Estimating Carbon Use Efficiency, Growth Respiration, and Maintenance Respiration from Crop Gas Exchange Measurements

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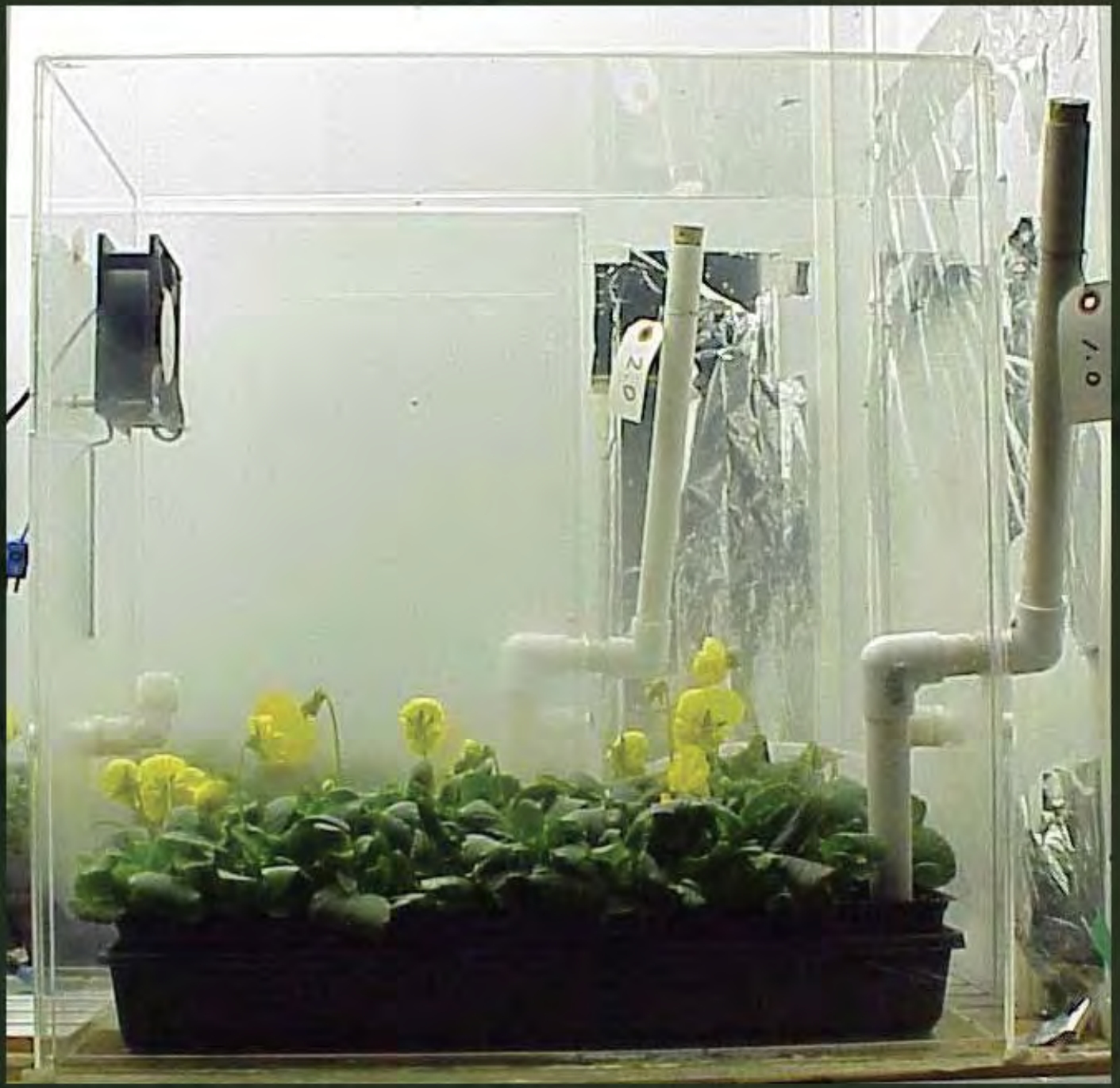
Why Photosynthesis?

- Plants contain approximately:
  - 40% C
  - 45% O
  - 6% H
- Leaf photosynthesis and plant growth or yield are poorly correlated

Whole Crop Photosynthesis and Growth

- Direct measure of C incorporated into the plant
- With continuous measurements, net carbon gain can be determined
- Daily net carbon gain closely related to growth rate
- Cumulative carbon gain closely related to dry mass

