HKU botanists discover plant growth technology that may alleviate climate change and food shortage

港大植物學家研發植物生長技術助緩解氣候變化和糧食短缺問題

Dr. Wallace LIM Boon-leong

BSc.(CUHK) D. Phil (Oxon)

School of Biological Sciences

The University of Hong Kong

香港大學生命科學學院

副教授林文量博士

World Population Prospect of the United Nations (2015)

世界人口趨勢 (1950-2050)

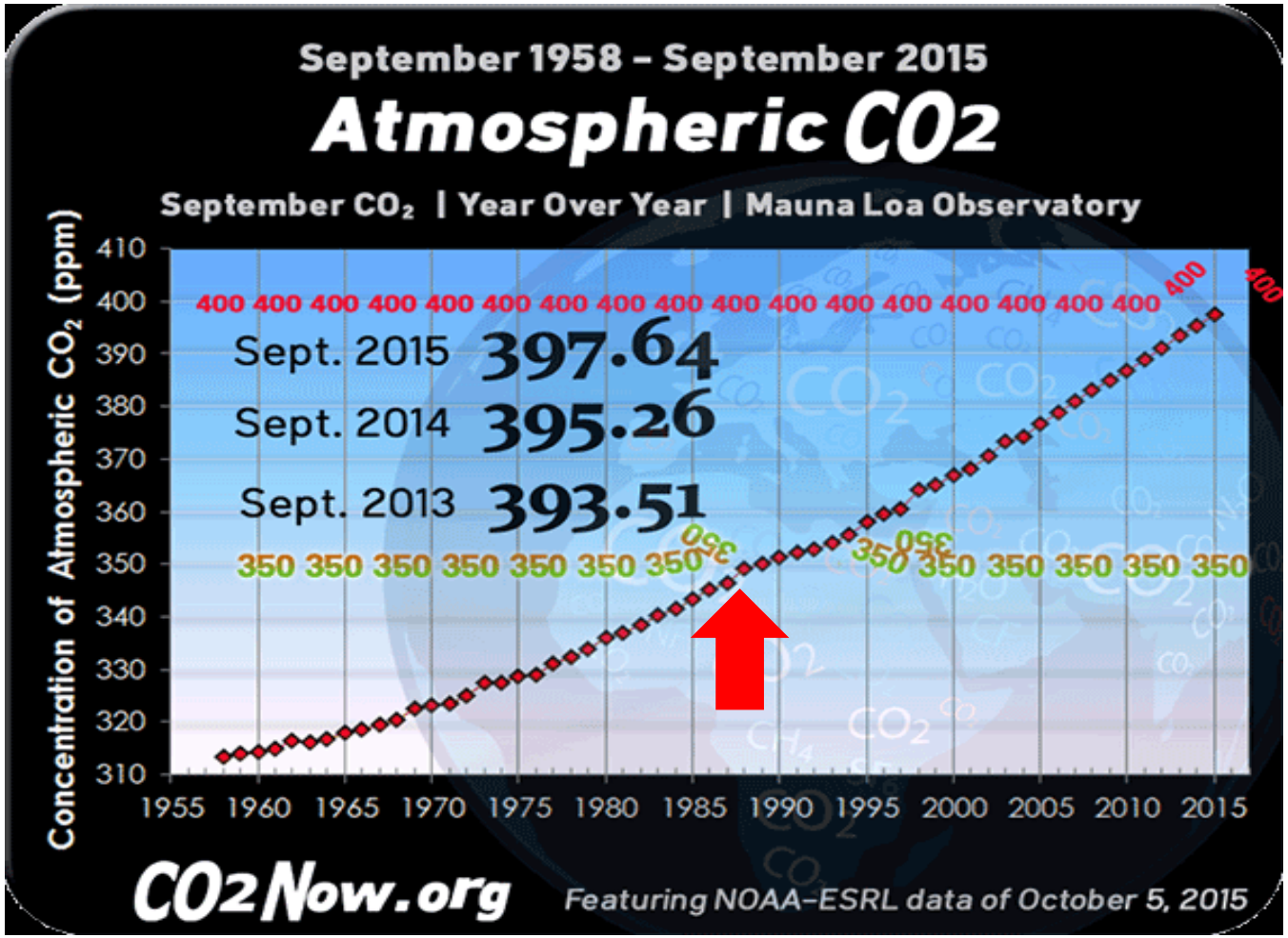
- By 2050, the global population will reach 9.7 billion, meaning a 57% increase since 2000
- 2050年世界人口將增加到97億比2000年增長57%

How much more food do we need?人類需要增加多少食物?

FAO warns world must produce 60% more food than 2005/07 by 2050 to avoid mass unrest (UN Food and Agriculture Organization, Assistant Director-General Dr. Hiroyuki Konuma, 10 Mar 2014)
聯合國糧農組織警告2050全球糧食產量比2005/07必需增加60%去避免糧食不足引起的動亂

Every moment everyone of us is releasing CO_2 to the atmosphere and leave it to the next generation

我們每一個人每時每刻都在釋放二氧化碳,留給下一代



Drop?

