Winter 12-2005

Emerging Research Techniques & New Instrumentation for Plant Biology

Bruce Bugbee
Utah State University, bruce.bugbee@usu.edu

Emerging Research Techniques & New Instrumentation for Plant Biology

Bruce Bugbee

Crop Physiology Laboratory

Utah State University

Emerging Research Techniques & New Instrumentation for Plant Biology

Happiness doesn't come from things,
it comes from interactions with people

Mahatma Gandhi





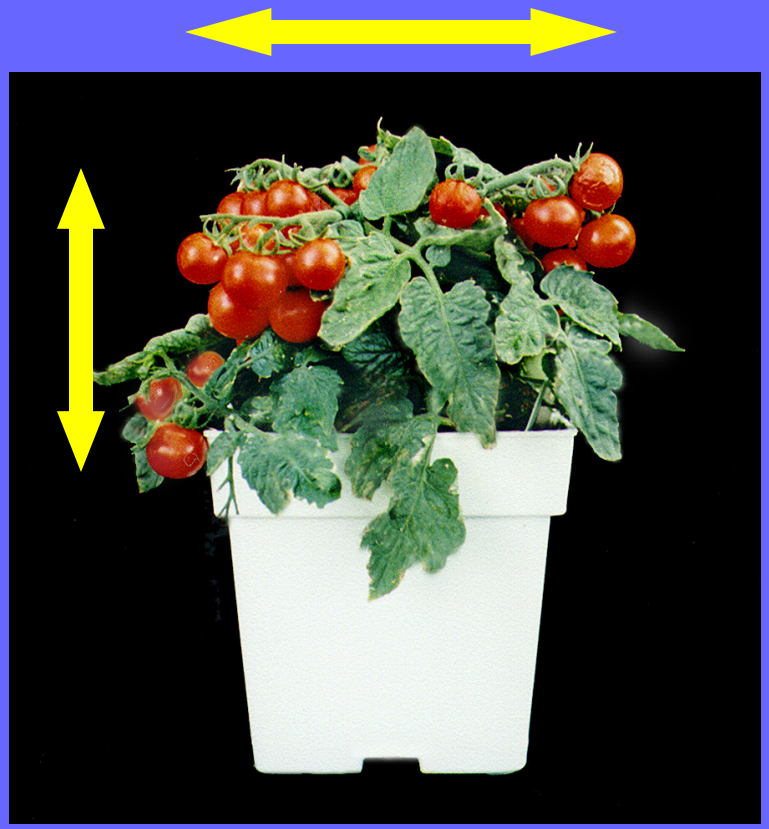




Water in

Non-destructive measurement of plant growth

