Root Restriction as a Factor in Photosynthetic Acclimation of Cotton Seedlings Grown in Elevated CO_2

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Why this paper?

Need to understand the detail about "pot size effect" for my manuscript…

Down regulation

Sink-source balance

Prof. Koike always give us the key words but
he dare to explain the derails considering students…
→ We can start study from these key words!

[Pot size effect?] Introduction

→ Look at HP of Takao Araya (from Tokyo Univ, Terashima lab)

This explanation is included the page;

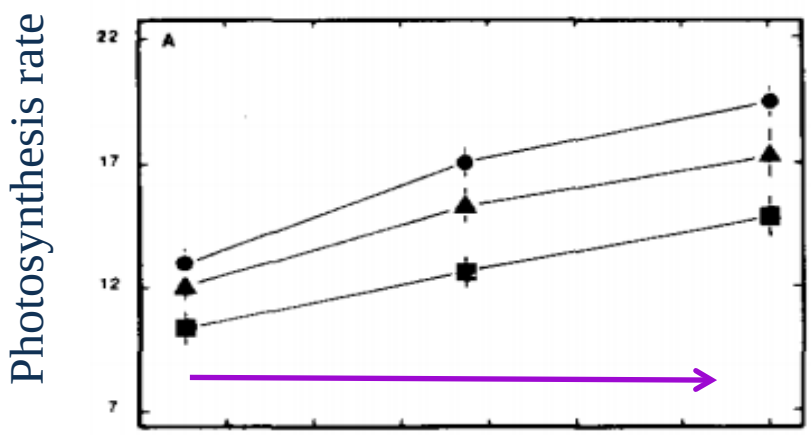
"Effects of **long-term high CO_2** on the **photosynthesis**…

(please check HP if want)

Down regulation

ポットサイズ効果

このような高CO2環境下での葉への炭水化物の蓄積が起こる原因として、「ポットサイズ効果」というものが知られています。ポットサイズ効果はArp (1991)で初めて示された仮説で、高CO2条件における光合成の抑制がポットが小さいときほど強く起こることから提唱されました。ポットが小さいときには、植物の根の成長は抑えられます（シュートの成長も部分的には抑えられるかもしれません）。この結果、もともとは根の成長に使うことができた炭水化物が利用されないまま葉に残り、結果として葉への炭水化物の蓄積と光合成速度の低下が起こります（Thomas and Strain 1991も同じような結果を示しています）。一方で、近年よくおこなわれるようになったFACE(Free air CO2 enrichment experiment、野外環境で植物をCO2噴出装置で囲って、その周辺のCO2濃度だけを上昇させる実験)では、ポット=地球であるにもかかわらず、高CO2条件での光合成速度の低下が観察されています（Nie et al. 1995, Long et al. 2004, Ainsworth and Long 2005）。したがって、ポット効果だけでは高CO2環境下における光合成能力の低下を説明することはできません。



(Evans *et al*. 1985)

350ppm CO_2 (Top)

675ppmCO_2 (Mid)

1000ppm CO_2 (Bot)

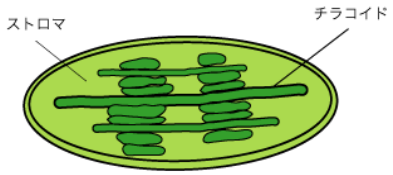
Short-term change (minute or hour)

Long-term change (day or weeks)

[Pot size effect?] Why down photosynthesis

- CO_2, the substrate in photosynthesis: $CO_2 + H_2O = CH_2O + O_2$
- Effect of long-term exposure of elevated CO_2