http://co2now.org/

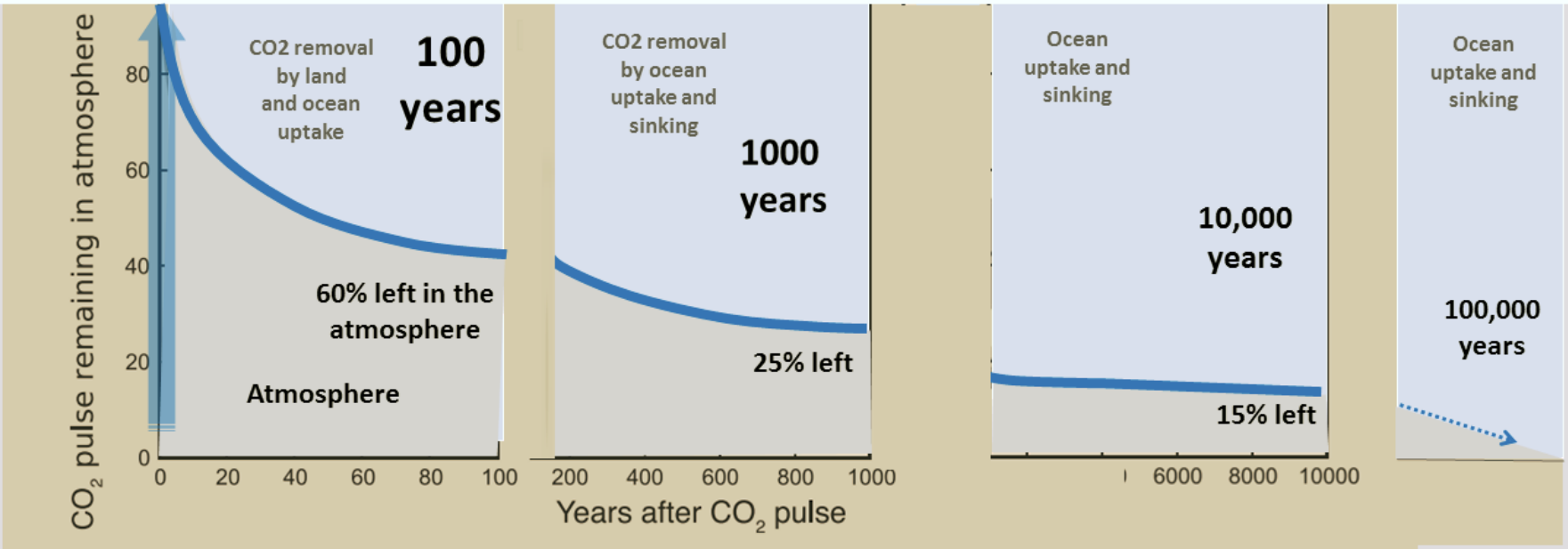
25%釋放于大氣層中的二氧化碳於一千年之後仍然存在

The removal of all the human-emitted CO2 from the atmosphere by natural processes will take a few hundred thousand years (high confidence) (AR5 Box 6.1)

CO2 is forever (David Archer 2008)

The atmospheric lifetime of CO2 is 100,000 years

1000 years after emissions 25% of CO2 is left in the atmosphere
...heating the earth surface and acidifying the oceans



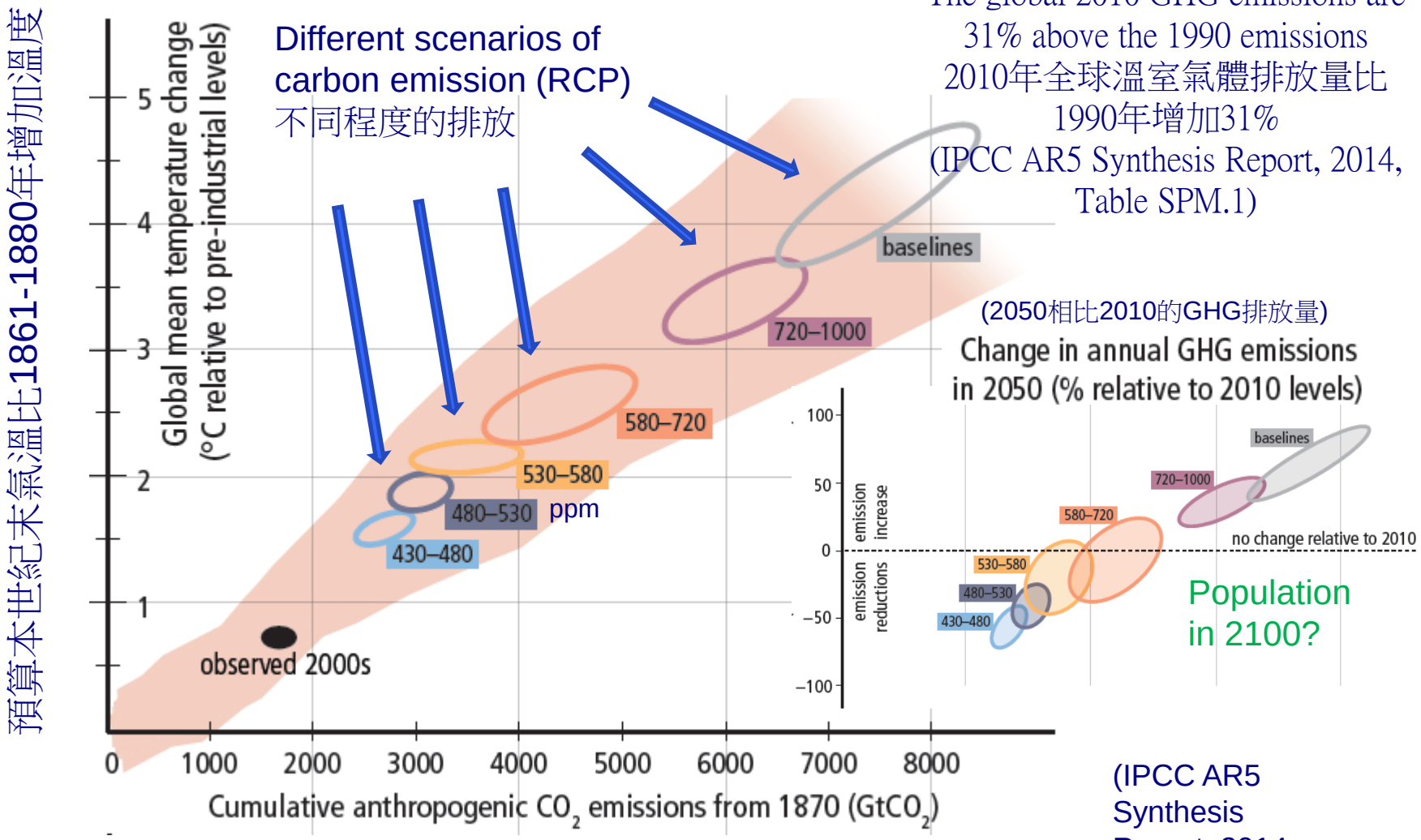
Percentage of emitted CO2 remaining in the atmosphere in response to an instantaneous CO2 pulse emitted to the atmosphere

from IPCC AR5 WG1 Box 6.1, Figure 1

Peter Carter

大部分空氣中的二氧化碳被海洋吸收令到海水變酸

Use of fossil fuels increases CO_2 emission and global temperature
使用化石能源增加二氧化碳排放導致全球氣溫上升



HKU technology speeds up photosynthesis
香港大學的技術能促進光合作用

Sun Light

Basic Photosynthesis

Oxygen O_2

Carbon Dioxide CO_2

CO_2二氧化碳

Photosynthesis

Sugars糖

香港大學的技術

HKU Technology

Cellulose for Cell Wall (Plant Growth)
細胞壁的纖維素
(植物生長)