Plexiglas chambers

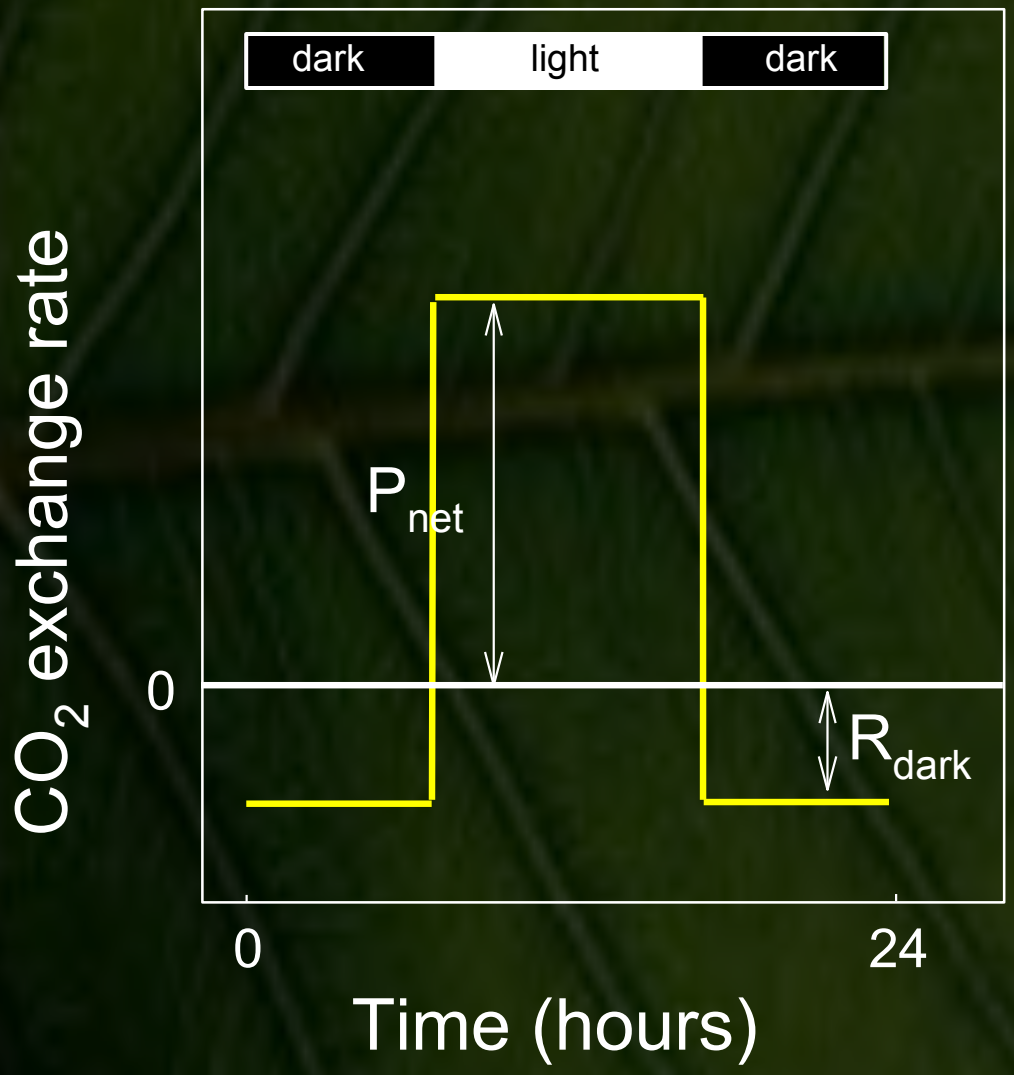


Corelli-Grappadelli and Magnanini, 1993, HortScience

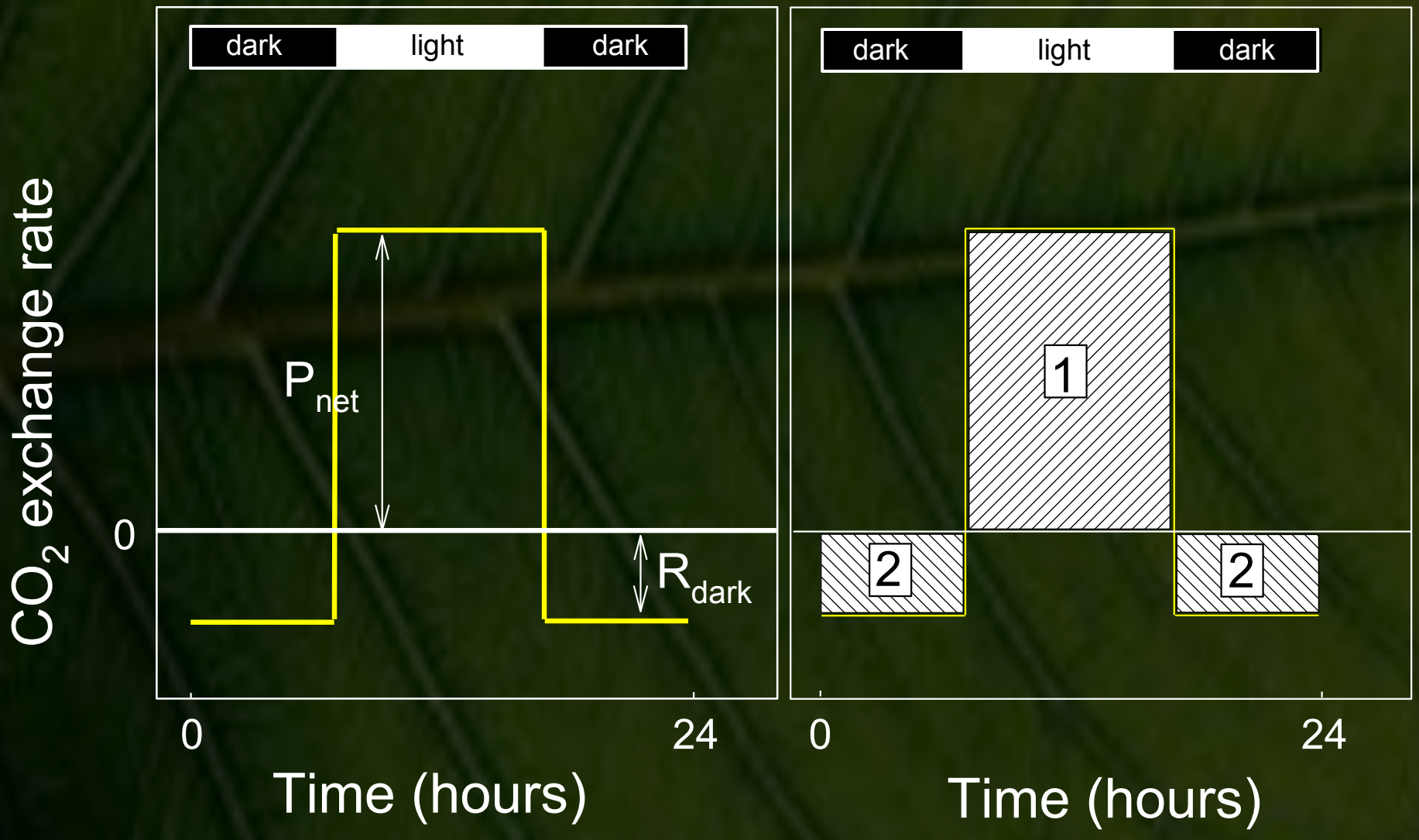

100% RH
70% RH
Fred Davies
Texas A&M

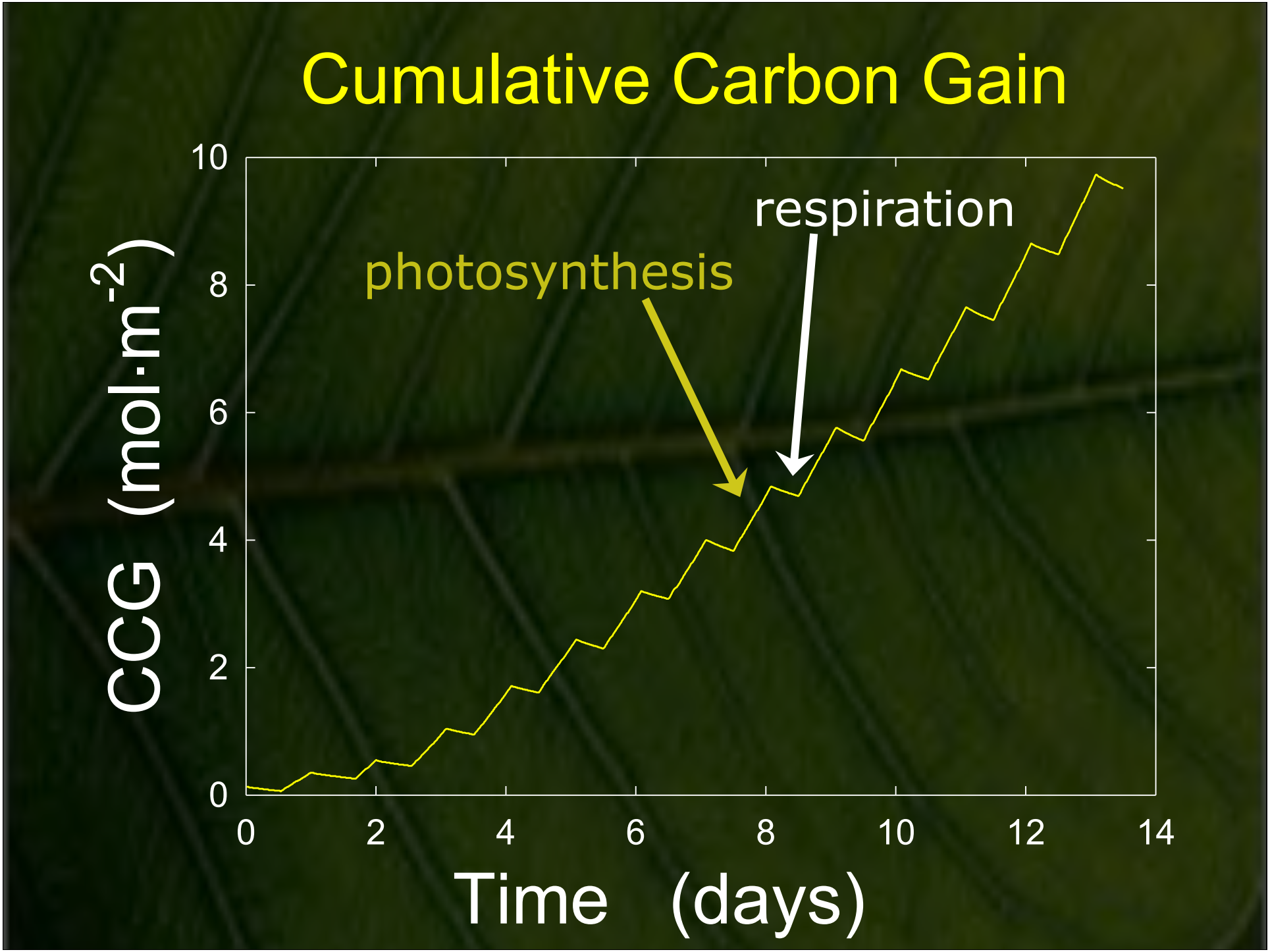

Soil-Plant-Atmosphere-Research chambers (SPAR)
USDA Beltsville