Non-destructive measurement of plant growth



Non-destructive measurement of plant growth

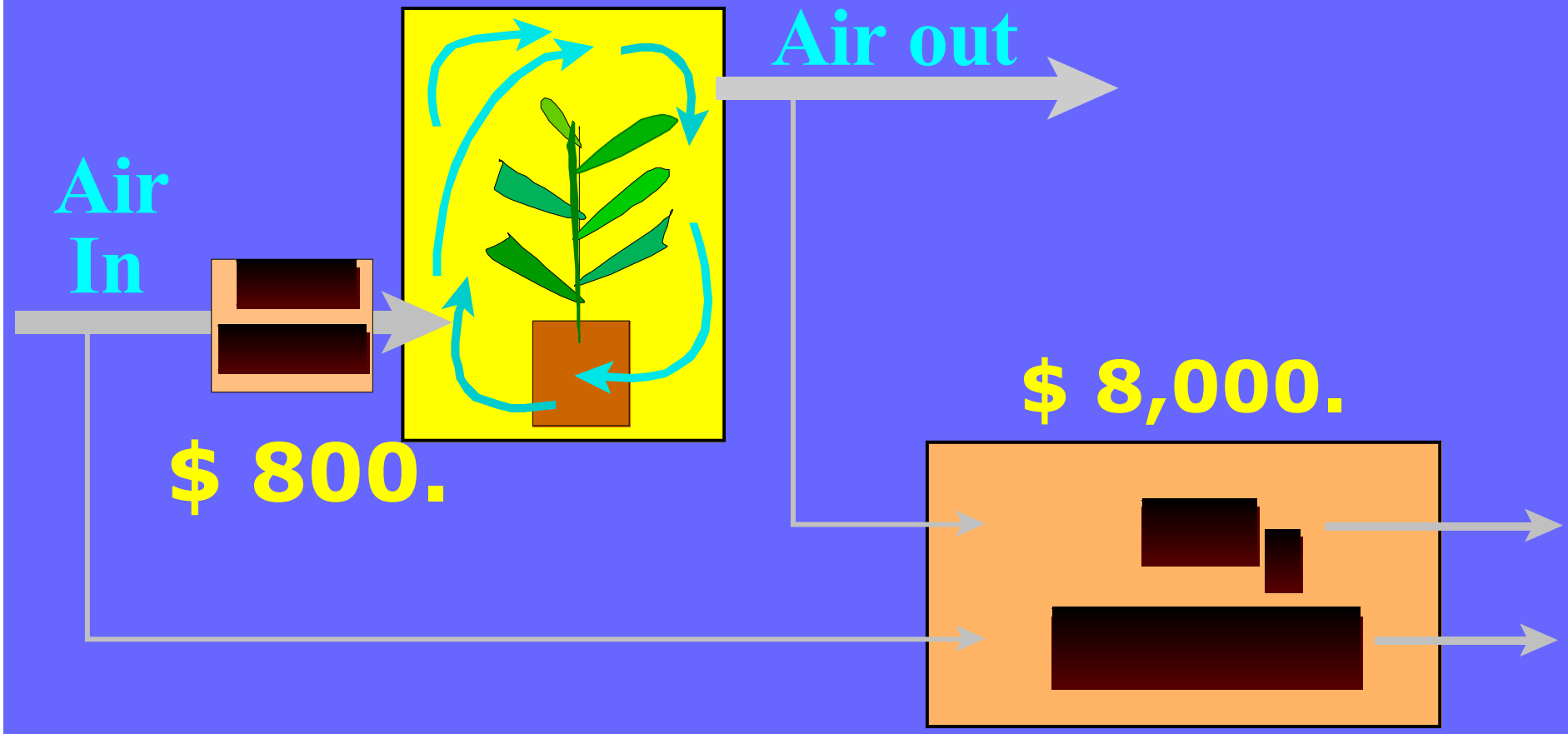
Review of Photosynthesis

$$CO_2 + H_2O \longrightarrow CH_2O + O_2$$

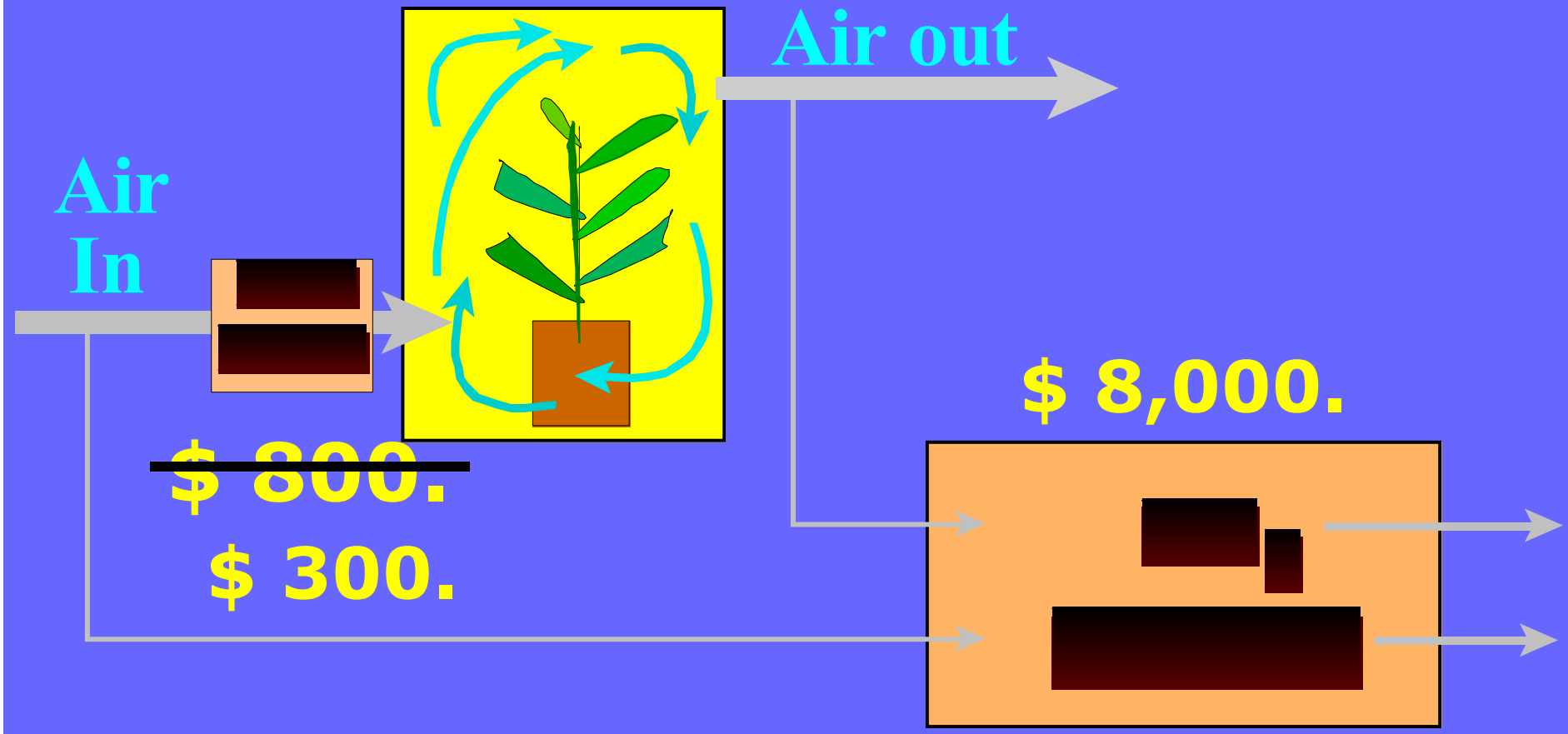
trace gas

carbohydrate

Measuring whole plant photosynthesis



Measuring whole plant photosynthesis

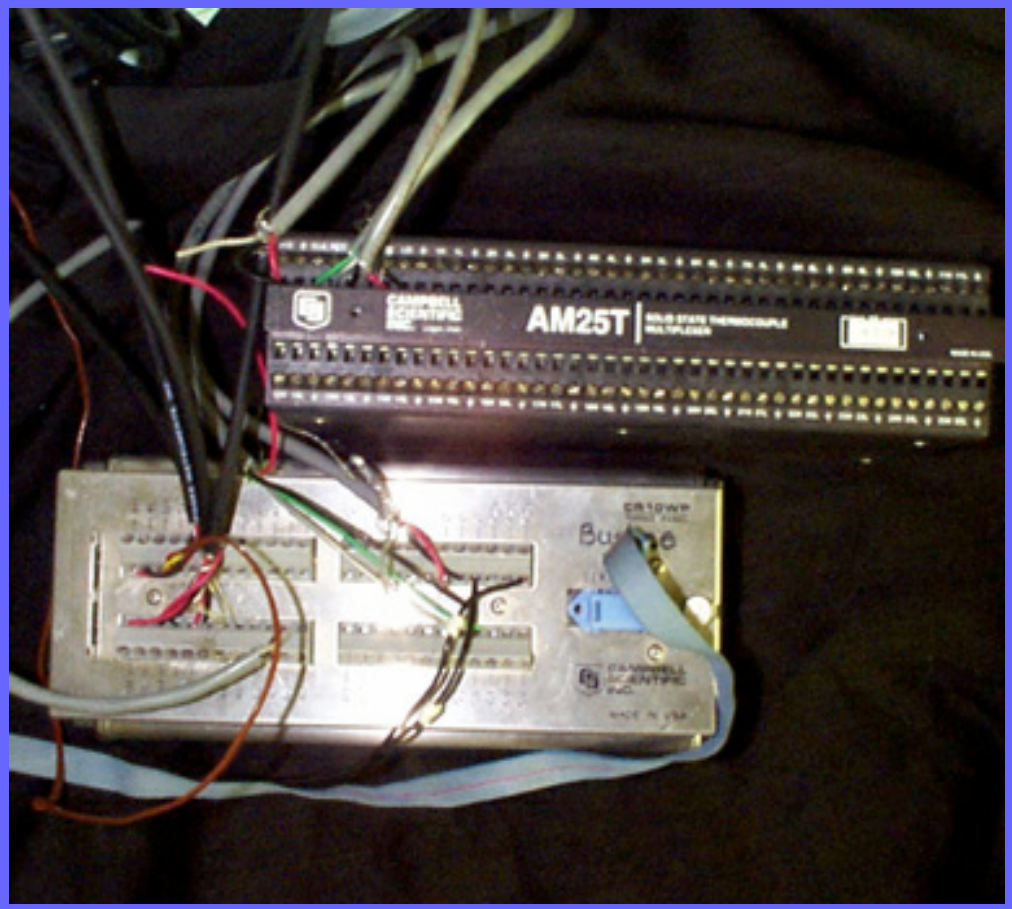


2 new CO_2 analyzers

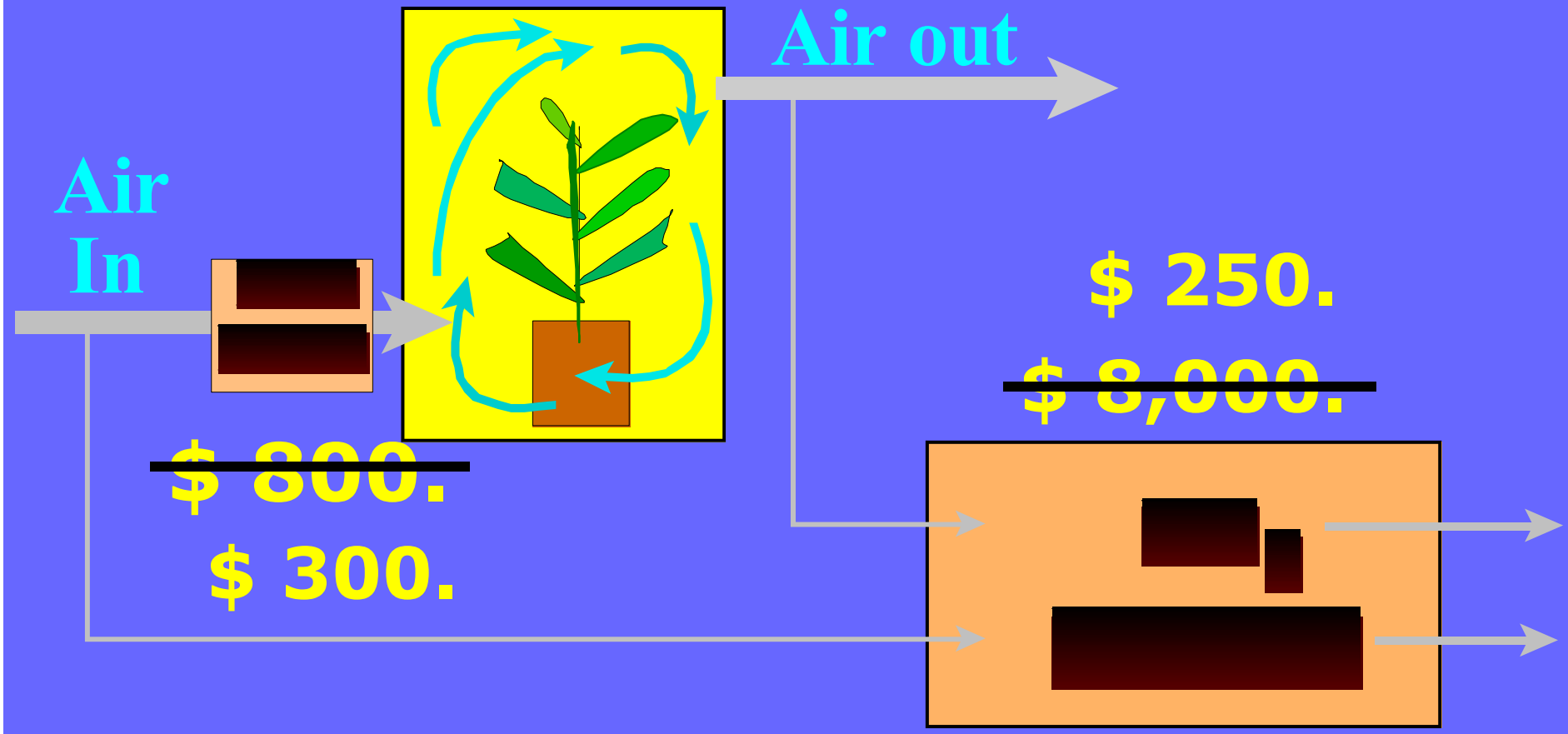
Digital Control Systems
$250.

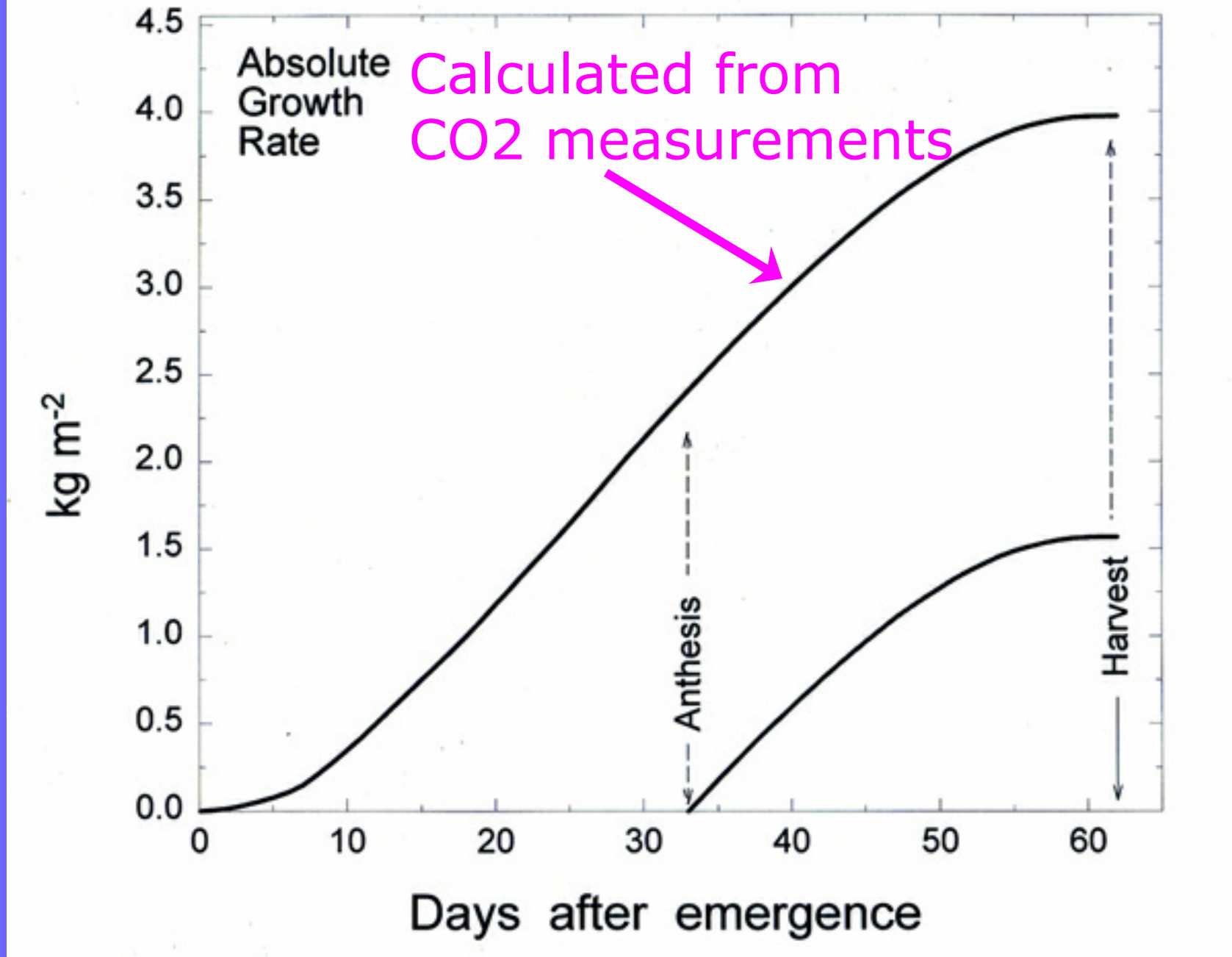
Visala
$450.