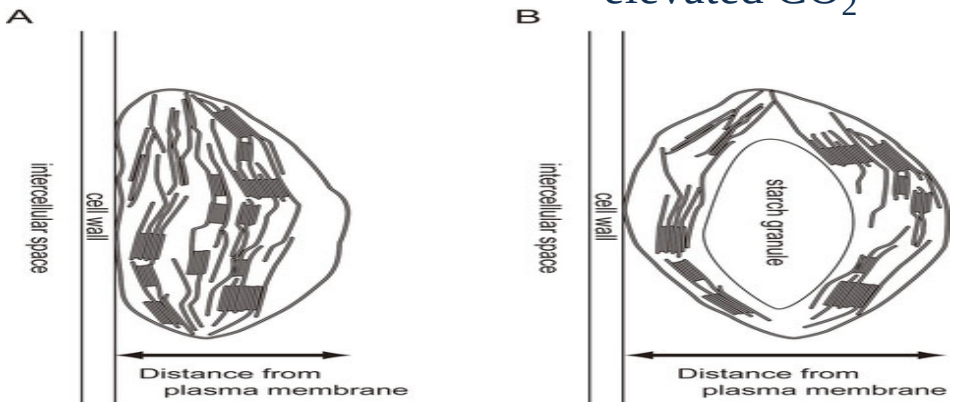
  <u>decrease photosynthesis</u>



→ Chloroplast damaged by starch accumulation

Ambient

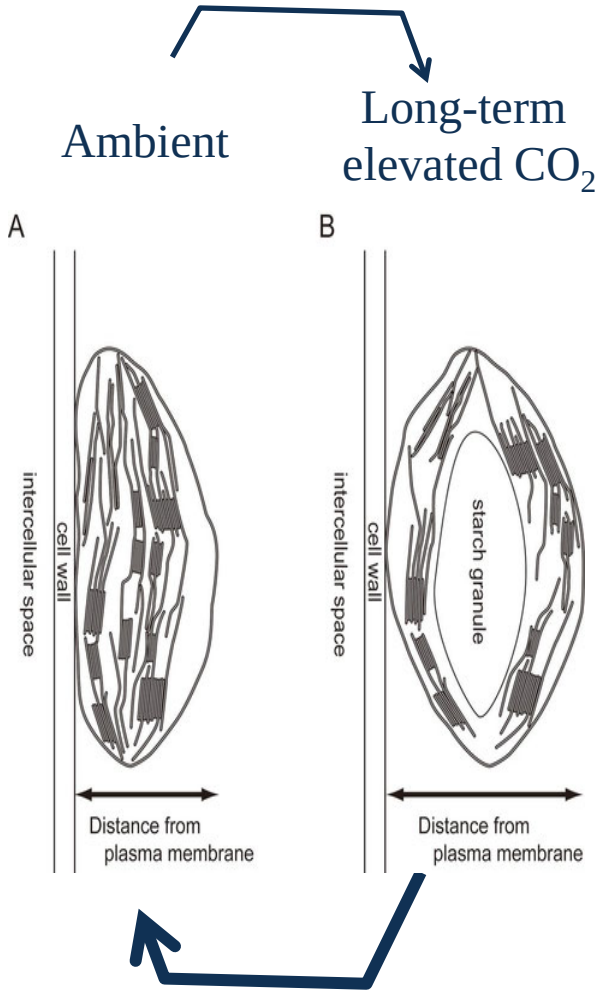
Long-term elevated CO_2



…Why accumulate?

→ **Pot size effect**
(Arp et al. 1991)

[Pot size effect?] Starch accumulation



- Effects of long-term exposure CO_2 accumulates a starch in chloroplast
- Starch accumulation might increase the size of chloroplast …

Accumulated starch leak out
when transfer from high CO_2 to ambient

…leak out (consume) ?

→ might move into other organs

→ **sink-source balance**

[Pot size effect?] Previous research

In soybean research,
the method changing sink-source balance: Destructive
→ Directly/ Indirectly affect: complicated design…