Diurnal CER

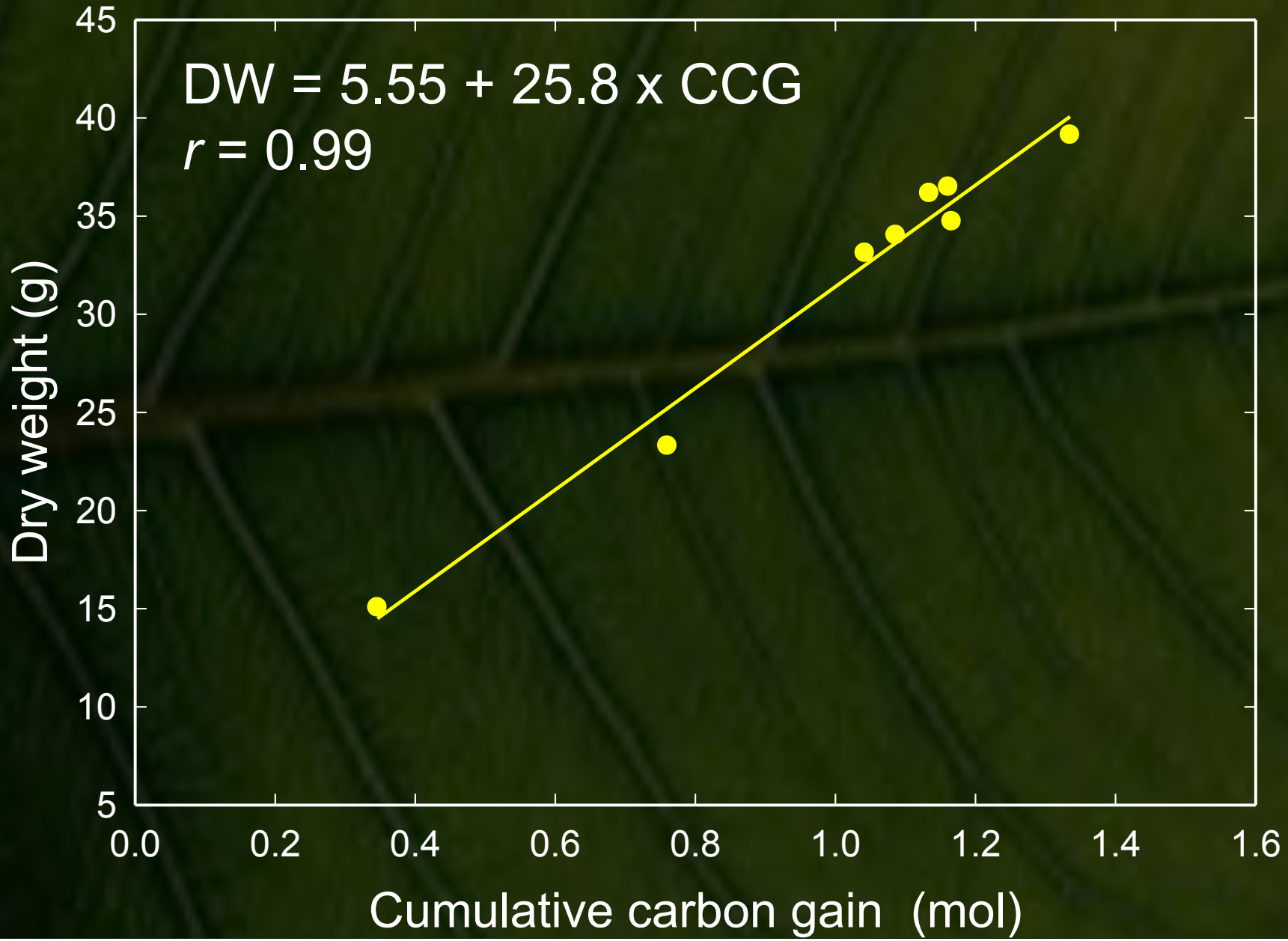

dark
light
dark
P_{net}
R_{dark}
0
CO_2 exchange rate
0
24
Time (hours)

Daily Carbon Gain (DCG)
(area 1 - area 2)



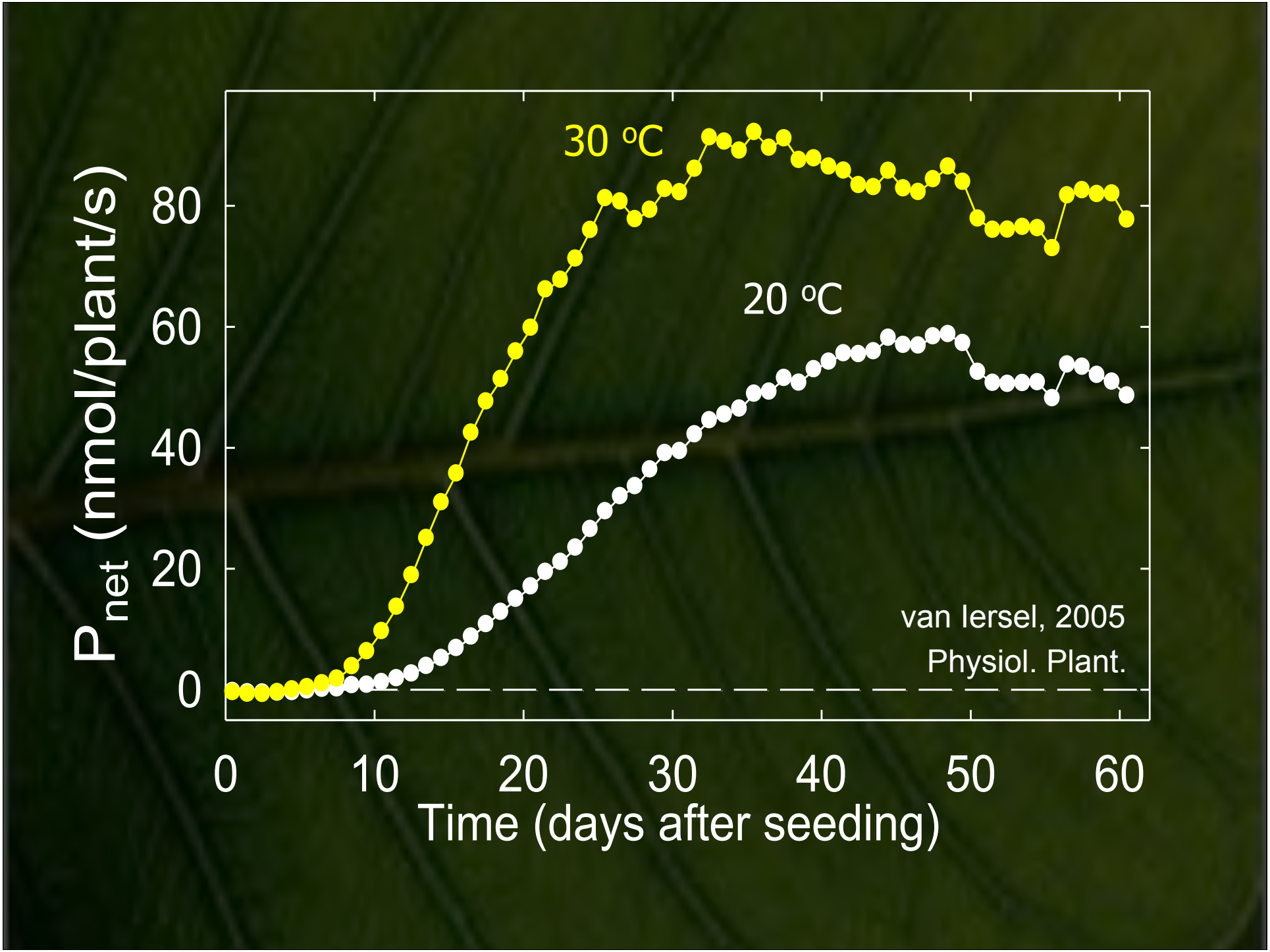

Cumulative Carbon Gain
CCG (mol·m-2)
Time (days)
photosynthesis
respiration
0
2
4
6
8
10
12
14