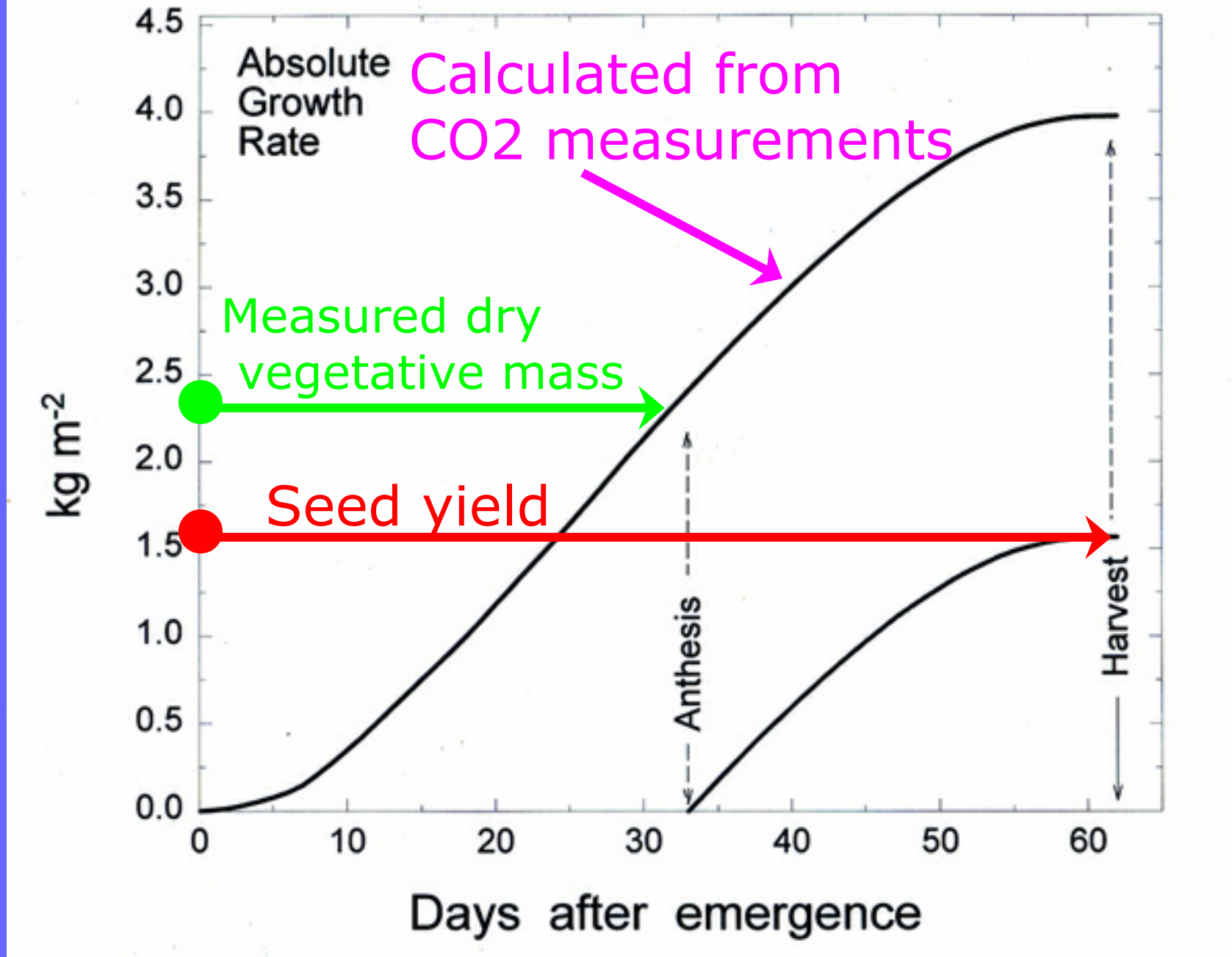
Dataloggers: recording volt meters

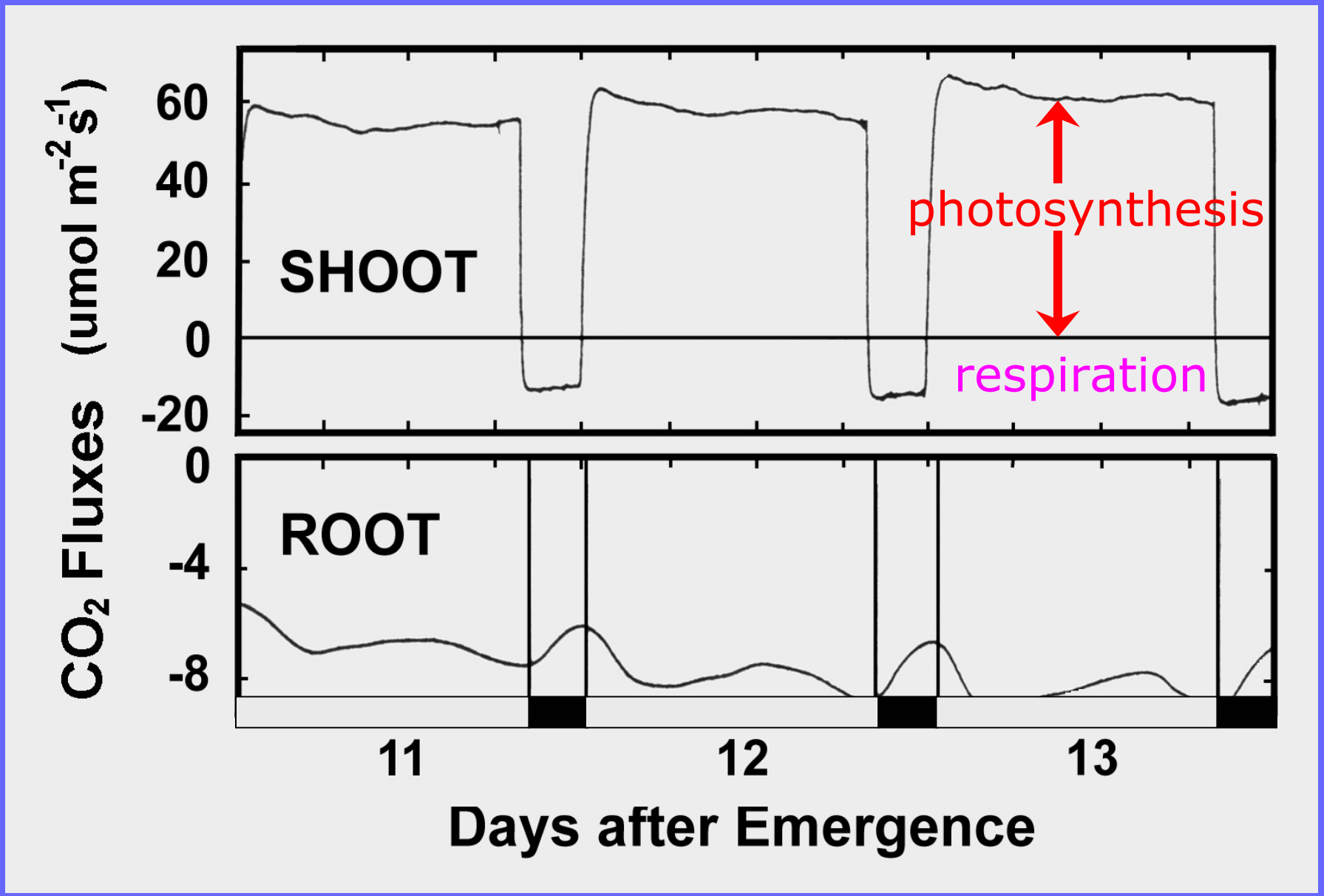


Measuring whole plant photosynthesis



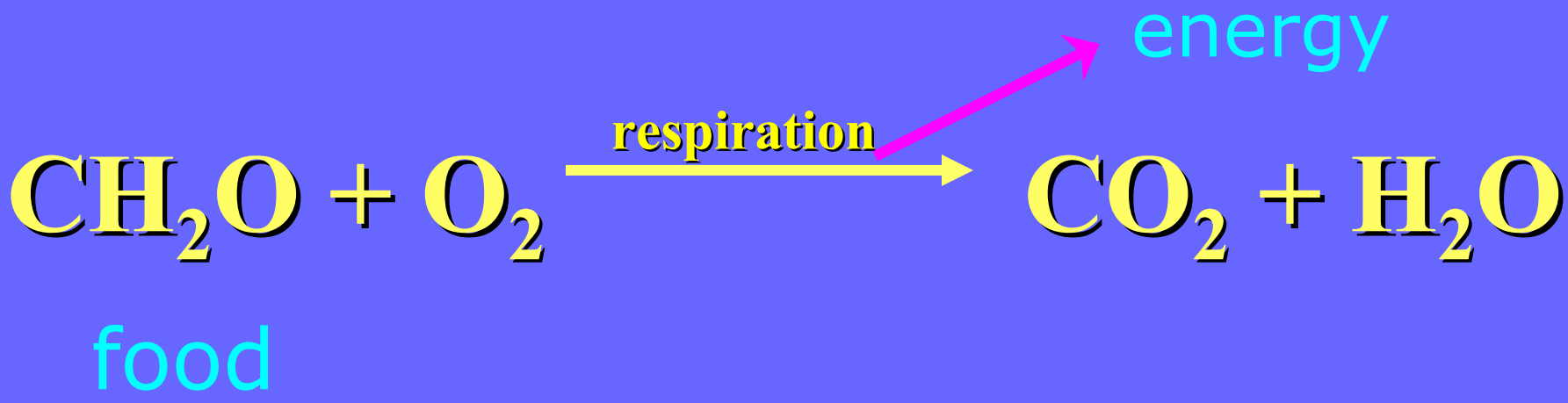

Absolute Growth Rate
Calculated from CO2 measurements
kg m-2
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
Anthesis
Harvest
Days after emergence


Absolute Growth Rate
Calculated from CO2 measurements
Measured dry vegetative mass
Seed yield
Anthesis
Harvest
kg m-2
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
Days after emergence

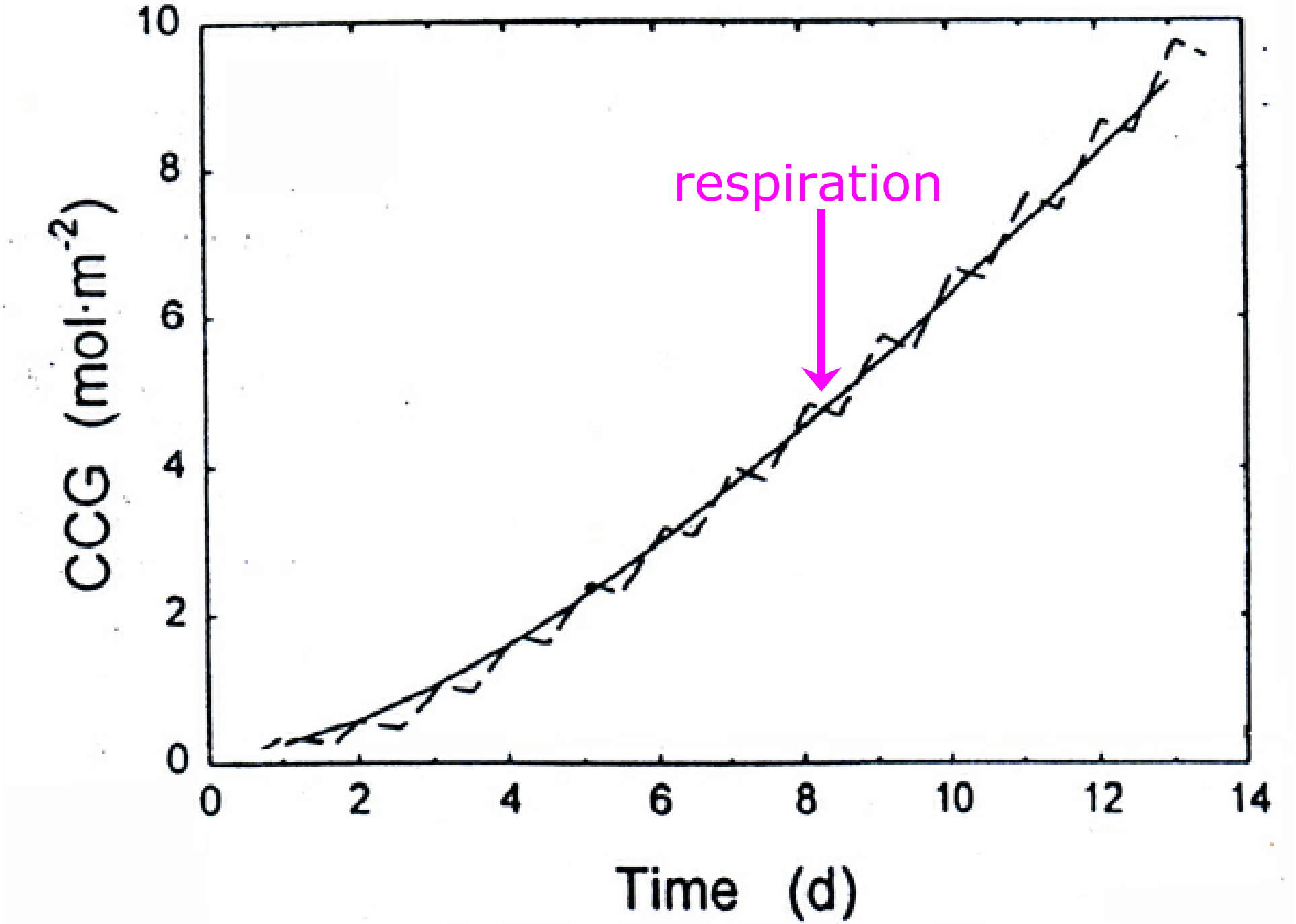


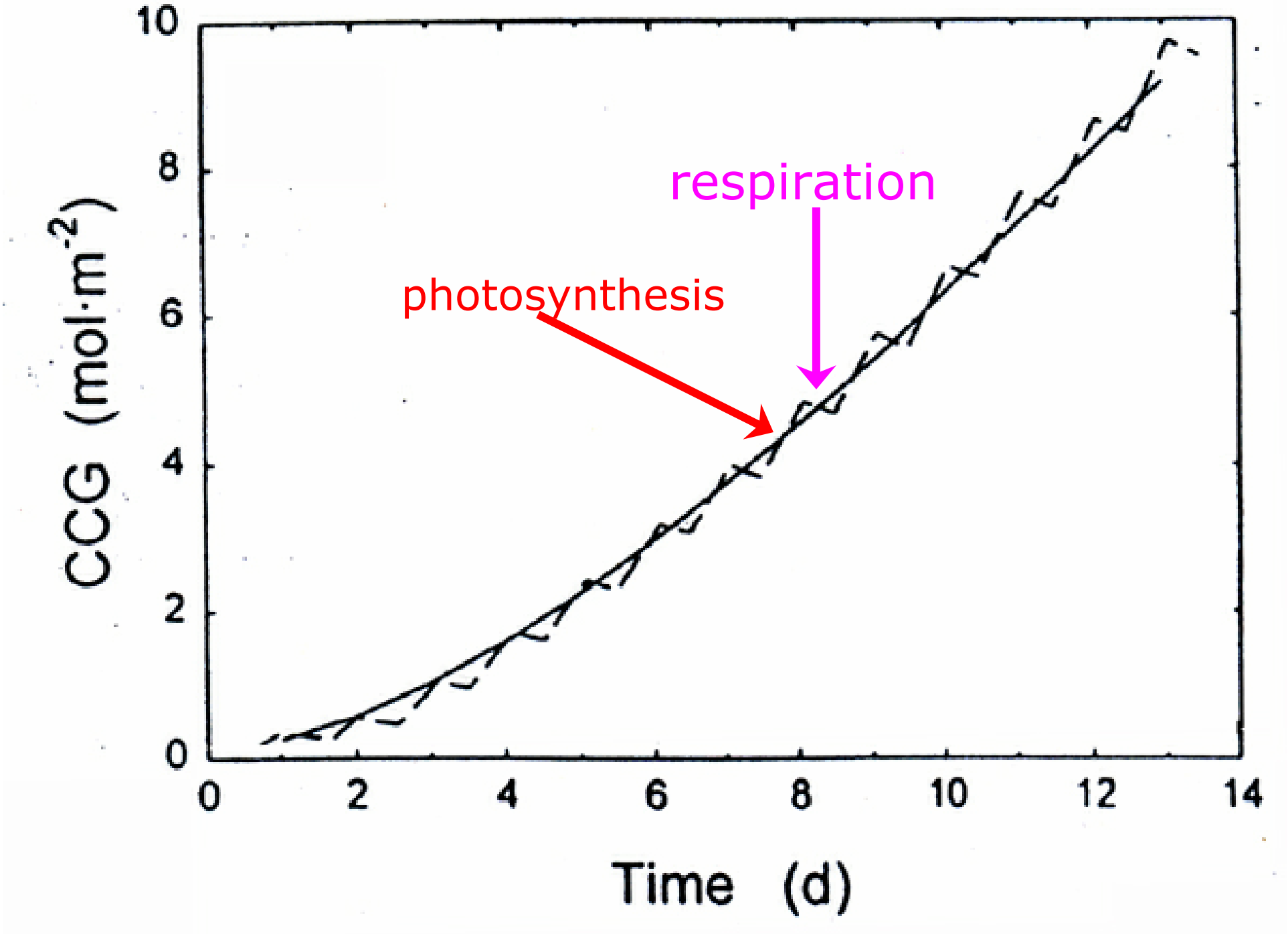
Monje and Bugbee 1996. Acta Hort. 440:123-126