Starch/Lipids for Seeds
種子的
澱粉質和油脂

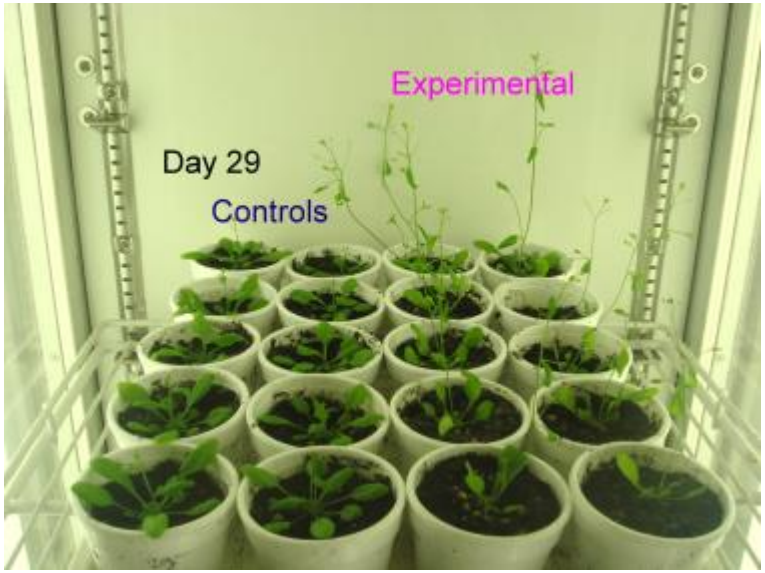
Overexpression of AtPAP2 make plants grow faster
超表達AtPAP2能促進植物生長

AtPAP2 is a gene that is found in all plant species
AtPAP2的基因在所有植物都可以找到

8 hrs light/day

Control Experimental

16 hrs light/day



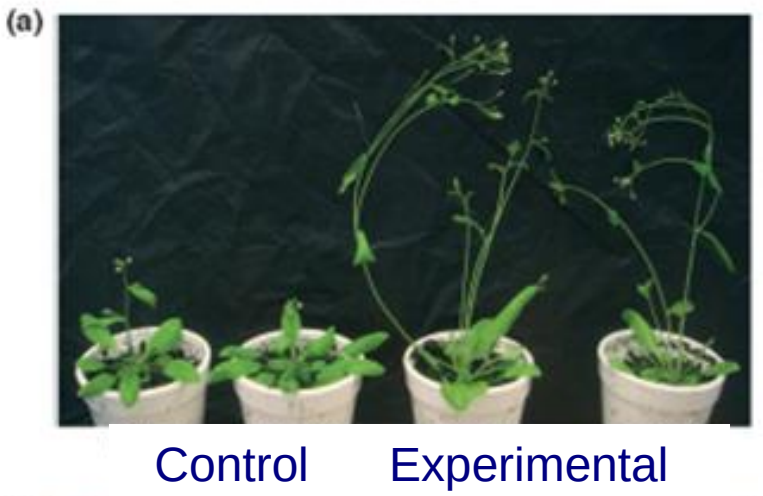
Control Experimental

種子產量	**STUDY No. 1**	**No. 2**
Seed Yield	+ 38 to 40 %	+ 55 to 57 %

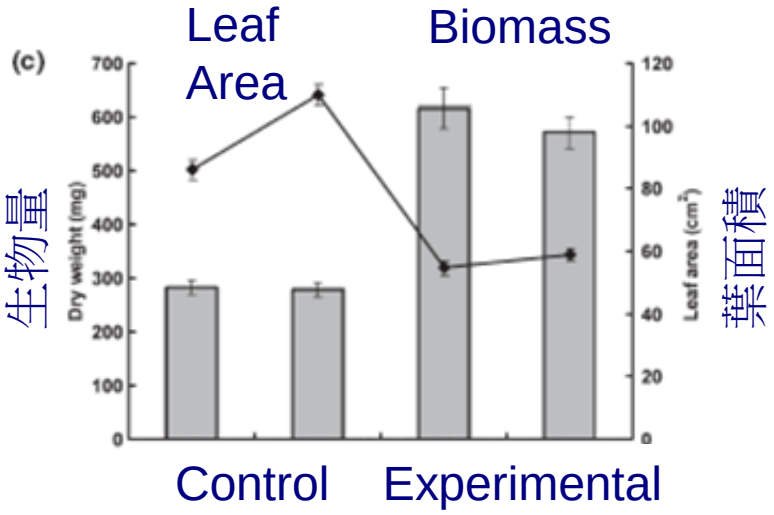
(Sun et al., New Phytologist, 2012)