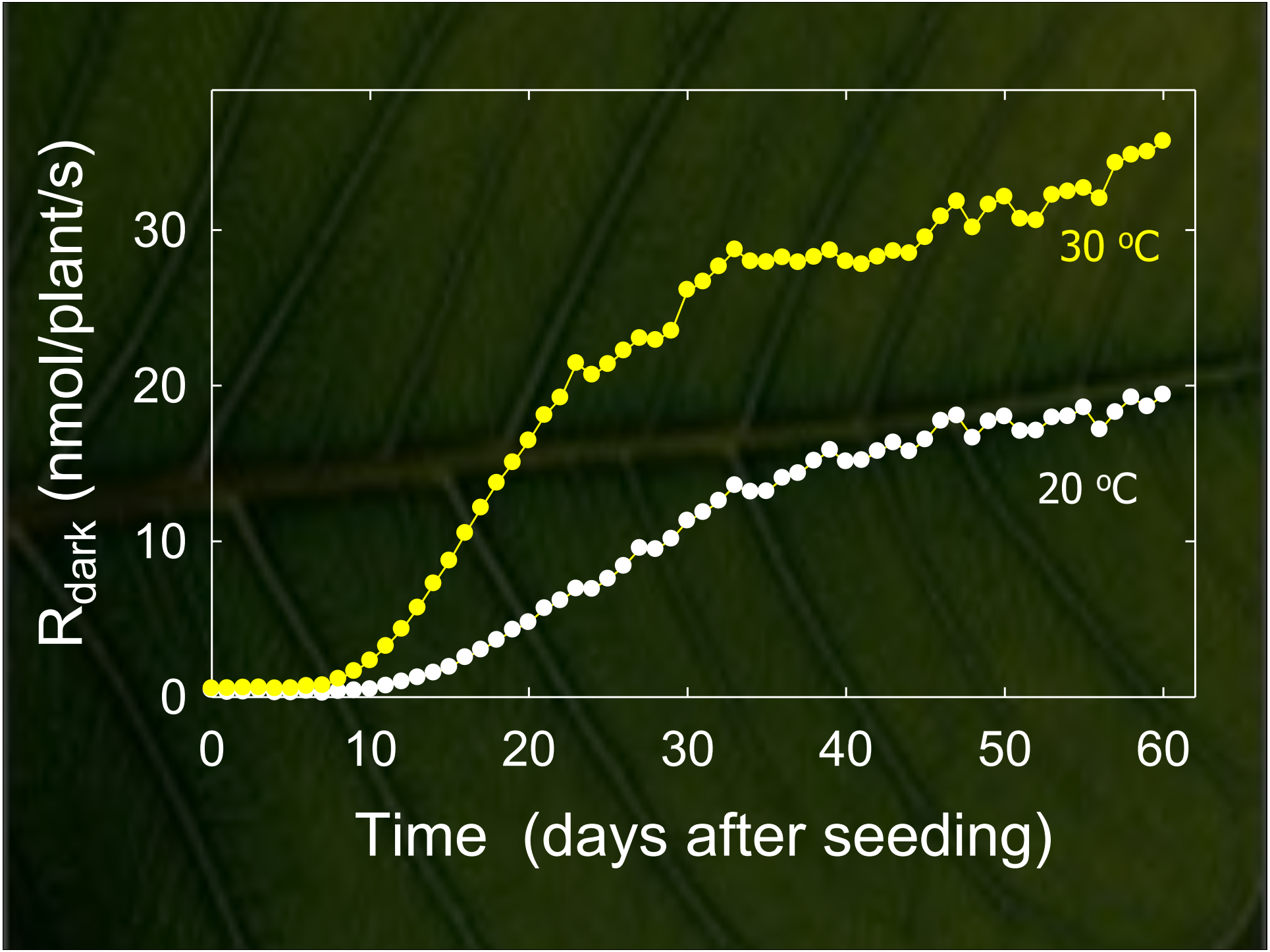
Whole Plant Photosynthesis and Growth



Case Study

- Marigold grown at 20 or 30 ^{o}C
- CO_2 exchange measured for 60 days


30 °C
20 °C
P_{net} (nmol/plant/s)
0
20
40
60
80
0
10
20
30
40
50
60
Time (days after seeding)
van Iersel, 2005
Physiol. Plant.