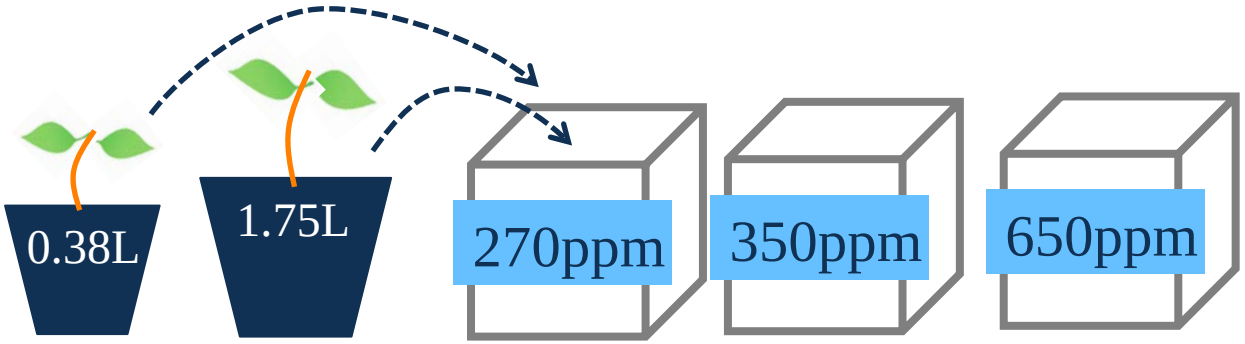
How to change the balance
by non-destructive ?
Which organs ?

Root: major metabolic sink organs

[Research question]

The effects of reduced sink strength on cotton seedlings grown with long-term CO_2 enrichment without wounding by organ removal

[Design] 2 pot size ×3 CO_2 level at phytotron



Subsample in each CO_2
Transplanted at 20 days

→ Focus on **pot effect**, **CO_2 effect**, and **transplanted effect**

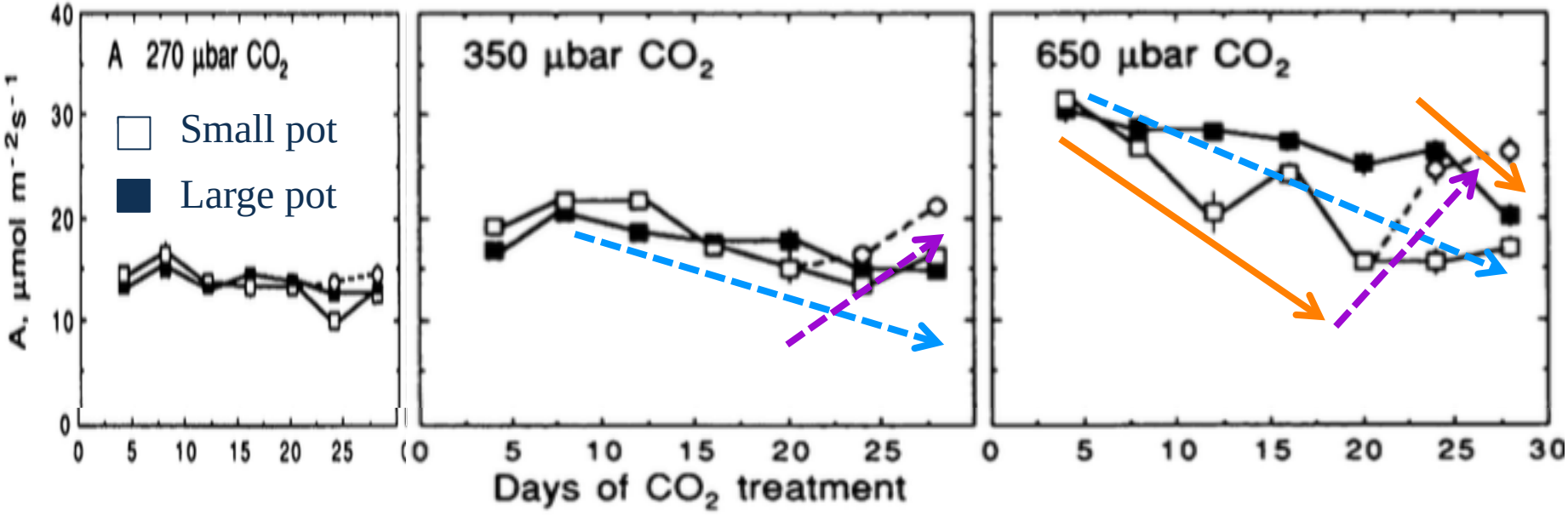
[Measurement]

Photosynthesis rate: every 4 day (Sub: day 20, 24, 28)

Starch : Once 1 week during 4 weeks

Biomass of each shoot : Finally dig out at 28 days

[Leaf responses: photosynthesis]



Pot :n.s., Day :n.s.,
TP:n.s.

