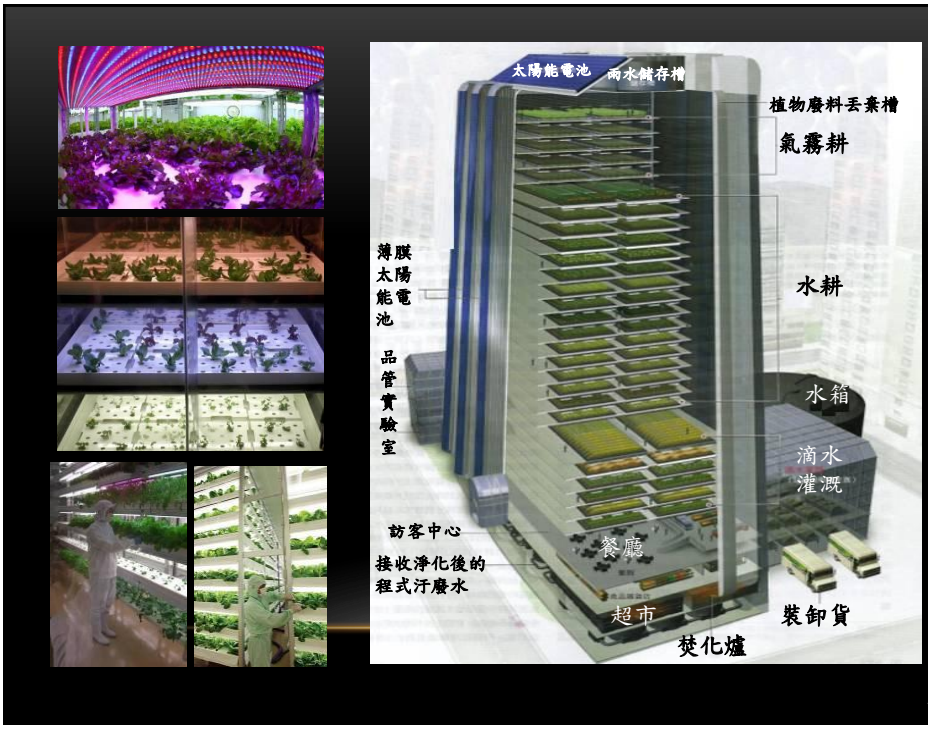


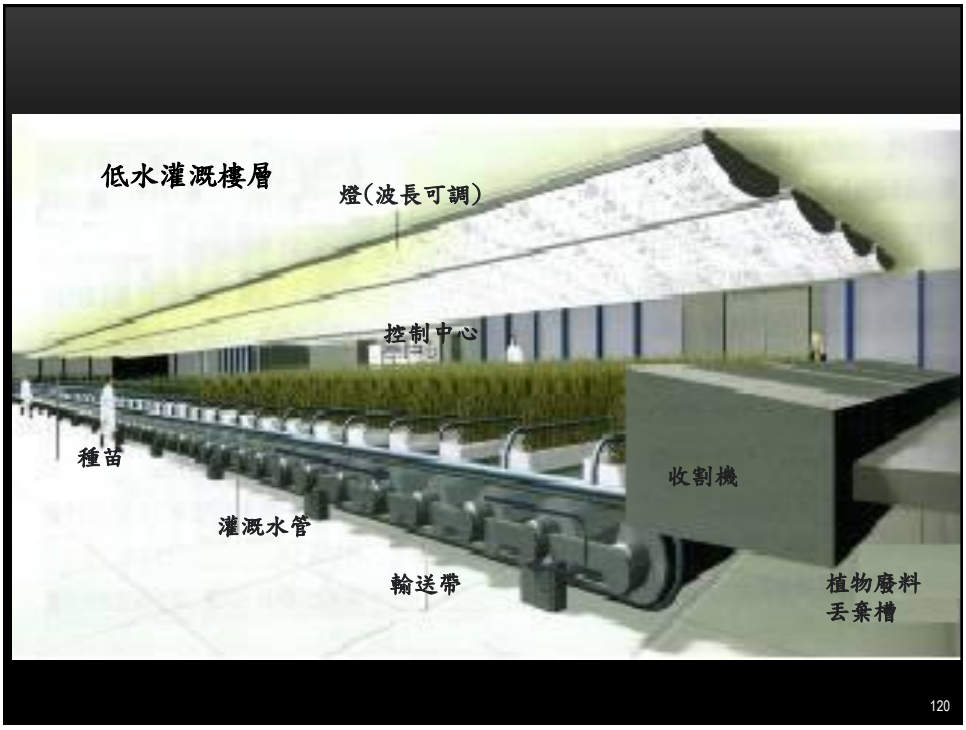

マイコミジャーナル




vue depuis le pont de l'Alma


© 2009 BLAKE


太陽能電池
雨水儲存槽
植物廢料丟棄槽
氣霧耕
薄膜太陽能電池
水耕
品管實驗室
水箱
滴水灌溉
訪客中心
接收淨化後的程式汙廢水
餐廳
超市
裝卸貨
焚化爐
119


低水灌溉樓層
燈(波長可調)
控制中心
種苗
灌溉水管
輸送帶
收割機
植物廢料丟棄槽
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結論

- 生物體光生理學值得深入了解
- LED結合再生能源可做出重大貢獻
- LED做植物栽培光源具高度價值
- LED做植物工廠人工光源已可實用化
- LED的紫外線光源與應用值得注意

謝謝聆聽　敬請指教!!!