Review of Respiration

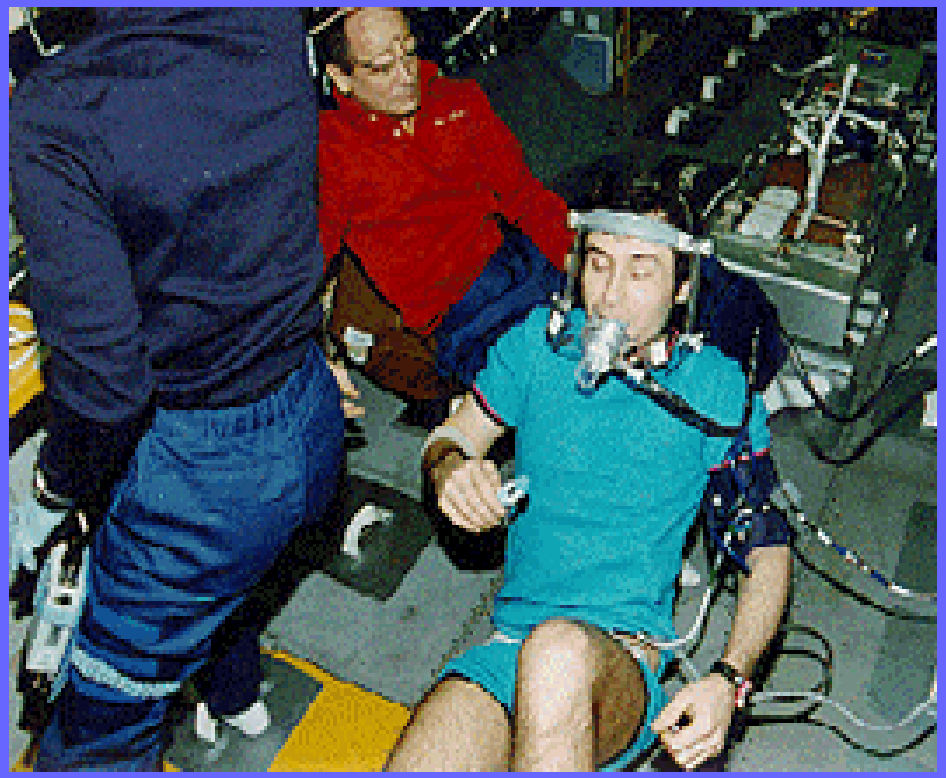


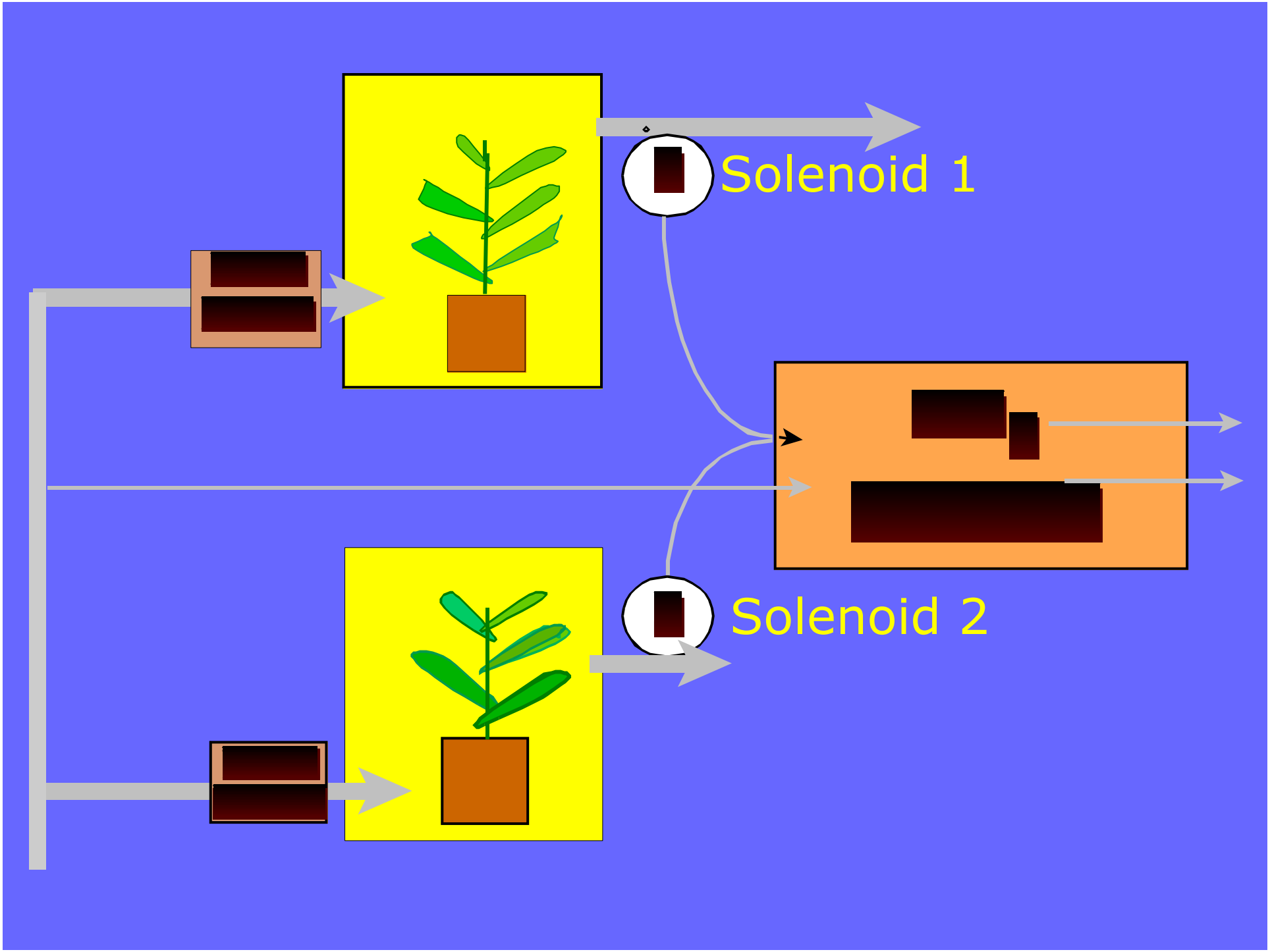
Review of Respiration


10
8
6
4
2
0
CCG (mol·m-2)
respiration
0
2
4
6
8
10
12
14
Time (d)

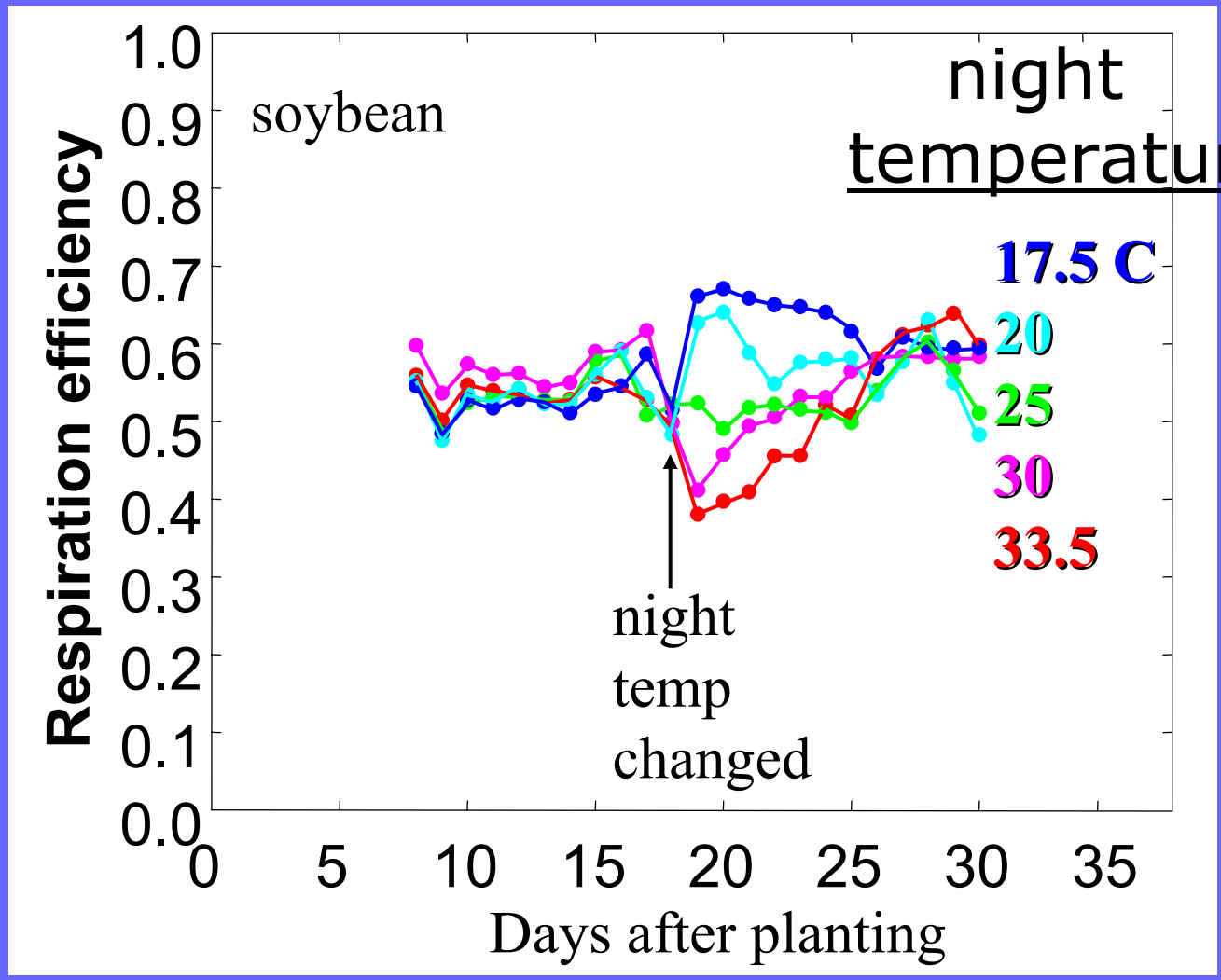

respiration
photosynthesis
CCG (mol·m-2)
Time (d)
0
2
4
6
8
10
12
14

Respiration research in Humans



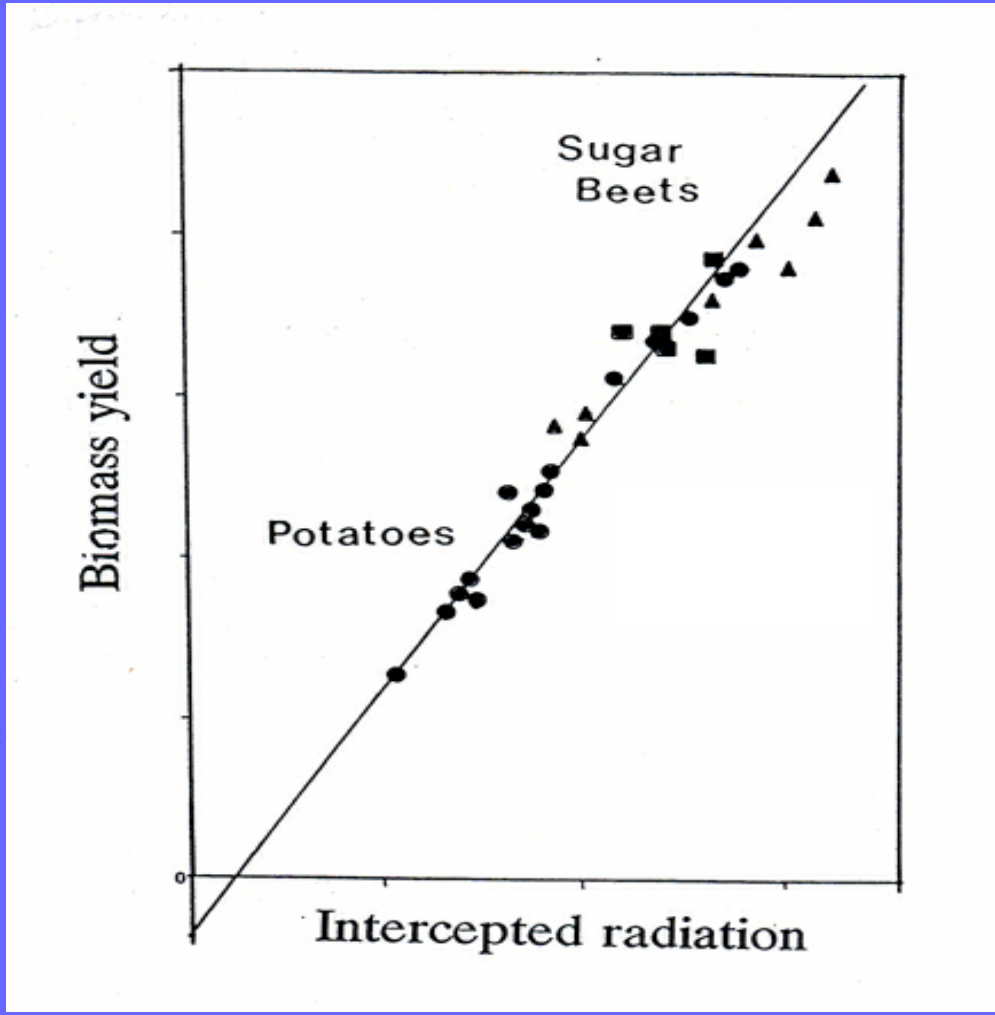

Solenoid 1
Solenoid 2


10 chamber gas exchange system


soybean
night
temperature
17.5 C
20
25
30
33.5
night
temp
changed
Respiration efficiency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
35
Days after planting