The experimental lines grow faster with less leaves

實驗組能夠以更少的葉面積快速生長



40-day-old

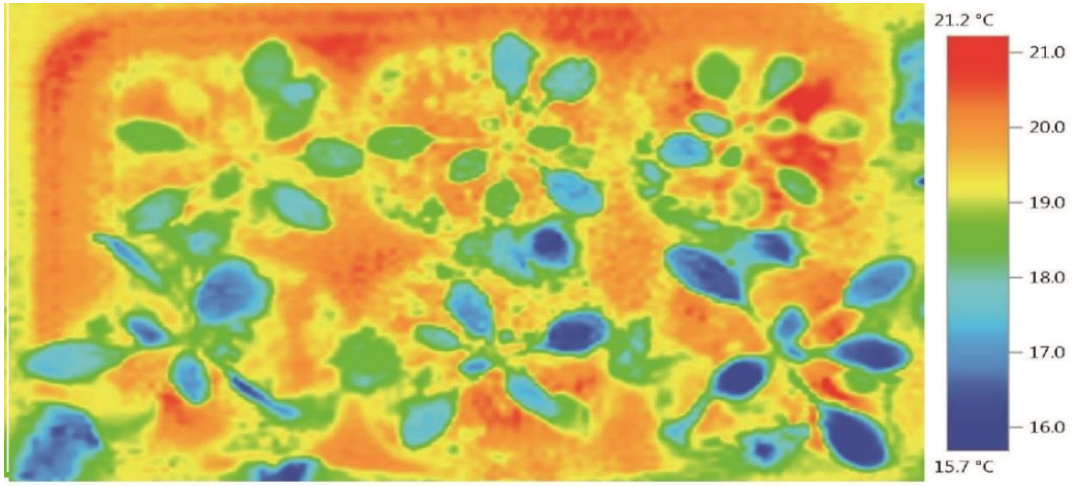


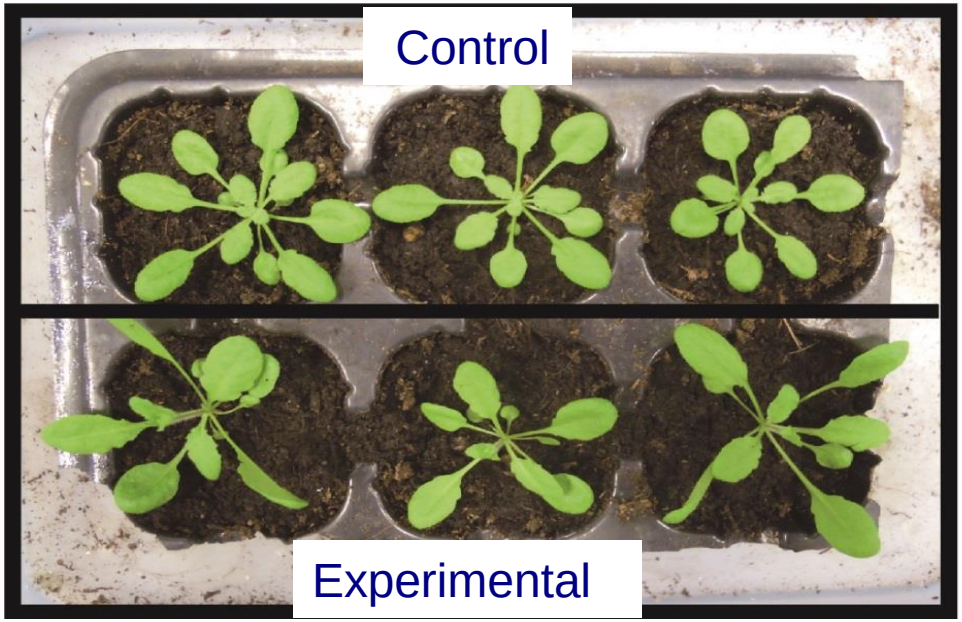
The energy capturing efficiency of the leaves is higher!

葉片捕獲太陽能的效率增加

(Sun et al., New Phytologist, 2012)

The experimental lines have higher transpiration rate
實驗組葉面蒸騰速度較高



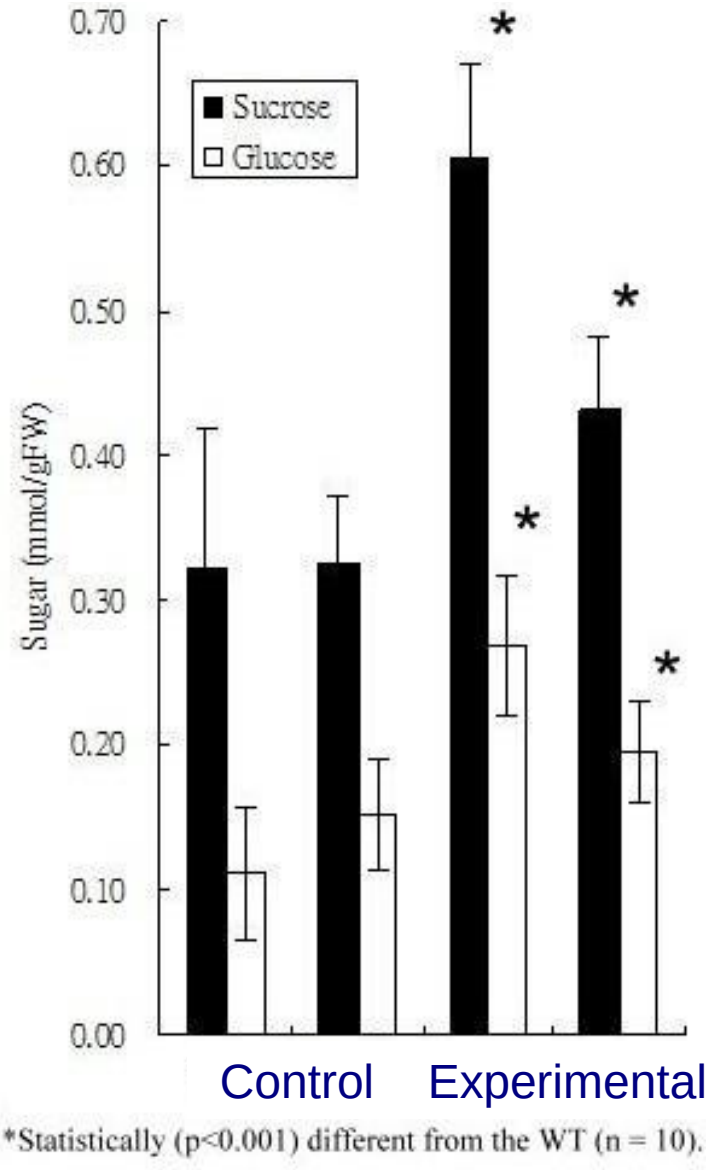


Infrared image of 24-day-old soil-grown Control and Experimental line. Top panel: Experimental line showed relatively cooler temperature than Control line under thermal imager.

紅外線檢測出實驗組的葉片表面溫度低於對照組的葉片表面溫度

(Infrared camera
紅外線相機)