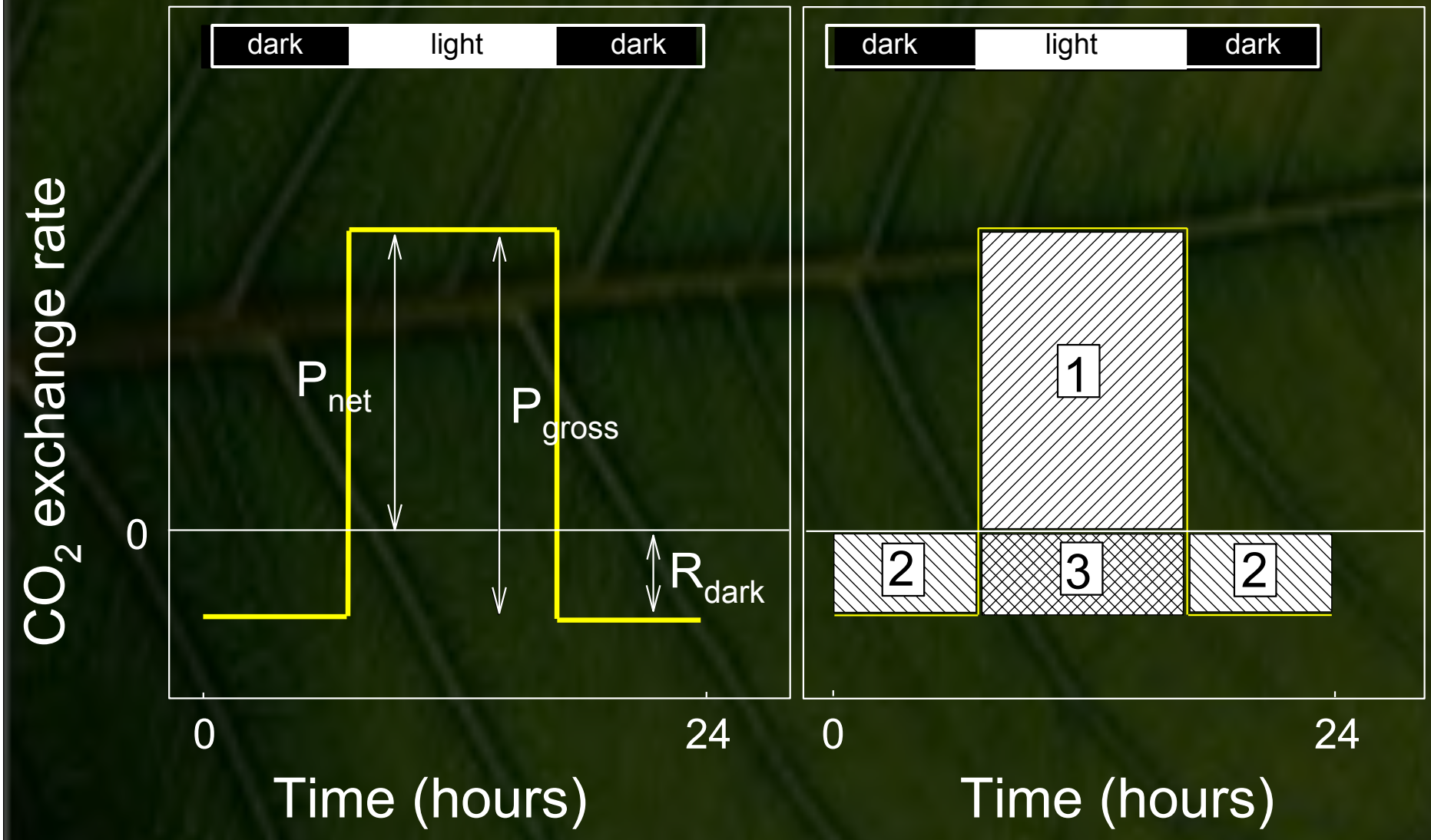

R_{dark} (nmol/plant/s)
0
10
20
30
0
10
20
30
40
50
60
Time (days after seeding)
30 °C
20 °C