Production efficiency depends on rapid radiation interception

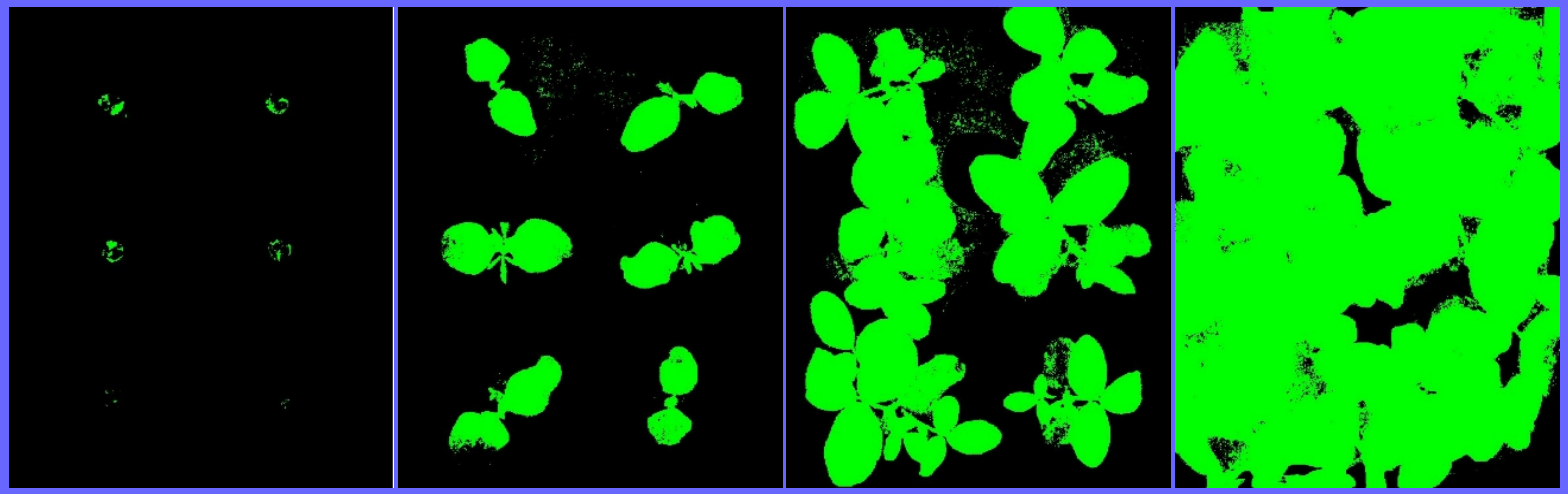
Dr. Maynard Bates

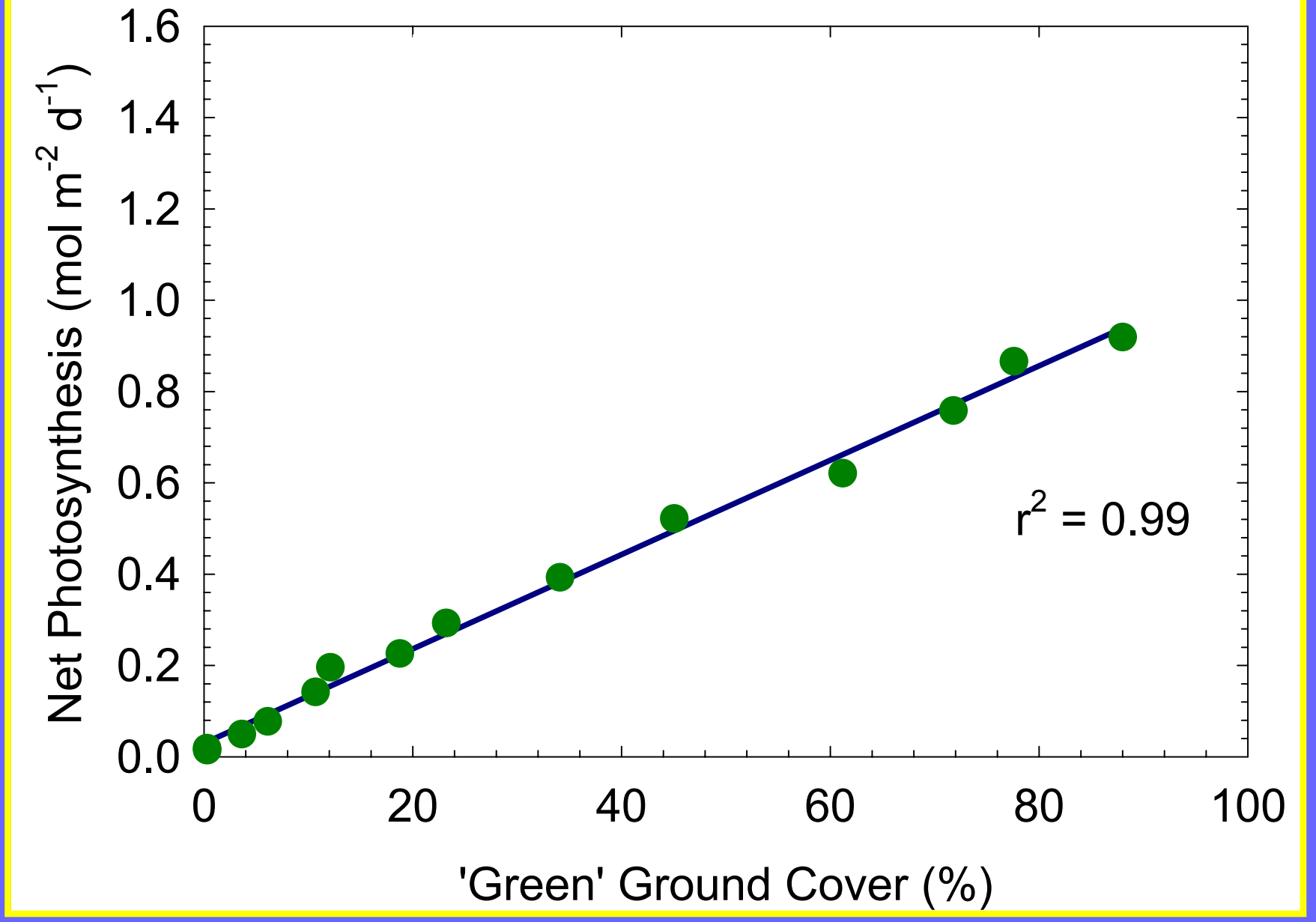


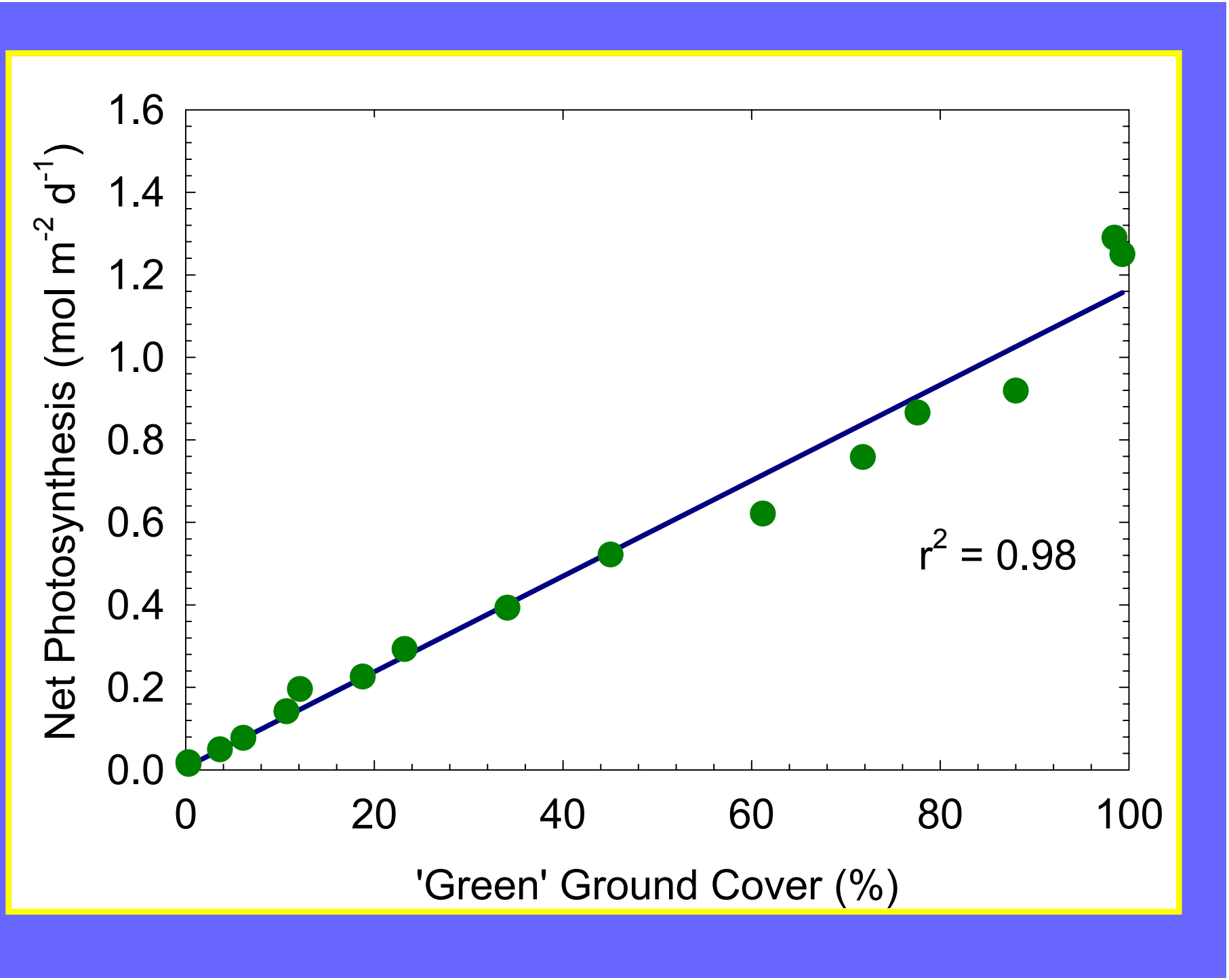
Digital cameras will soon be ubiquitous

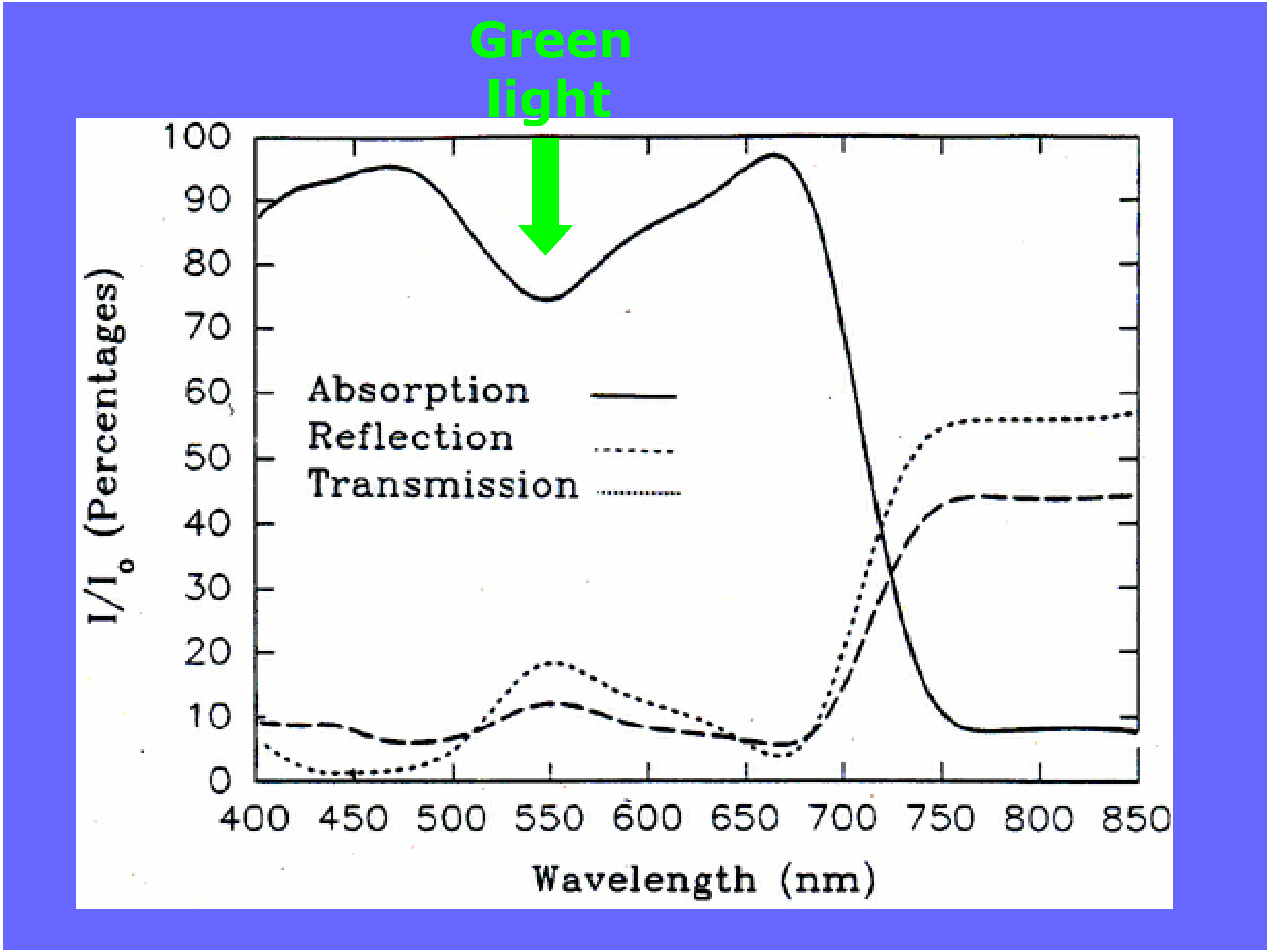
Photograph with digital camera

Digital image for % ground cover analysis

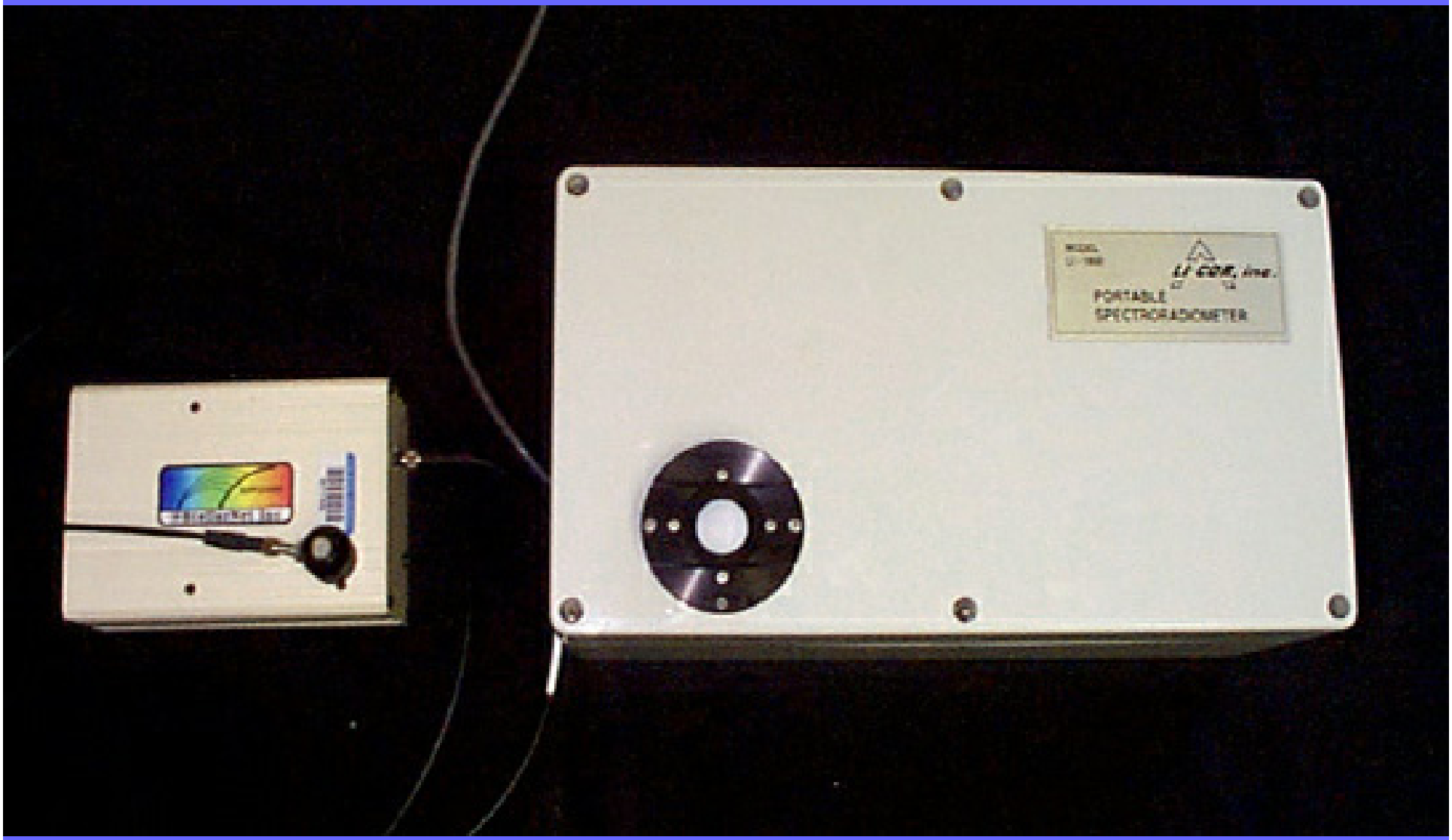



Net Photosynthesis (mol m-2 d-1)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