The experimental lines have higher leaf sugars
實驗組含有更高糖分子



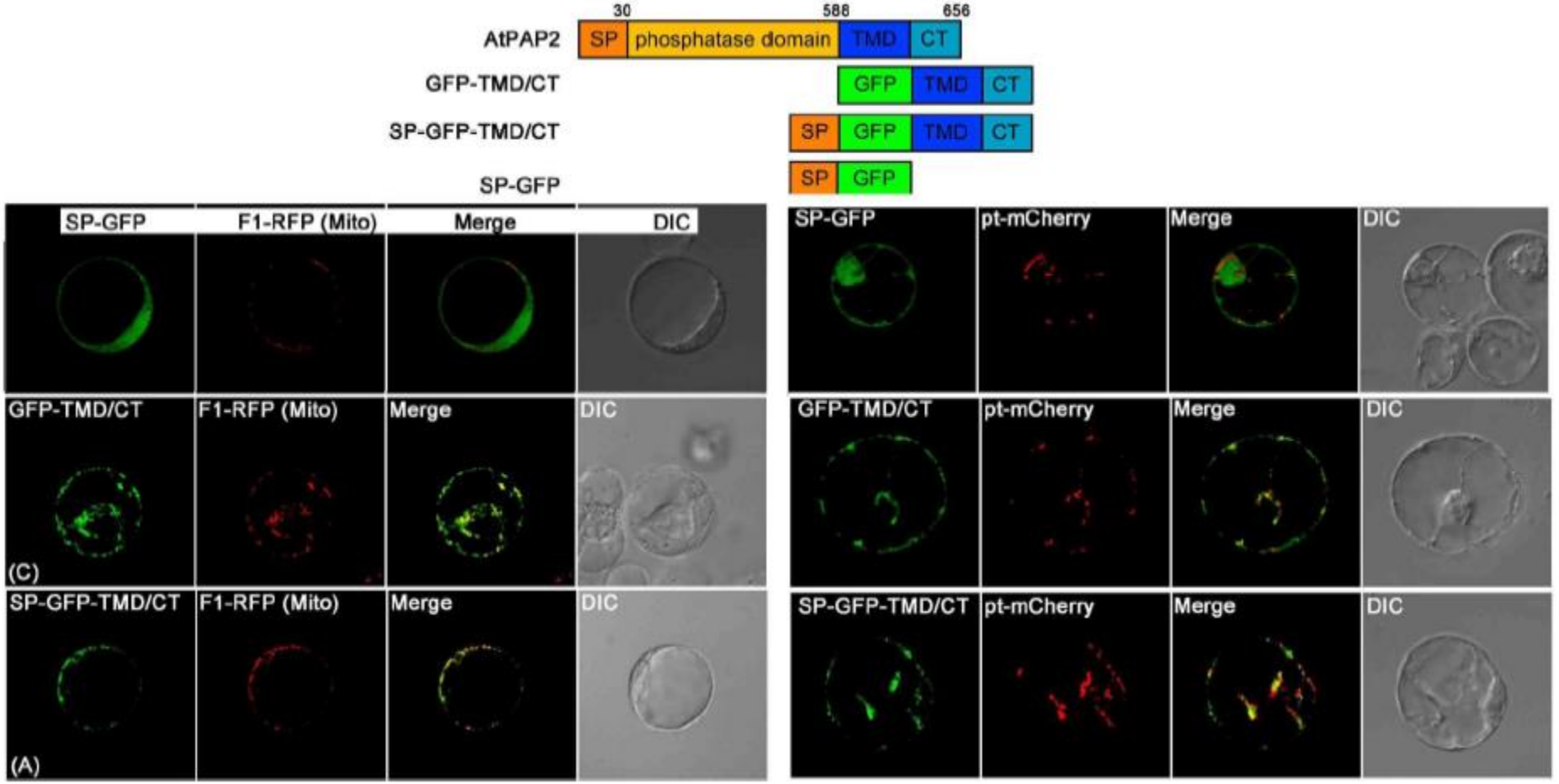
*Statistically ($p<0.001$) different from the WT ($n = 10$).

- Higher sucrose 蔗糖
- Higher glucose 葡萄糖

Driving force of growth and development.
植物生長的推動力

AtPAP2 is dually targeted to both chloroplasts and mitochondria

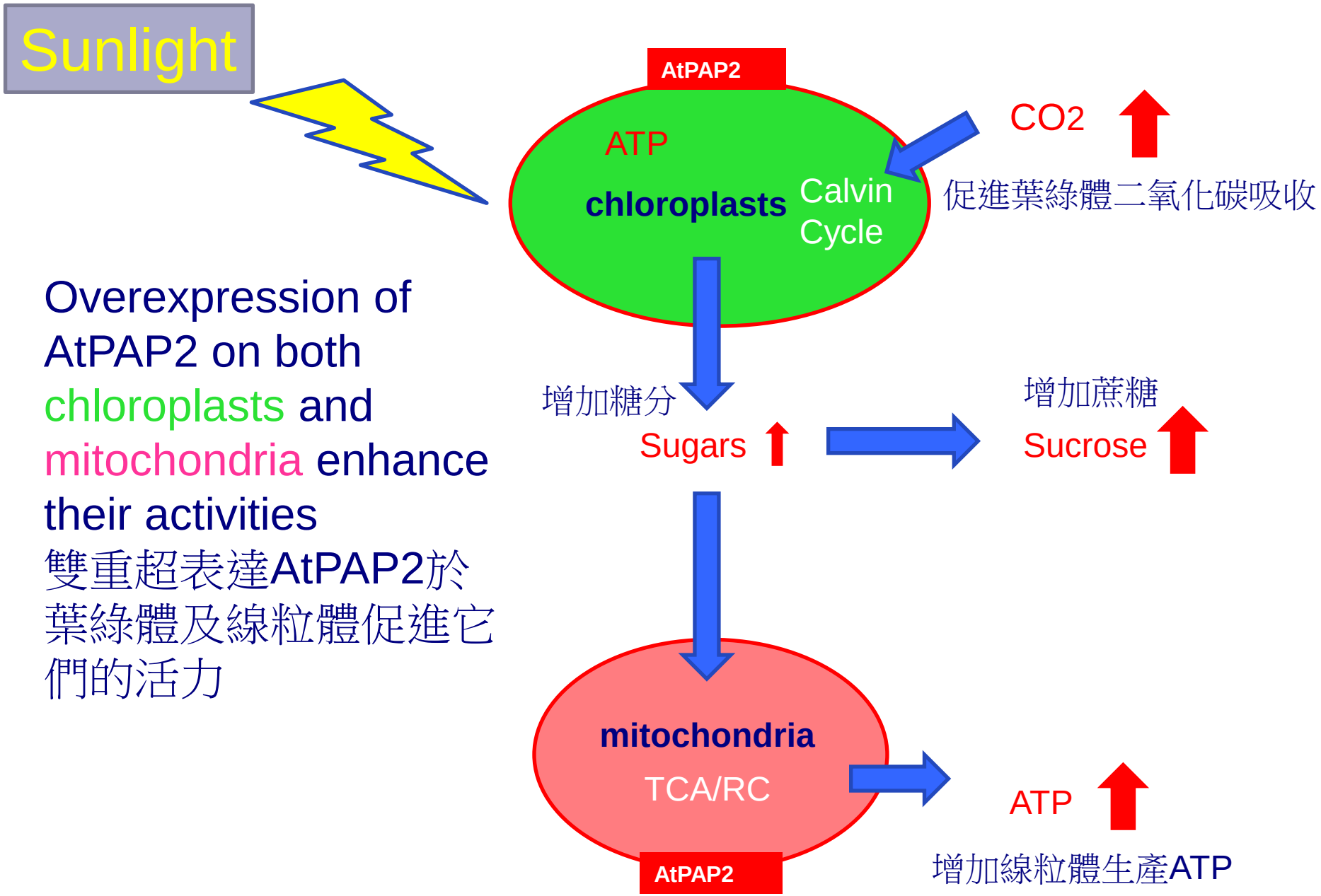
AtPAP2雙定位於葉綠體及線粒體



Mitochondria 線粒體

Chloroplasts 葉綠體

(Sun et al. Plant signaling & Behavior, 2012)



Overexpression of AtPAP2 on both chloroplasts and mitochondria enhance their activities