Pot :n.s., Day :***
TP:***

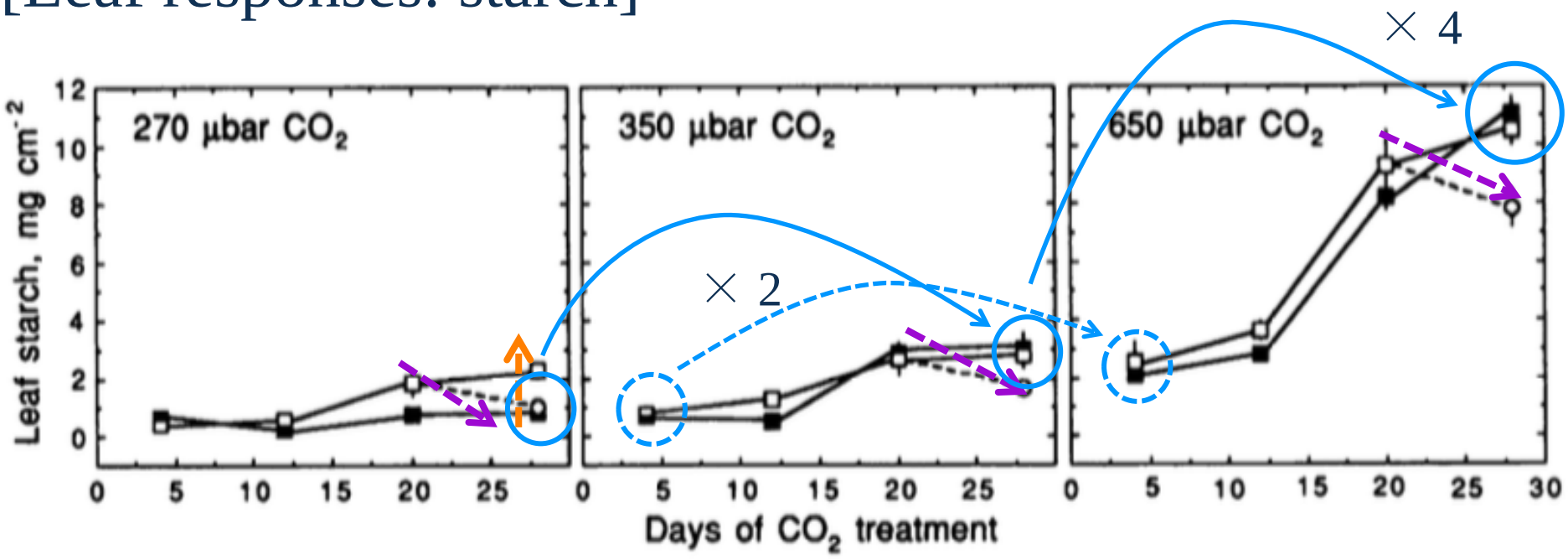
Pot :***, Day :***
P×D:***, TP:***

Effect of pot size: significant at 650 ppm

Effect of days of CO_2 : significant at 350 ppm and 650 ppm

Effect of transplanted : significant at 350 ppm and 650 ppm

[Leaf responses: starch]