'Green' Ground Cover (%)
r2 = 0.99


Net Photosynthesis (mol m-2 d-1)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
'Green' Ground Cover (%)
r2 = 0.98

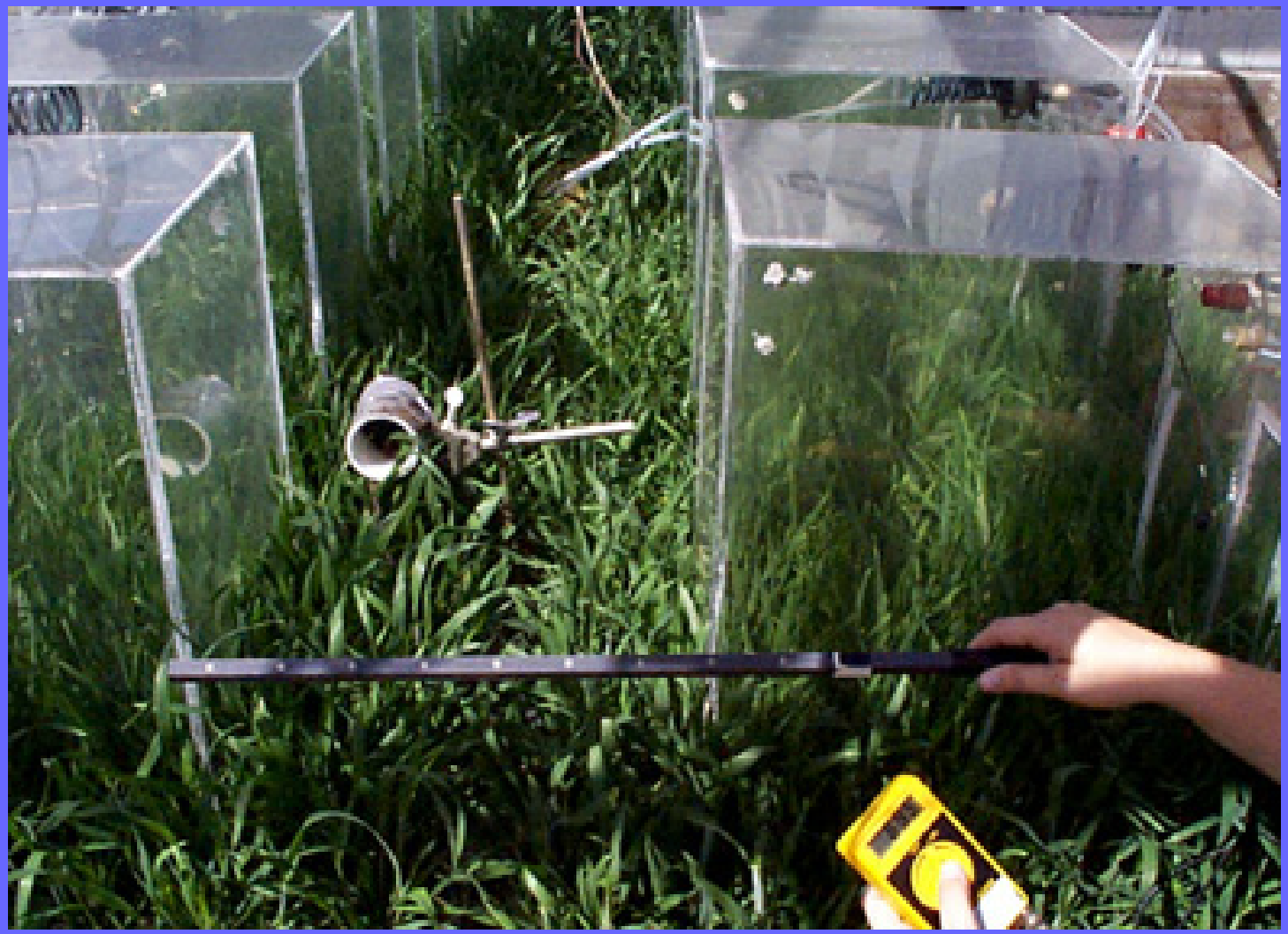

Green light
100
90
80
70
60
50
40
30
20
10
0
I/I$_o$ (Percentages)
Absorption
Reflection
Transmission
400 450 500 550 600 650 700 750 800 850
Wavelength (nm)

Digital chlorophyll meter $1500.



StellarNet
spectrometer
$2,800.

LI-COR
spectroradiometer
$18,000.