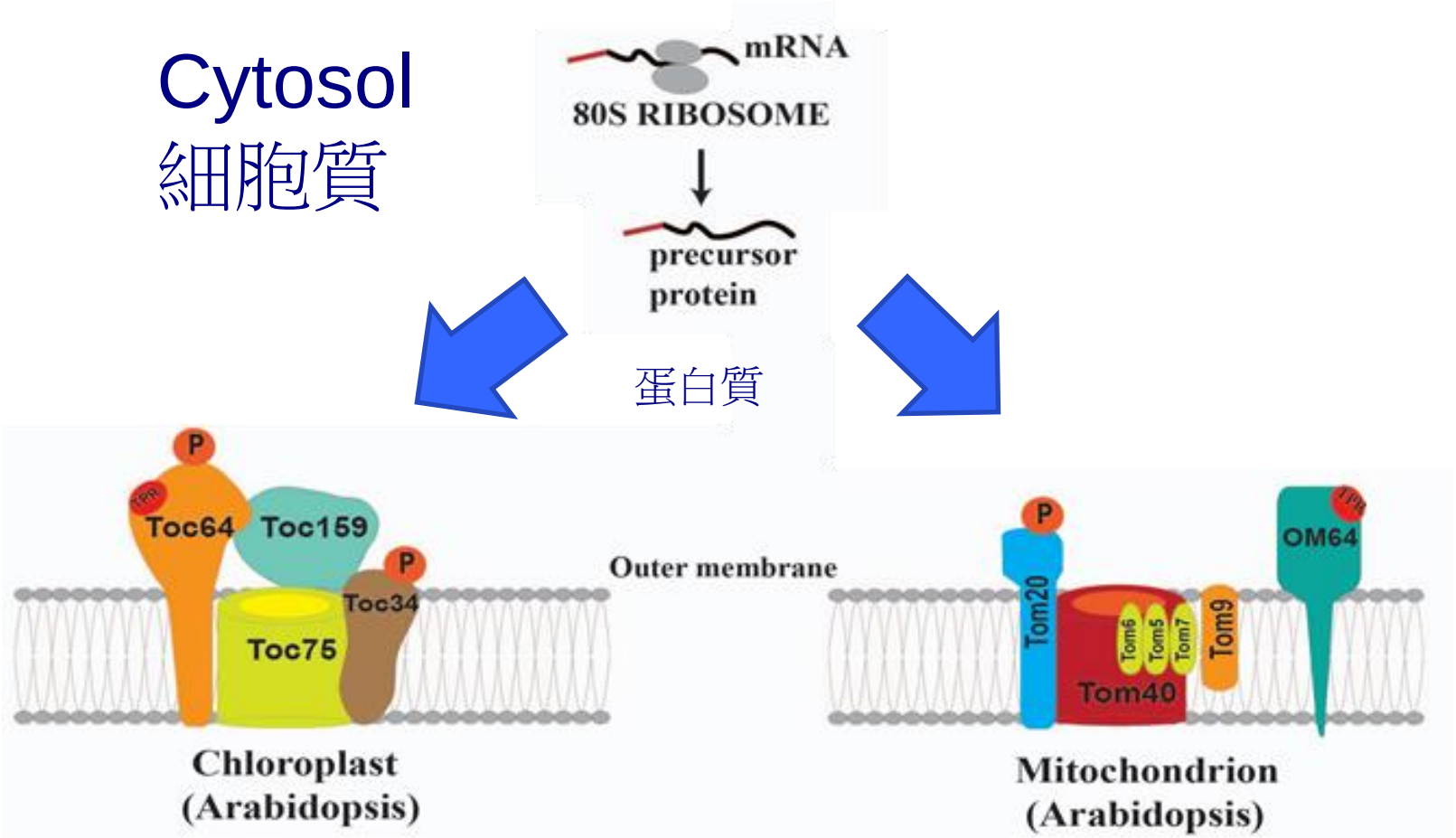
雙重超表達AtPAP2於葉綠體及線粒體促進它們的活力

(Liang et al., Frontiers in Plant Science, 2015)

Many nuclear-encoded proteins are imported into chloroplasts and mitochondria after synthesis in cytosol