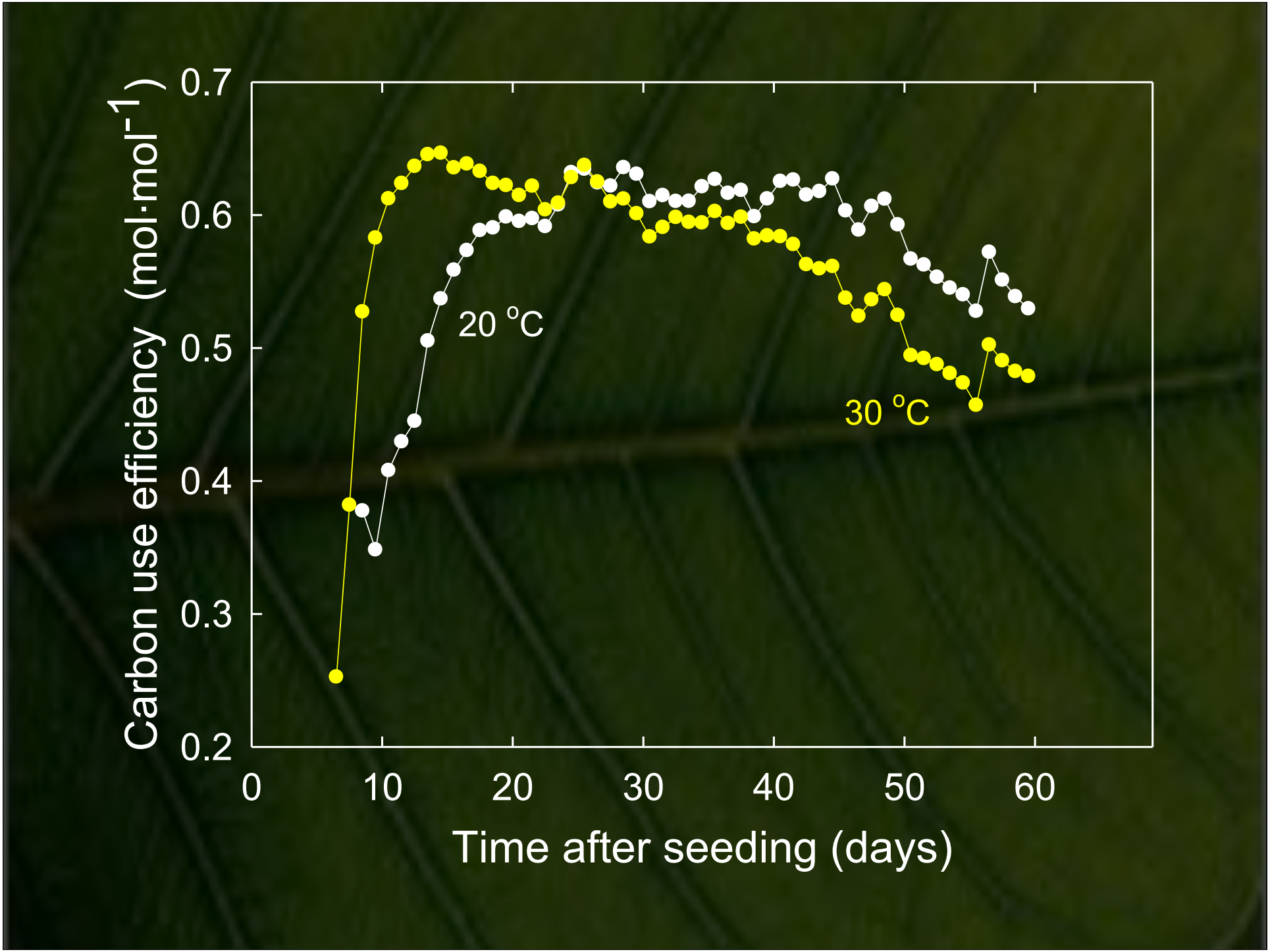
Data Interpretation

- Carbon-use efficiency =

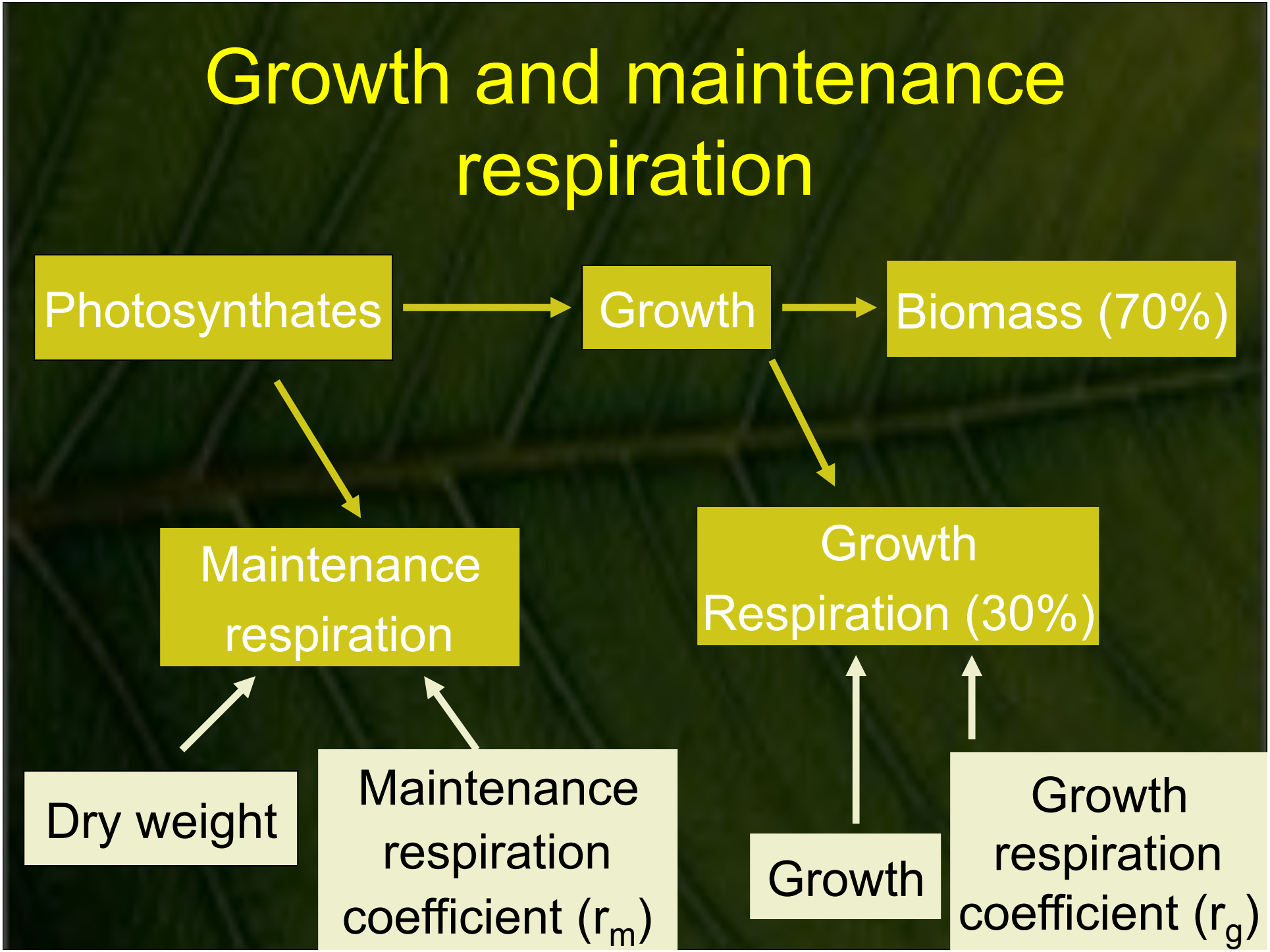
$$\frac{\text{Net amount of carbon incorporated into the plant}}{\text{Gross amount of photosynthates produced}}$$

Carbon Use Efficiency
(area 1 - area 2)/(area 1 + area 3)




Carbon use efficiency (mol·mol-1)
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60
Time after seeding (days)
20 °C
30 °C