In development:
A light bar with green, red,
and far-red sensors

Managing nutrients in recirculating hydroponic systems

ions

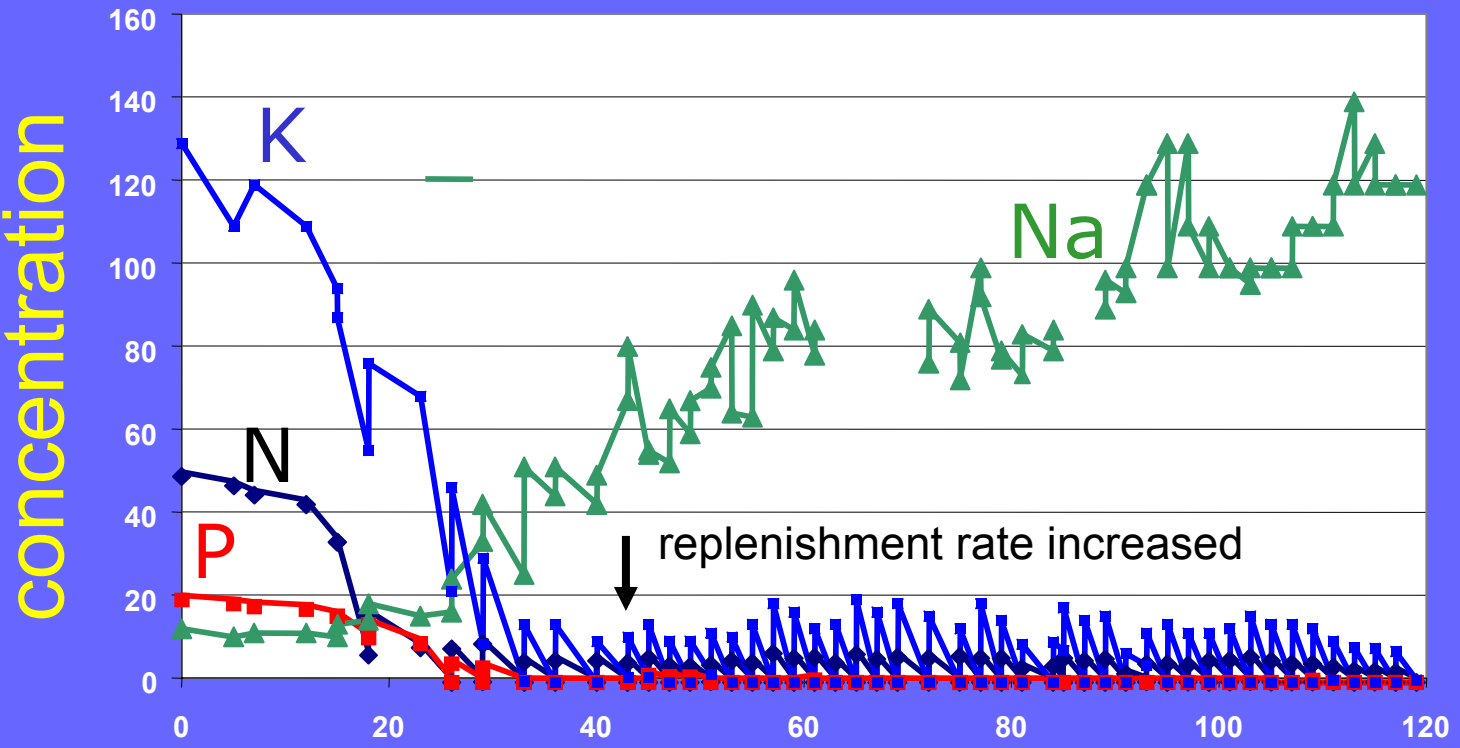
Bulk Solution

~ 0.01 %

ions

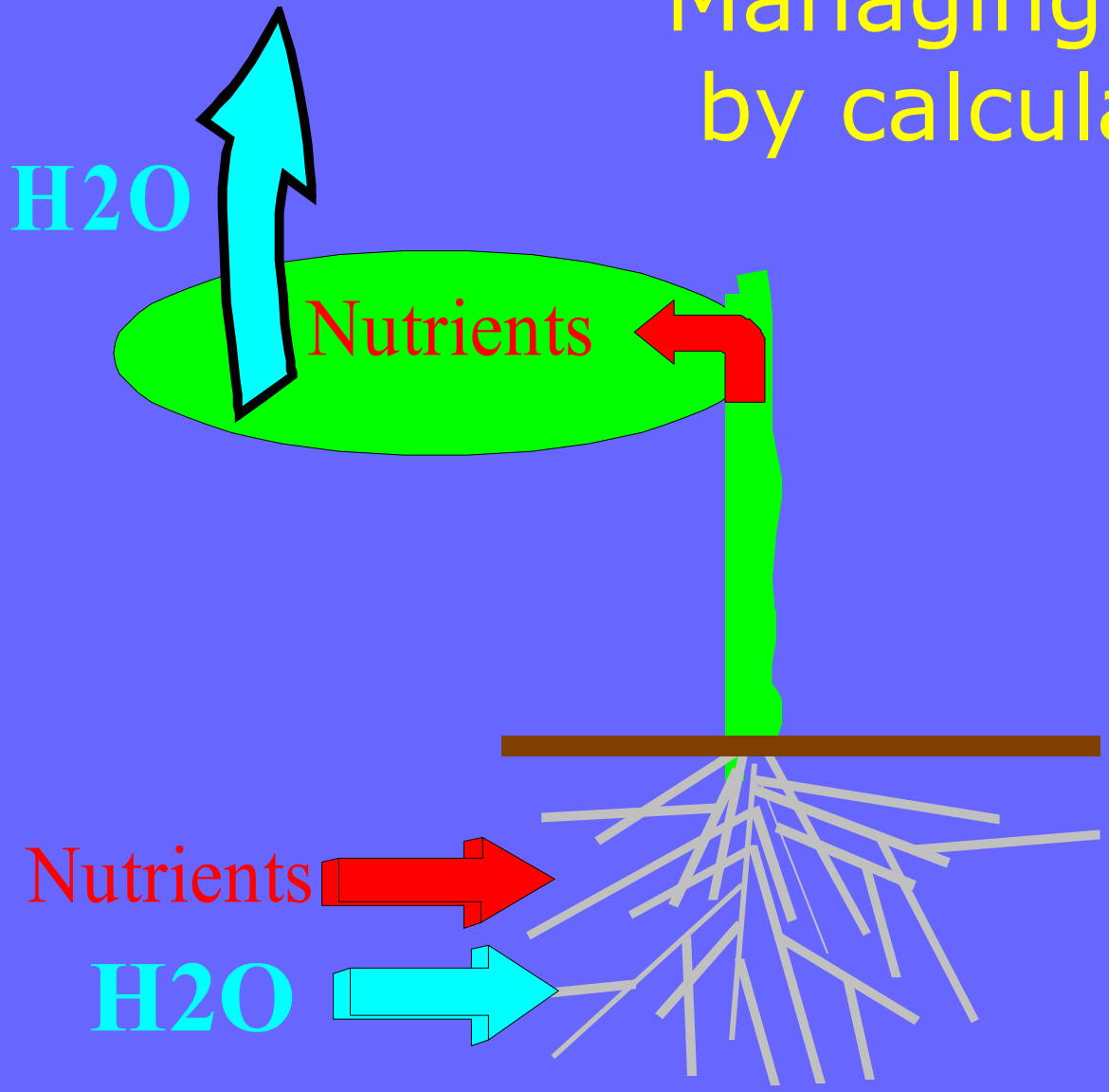
Solid phase storage is ~99.99 %

Concentration of Ions in recirculating Nutrient Solution

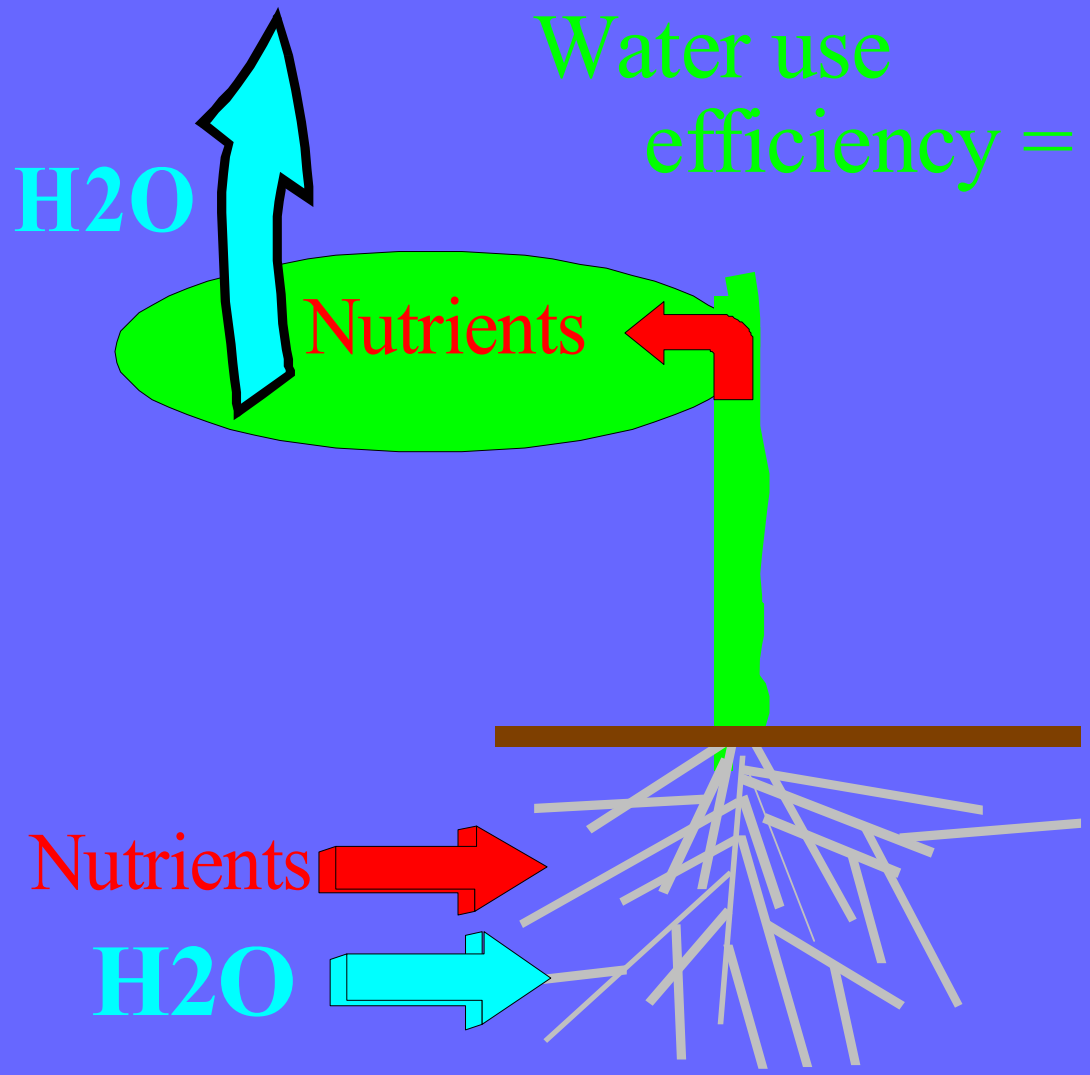


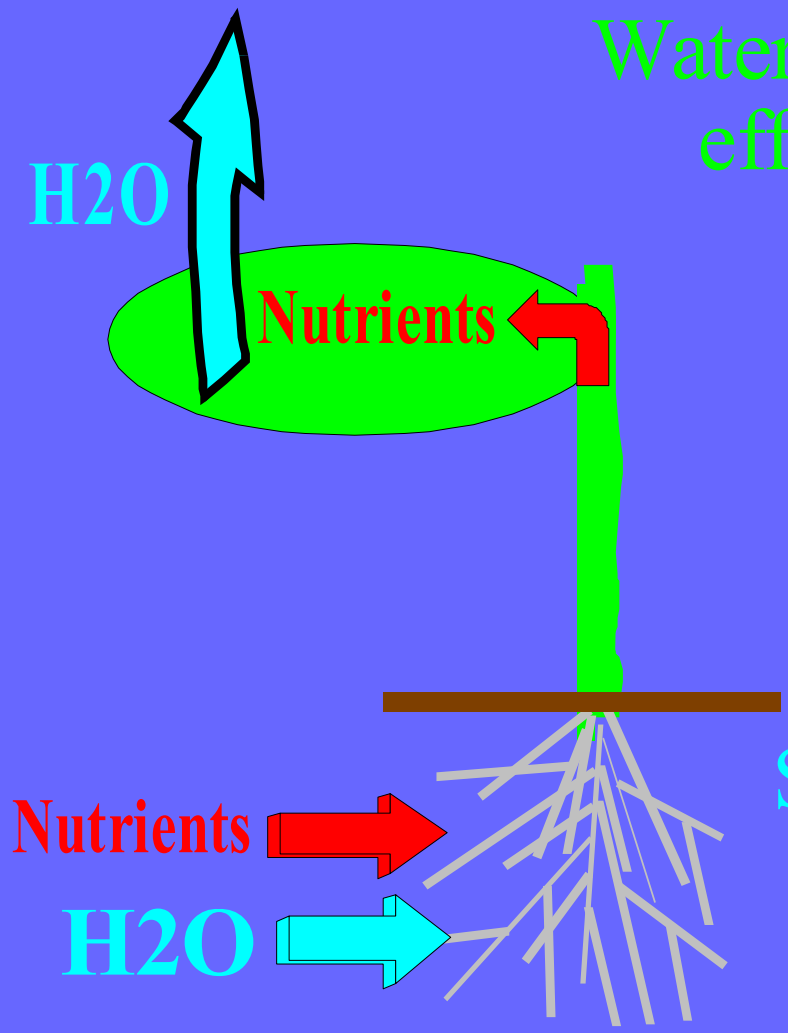
Data from NASA Johnson Space Center

Managing nutrients by calculation



Water use efficiency = $\frac{\text{kg biomass}}{\text{kg water}}$





$$\text{Water use efficiency} = \frac{\text{kg biomass}}{\text{kg water}}$$

$$\text{Nutrient concentration:} \frac{\text{mg}}{\text{kg biomass}}$$

$$\text{Solution concentration:} \frac{\text{mg}}{\text{kg water}}$$

Water use efficiency = $\frac{\text{kg biomass}}{\text{kg water}}$ $\frac{1 \text{ kg biomass}}{300 \text{ kg water}}$