很多在細胞質合成的蛋白質要進入葉綠體及線粒體

Cytosol
細胞質

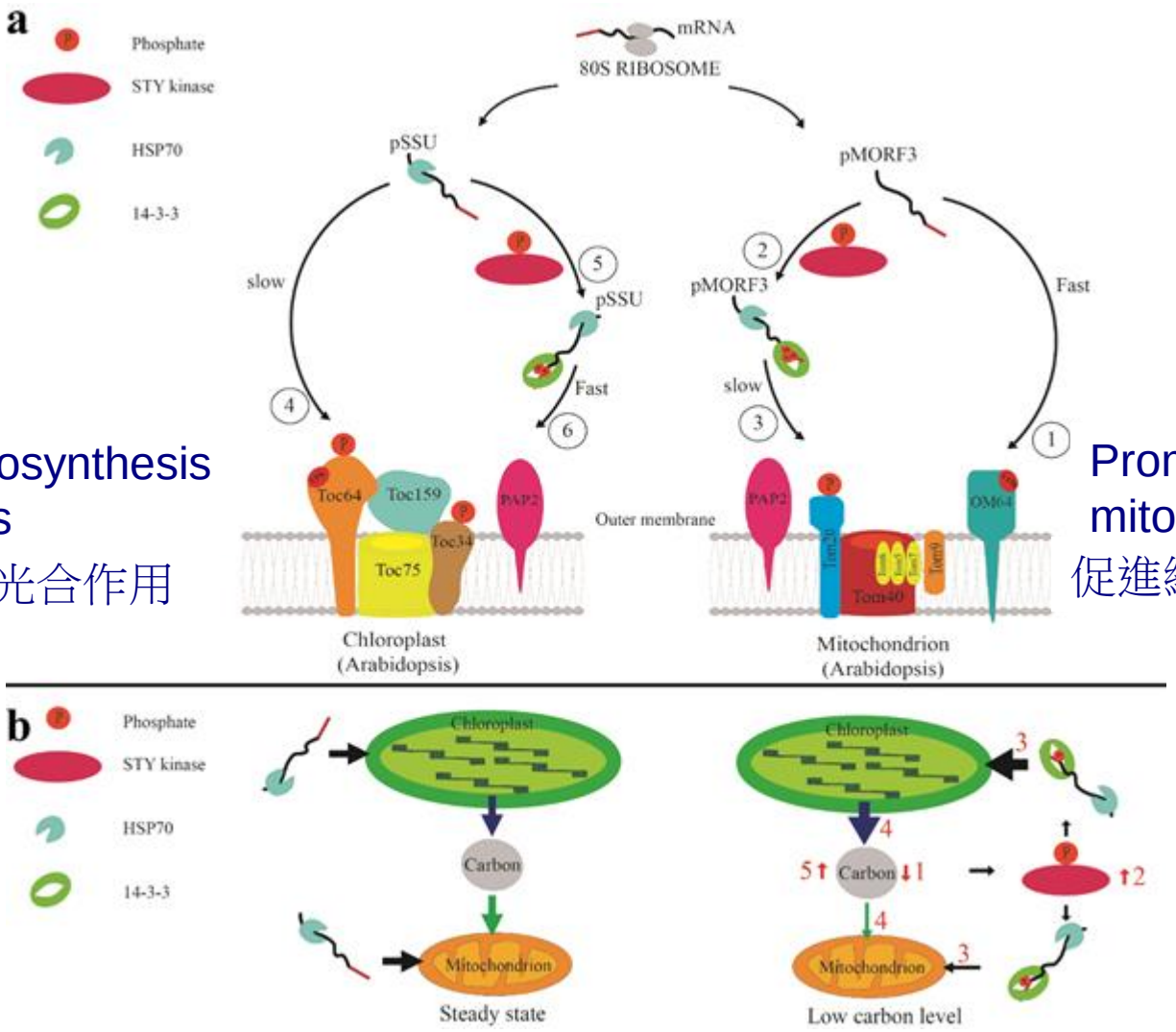


TOC
葉綠體外膜轉運通道

TOM
線粒體外膜轉運通道

AtPAP2 promotes the import of certain proteins into chloroplasts and mitochondria
AtPAP2功能是促進某些蛋白質進入葉綠體及線粒體

Promote photosynthesis in chloroplasts
促進葉綠體的光合作用

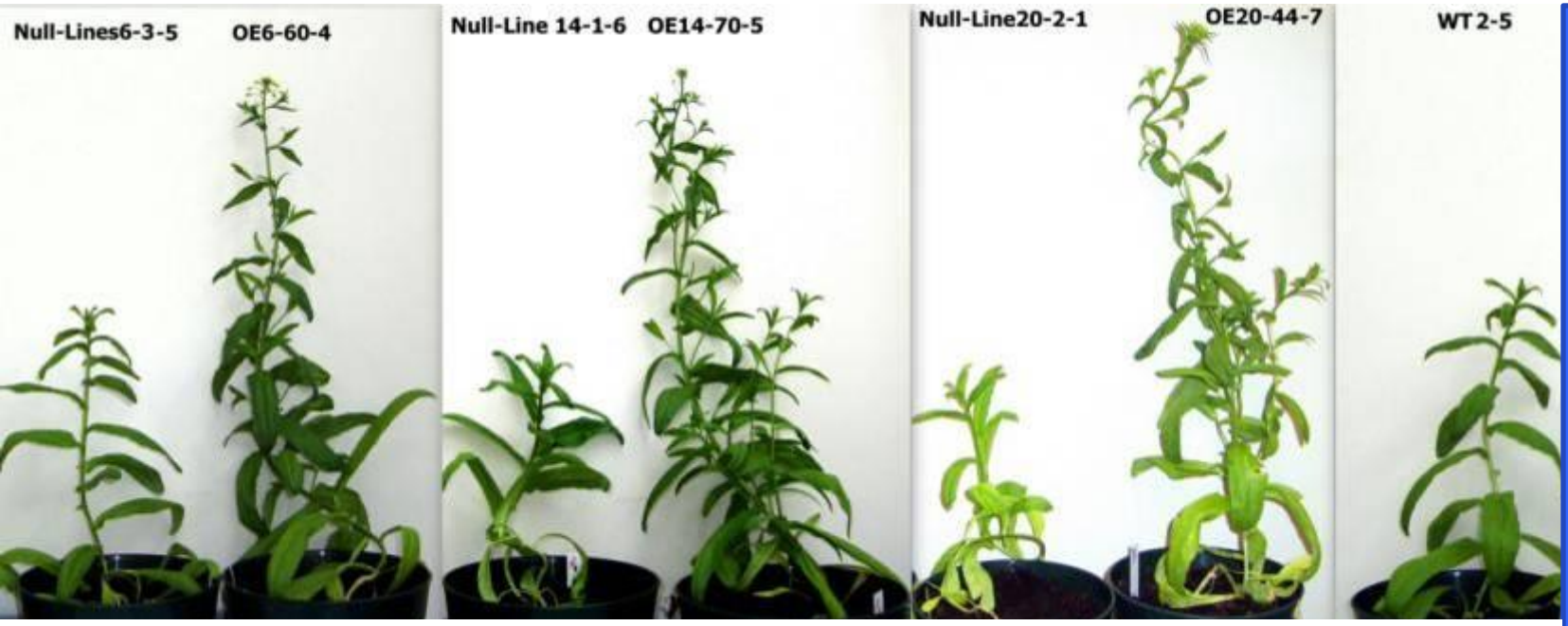


Promote activity of mitochondria
促進線粒體製造能量

(Law et al., Plant Physiology, 2015)

AtPAP2 promote growth of Biofuel Crop (*Camelina sativa*)

AtPAP2能夠促進生物航空燃料植物(亞麻薺)的生長



Phenotype (40 days old in growth chamber)

AtPAP2 protein expression level

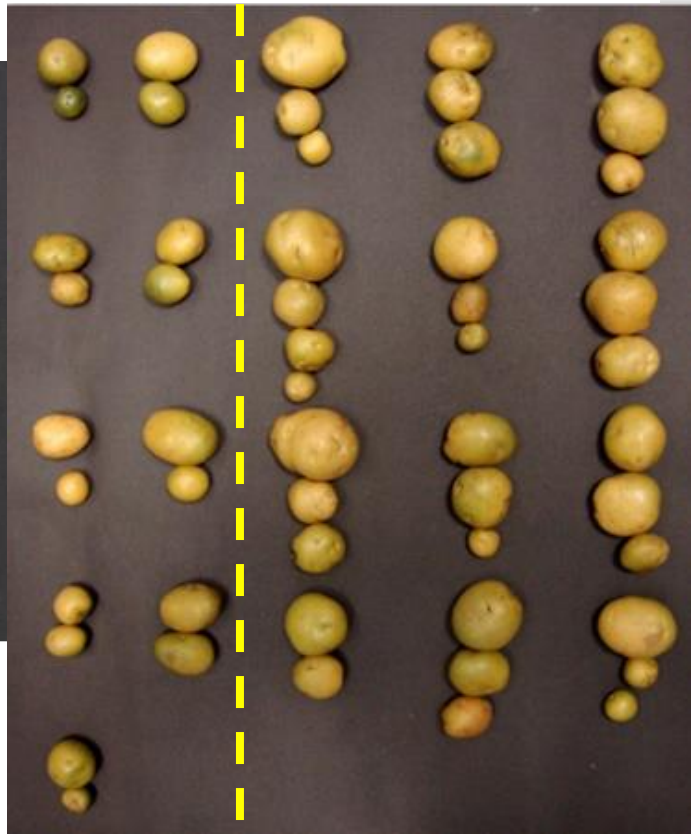
Camelina-based jet fuel reduces carbon emissions by around 80% (Japan Airline, 2009)