Growth and maintenance respiration



Growth and maintenance respiration

- $R = R_m + R_g = r_m \times \text{weight} + r_g \times \text{growth}$

- $R / \text{weight} = r_m + r_g \times \text{growth/weight}$

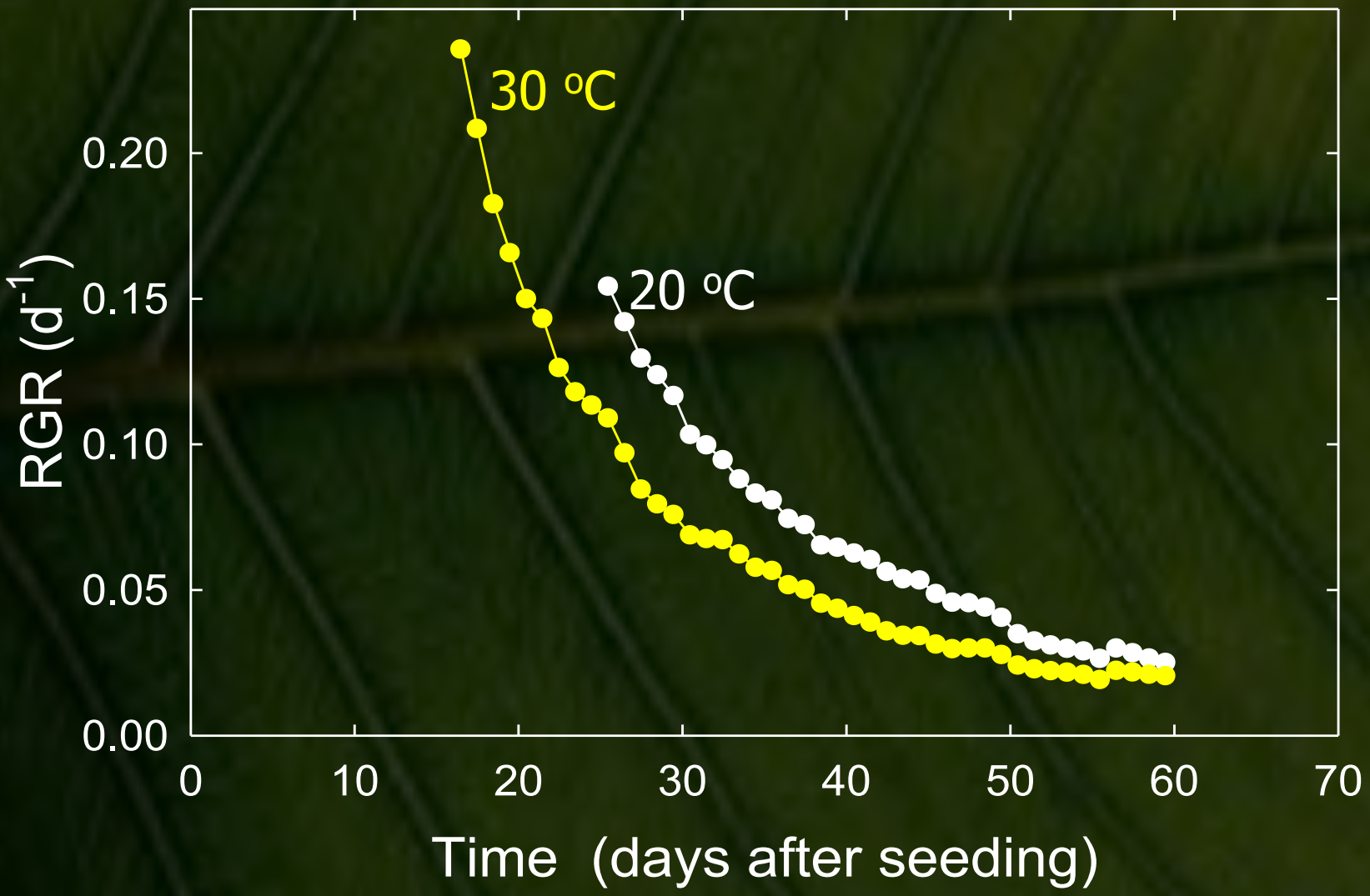
  $= r_m + r_g \times RGR$

  IF r_m and r_g are constants, they can be estimated from linear regression

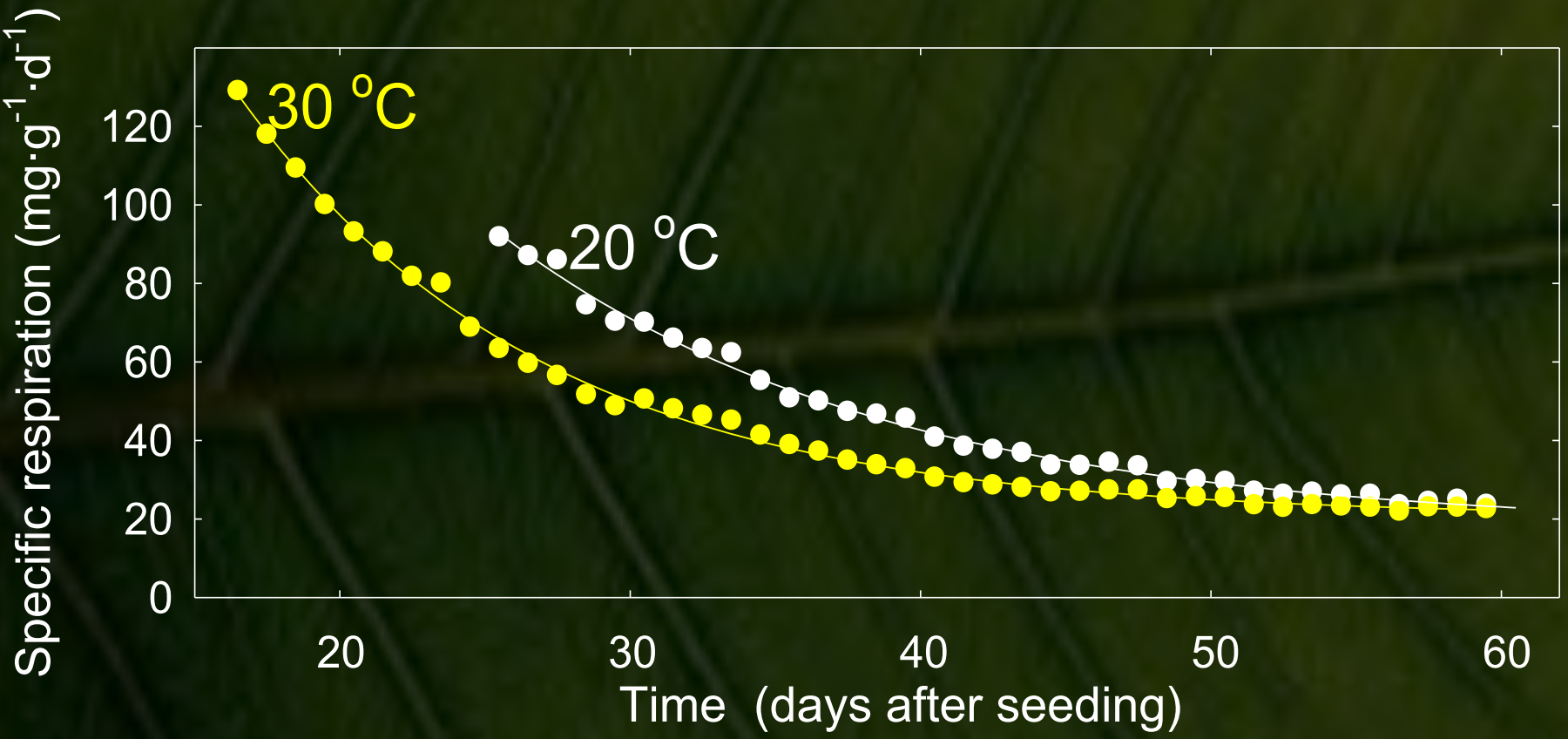
Calculations

- Growth rate and plant dry weight were calculated from CO_2 exchange measurements and carbon content of the plants
- RGR (growth rate / dry weight) and specific respiration rate (R_{dark} / dry weight) were calculated from these data