Pot :**, TP:*

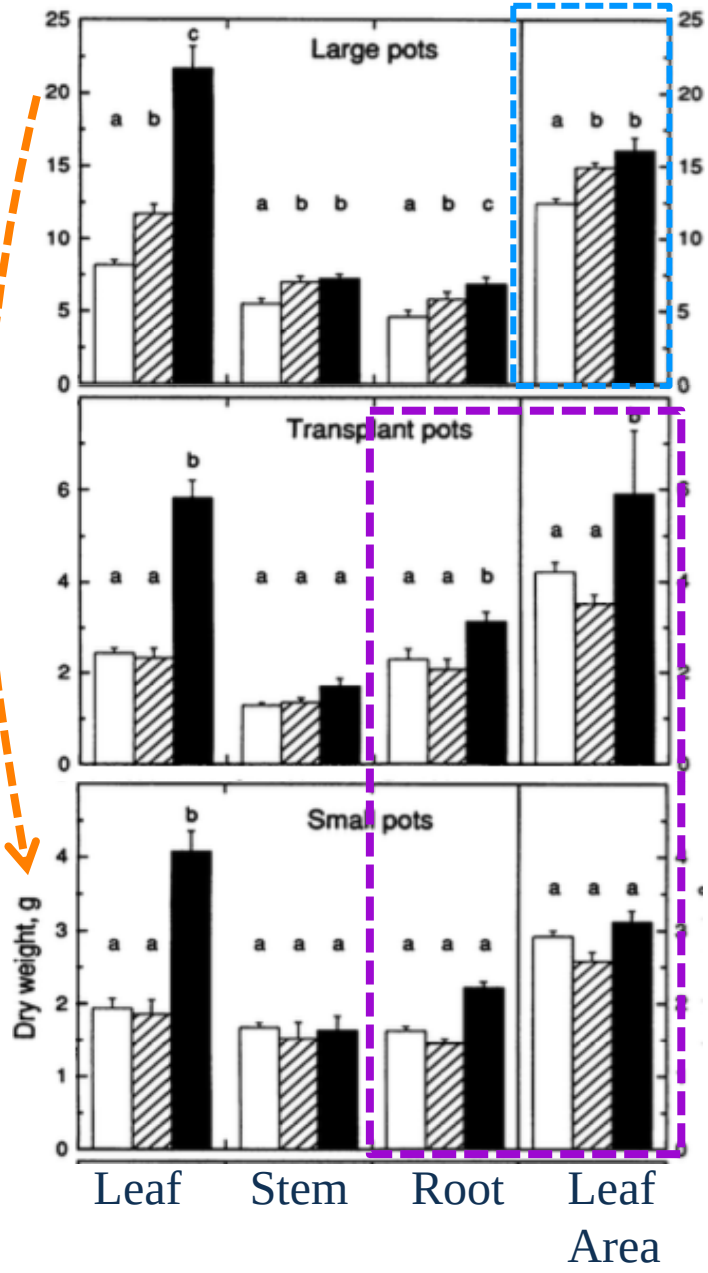
Pot :n.s., TP:*

Pot :n.s., TP:*

Effect of pot size: significant at 270 ppm only

Effect of transplanted decreased starch significantly

Effect of elevated CO_2 increased starch,
especially from 350 to 650 ppm on 4 day,
in large pot but not in small on 28 day



[Biomass]

Effect of pot decrease over 250%

Leaf area responses to elevated CO_2
→increases in large but not in small

Effect of transplanted:
Increases on Root dry weight, Leaf area more than in small pot

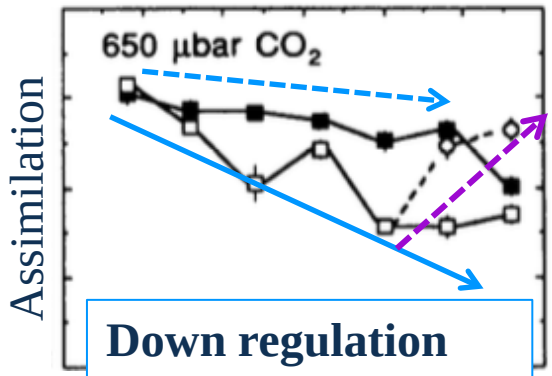
Root binding occurred on 8 day in small (根まき) on 24~28 day in large