亞麻薺籽裝造的生物航空燃油能減低80%碳排放(2009年日本航空成功試飛)

(Zhang et al., Biotechnology for Biofuels, 2012)

AtPAP2 can promote growth and yield in potatoes
AtPAP2夠促進馬鈴薯的生長及產量

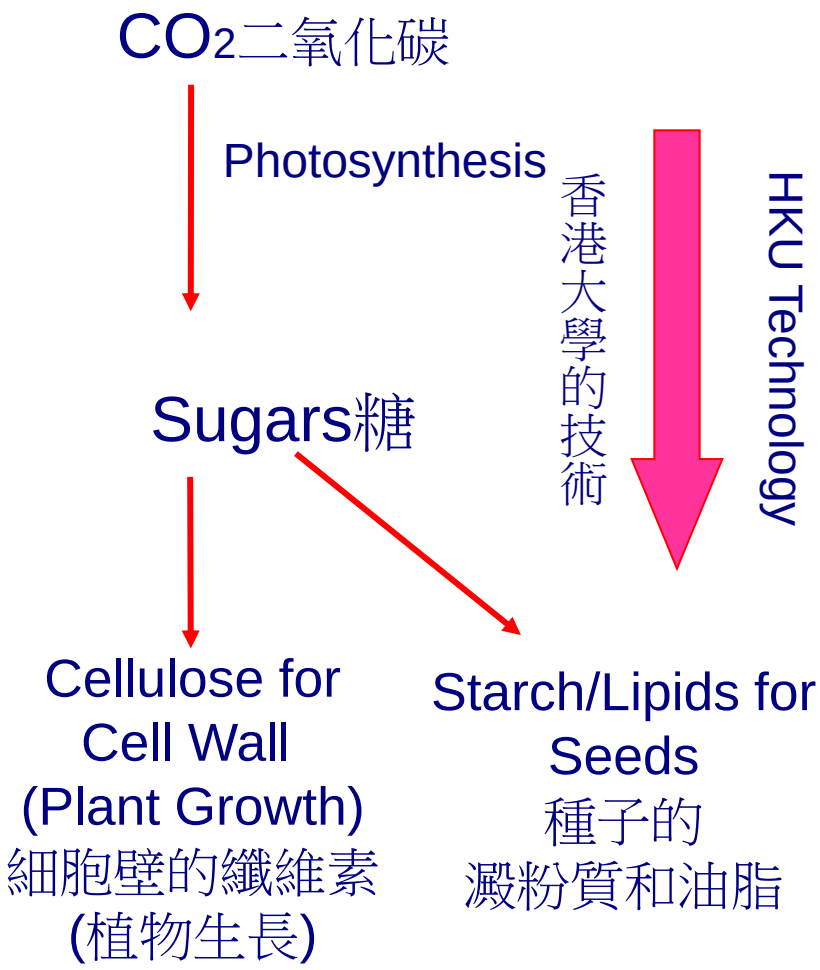
Control Experimental



(Zhang et al., FEBS Letters, 2014)

HKU botanists discover plant growth technology that may alleviate climate change and food shortage

港大植物學家研發植物生長技術助緩解氣候變化和糧食短缺問題



Crops農作物

Food糧食

Trees樹

Forestry森林

Algae藻

Biofuels生物燃料

Ocean海洋

Journal articles on AtPAP2

1. C. Liang, Y. Zhang, S. Cheng, S. Osorio, Y. Sun, A. Fernie, C.Y.M. Cheung, **B. L. Lim** (2015) Impacts of high ATP supply from chloroplasts and mitochondria on the leaf metabolism of *Arabidopsis thaliana*. Frontiers in Plant Science (in press).
2. Y. Law, R. Zhang, X. Guan, S. Cheng, F. Sun, O. Duncan, M. W. Murcha, J. Whelan, **B. L. Lim** (2015) Phosphorylation and dephosphorylation of the presequence of pMORF3 during import into mitochondria from *Arabidopsis thaliana.* Plant Physiology 169:1344-55.
3. Y. Zhang, F. Sun, J. Fettke, M. A. Schöttler, L. Ramsden, A. R. Fernie, **B. L. Lim** (2014) Heterologous expression of *AtPAP2* in transgenic potato influences carbon metabolism and tuber development. FEBS Letters 588(20):3726-3731.
4. C. Liang, X. Liu, Y. Sun, S. Yiu, **B. L. Lim** (2014) Global small RNA analysis in fast-growing Arabidopsis thaliana with elevated concentrations of ATP and sugars. BMC Genomics 15:116-128.
5. F. Sun, C. Liang, J. Whelan, J. Yang, P. Zhang and **B. L. Lim** (2013) Global transcriptome analysis of AtPAP2 - overexpressing *Arabidopsis thaliana* with elevated ATP. BMC Genomics 14:752-763.
6. F. Sun., C. Carrie, S. Law, M. Murcha, R. Zhang, Y. Law, P.K. Suen, J. Whelan, and **B. L. Lim** (2012) AtPAP2 is a tail-anchored protein in the outer membrane of chloroplasts and mitochondria. Plant Signaling & Behavior 7:927-932.
7. Y. Zhang., L.Yu, K. Yung, Y. Leung, F. Sun and **B. L. Lim** (2012). Over-expression of AtPAP2 in Camelina sativa leads to faster plant growth and higher seed yield. Biotechnology for Biofuels 5:19-28.
8. F. Sun, P. K. Suen, Y. Zhang, C. Liang, C Carrie, J Whelan, J. Ward, N.D. Hawkins, L Jiang and B. L. Lim (2012) A dual-targeted purple acid phosphatase in Arabidopsis thaliana moderates carbon metabolism and its overexpression leads to faster plant growth and higher seed yield. New Phytologist 194: 206–219.


Thanks for your attention!
謝謝!