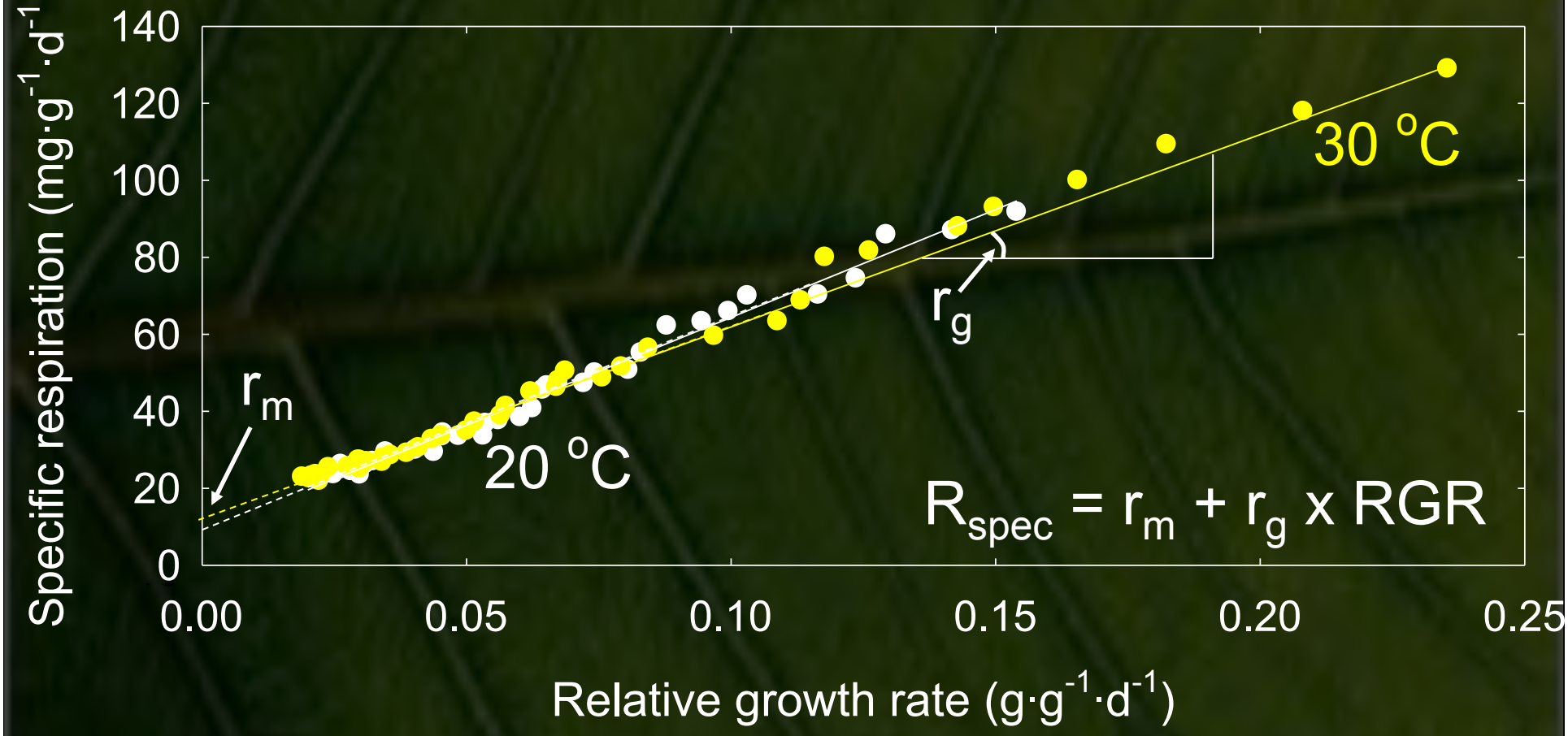
Relative growth rate



Growth and maintenance respiration



Growth and maintenance respiration

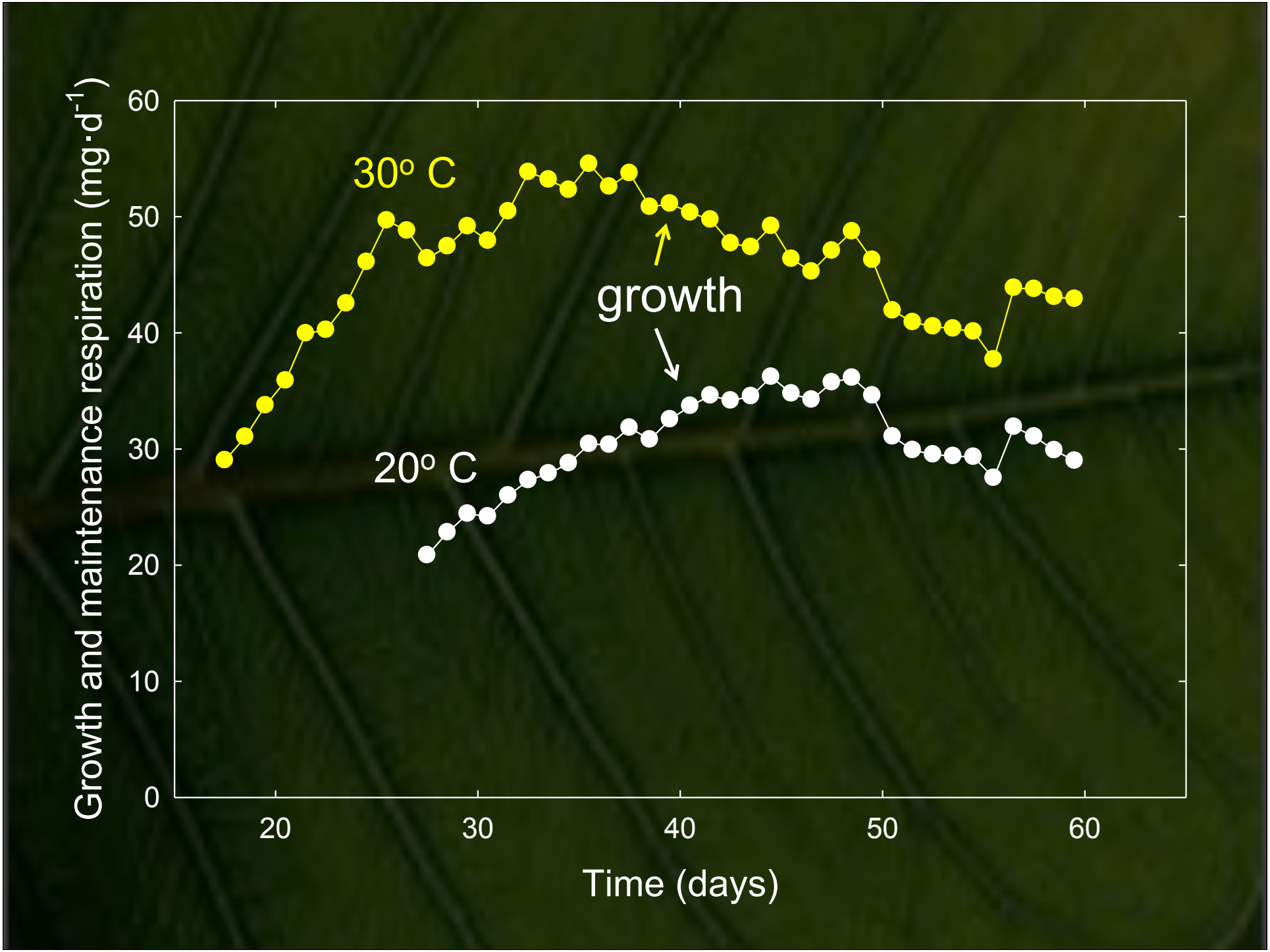


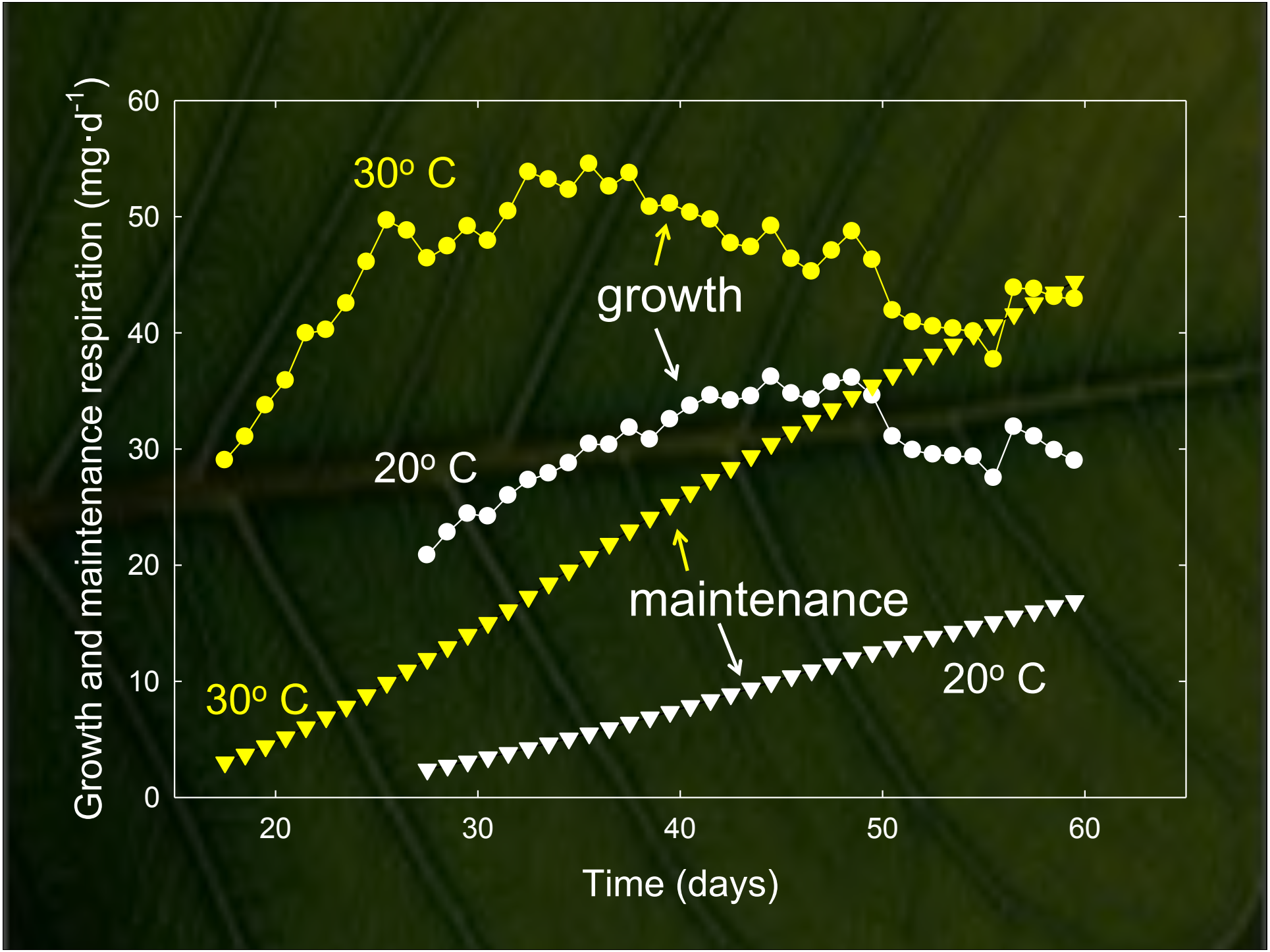
Growth and maintenance respiration

Temperature	m_r (mg g^{-1} d^{-1})	g_r (g g^{-1})
20 °C	8.4 ± 0.6	0.56 ± 0.01
30 °C	11.9 ± 0.5	0.50 ± 0.01
Q_{10}	1.42	0.89

Maintenance respiration = m_r × dry mass

Growth respiration = g_r × growth rate


Growth and maintenance respiration (mg·d-1)
60
50
40
30
20
10
0
30o C
growth
20o C
20
30
40
50
60
Time (days)


Growth and maintenance respiration (mg·d-1)
60
50
40
30
20
10
0
20
30
40
50
60
Time (days)
30o C
growth
20o C
maintenance
30o C
20o C

Conclusions

- Continuous whole plant CER gives:
  - Direct measure of growth
  - Physiological components of growth
    - Carbon use efficiency
    - growth respiration
    - maintenance respiration


Thank you