Leaf biomass showed largest responses
→Even in small, leaf biomass increased

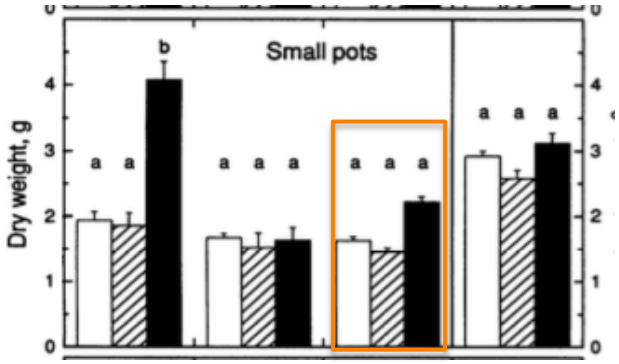
270ppm 350ppm 650ppm

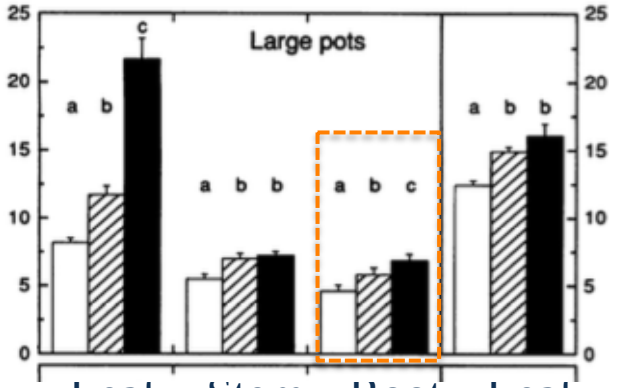
[Discussion]

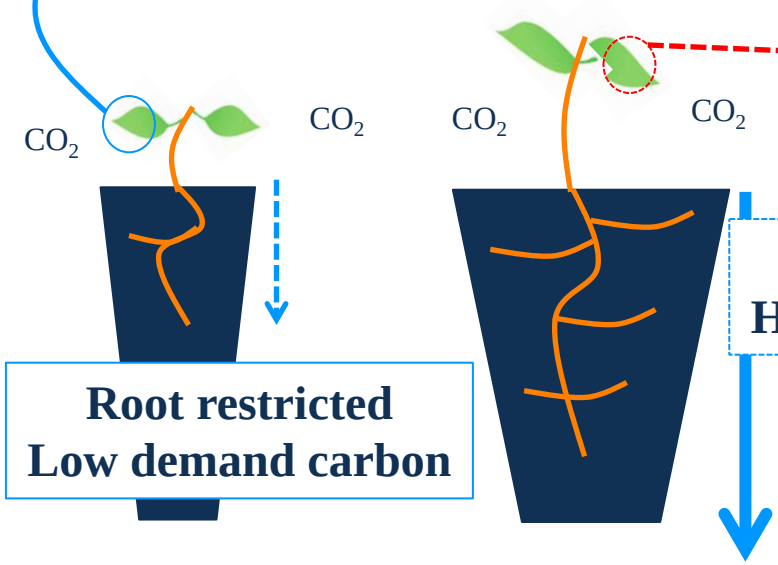
Under 650 ppm CO_2, decline of photosynthesis was correlated with inadequate root biomass in small pot



Down regulation caused by small pot



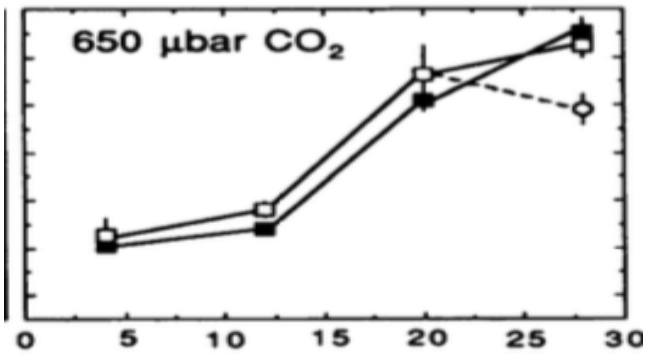




Root restricted
Low demand carbon

Low restricted
High demand carbon

However, accumulated starch: N.S.



Synthesis rate or phloem loading might limit of translocation…

[Conclusion]

Some plants may show reduced responses to CO_2
because of low sink demand caused by root limitation
(pot size effect)

→ studies without adequate rooting volume may lead to inaccurate conclusion about the responses to CO_2

[The latest hypothesis and research about feedback inhibition of photosynthesis]

1. Effects of accumulated starch on photosynthetic genes
2. Effects of accumulated starch decreasing liberated phosphate
3. Effects of accumulated starch decreasing mesophyll conductance

→ Dr. Araya have already researched these objectives

Effects of Carbohydrate Accumulation on Photosynthesis Differ between Sink and Source Leaves of *Phaseolus vulgaris* L.

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