Nutrient concentration: $\frac{\textbf{mg}}{\textbf{kg biomass}}$ $\frac{\textbf{40 g K+}}{\textbf{kg biomass}}$ (4%)

Solution concentration: $\frac{\text{mg}}{\text{kg water}}$ $\frac{40 \text{ g } K^+}{300 \text{ Liters water}}$

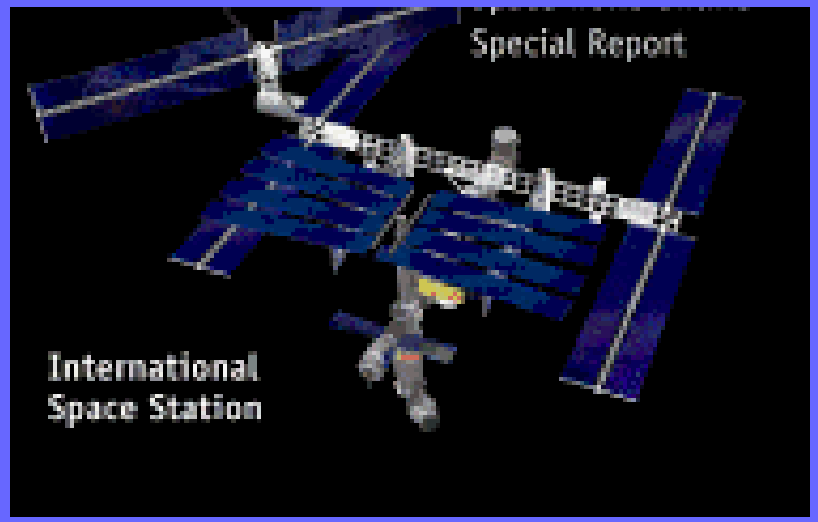
$\frac{3.4 \text{ mmol } K^+}{\text{Liter}}$


NH3
SO4
PO4
NO3
SMART COLORIMETER
OPERATOR'S MANUAL
LaMotte
SMART COLORIMETER
OFF
EDIT
USE

Concluding thoughts

Budgets

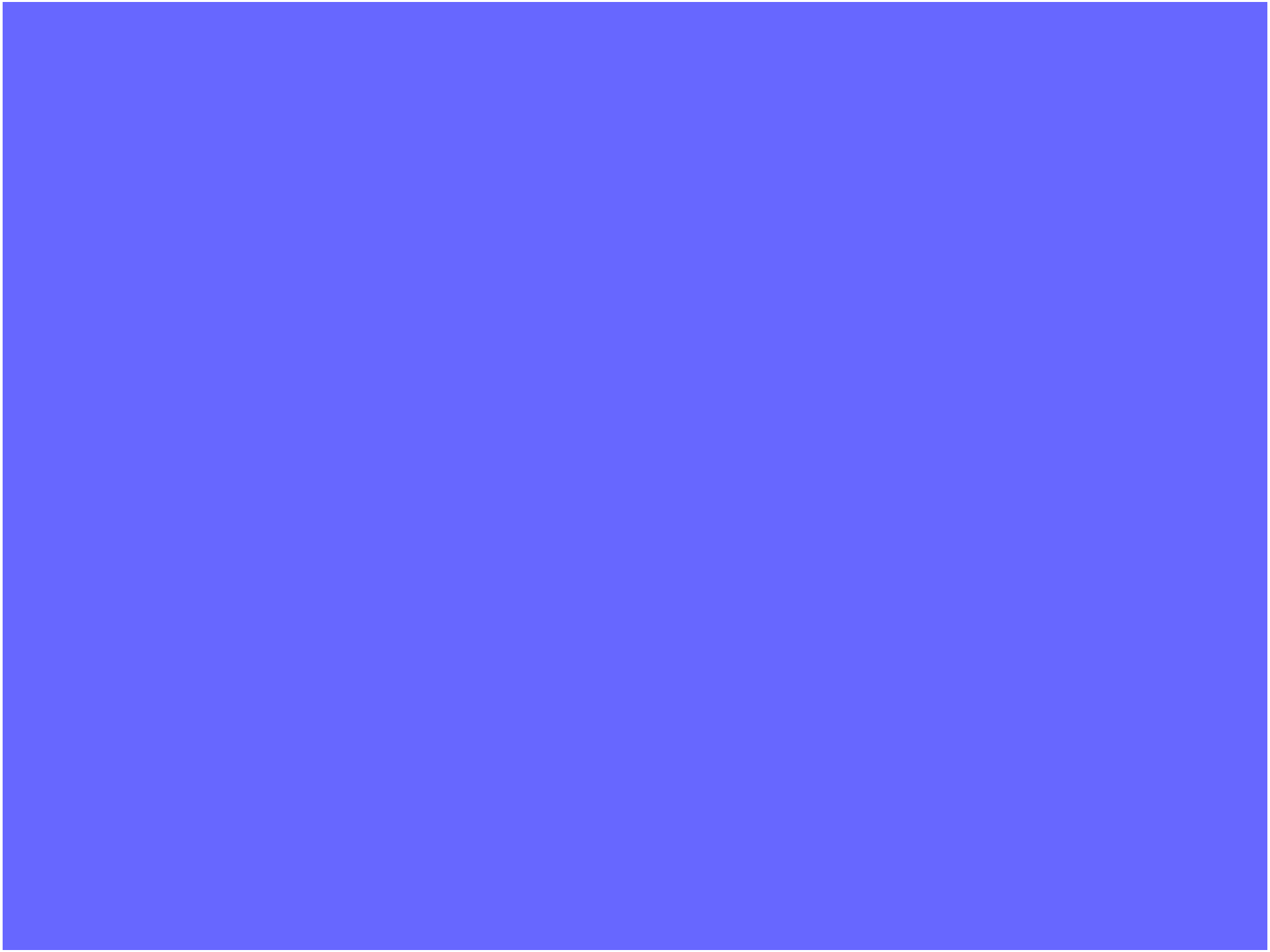
	billion dollars
US Military	251
Stealth bomber	72
Attack submarine	67
Space station	37

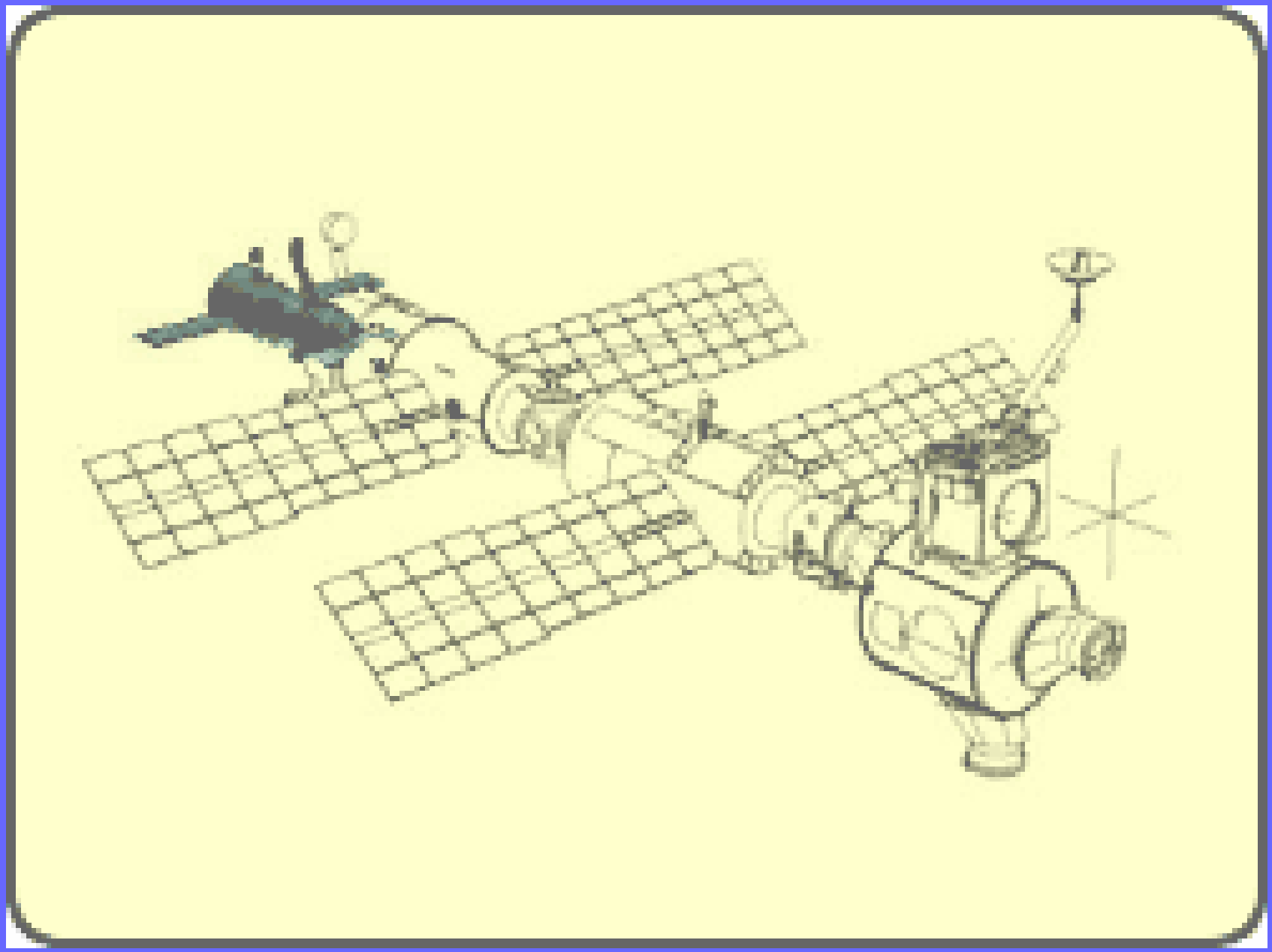


Crew of the next NASA mission to the space station

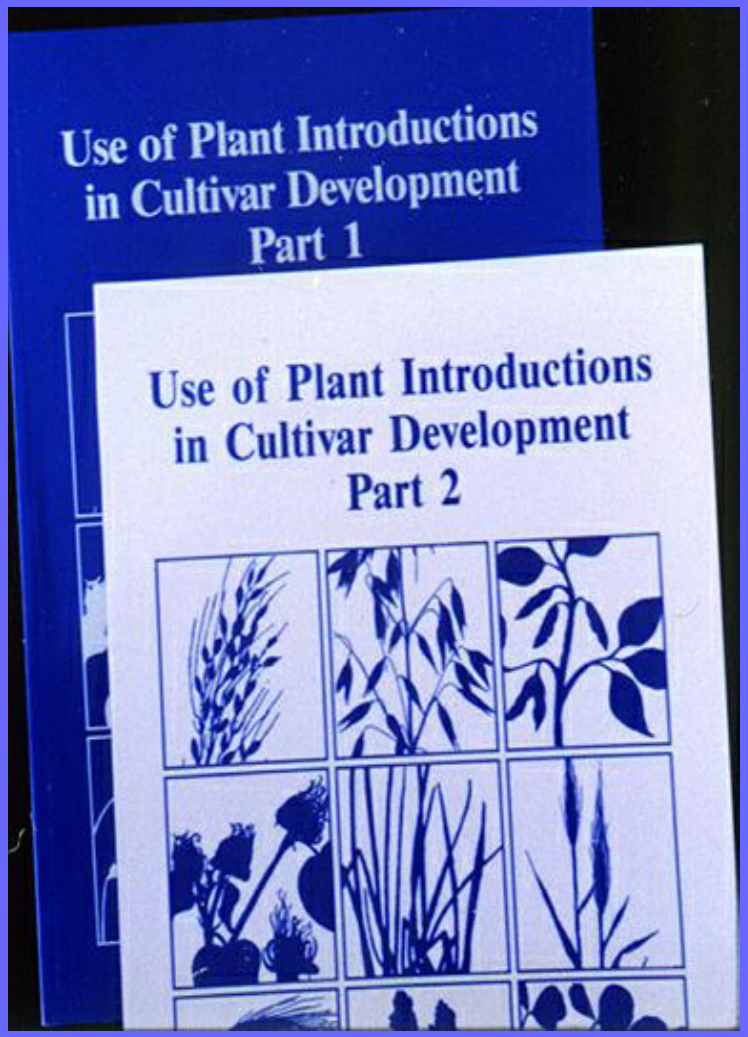
(scheduled to launch in 2 weeks)

The space is scheduled to be permanently manned starting 30 October 2000





New Techniques: Genetics



We have not achieved an efficient food production system in US Agriculture by manipulating only the environment.

Genetic engineering techniques now allow us to quickly develop new crop cultivars.

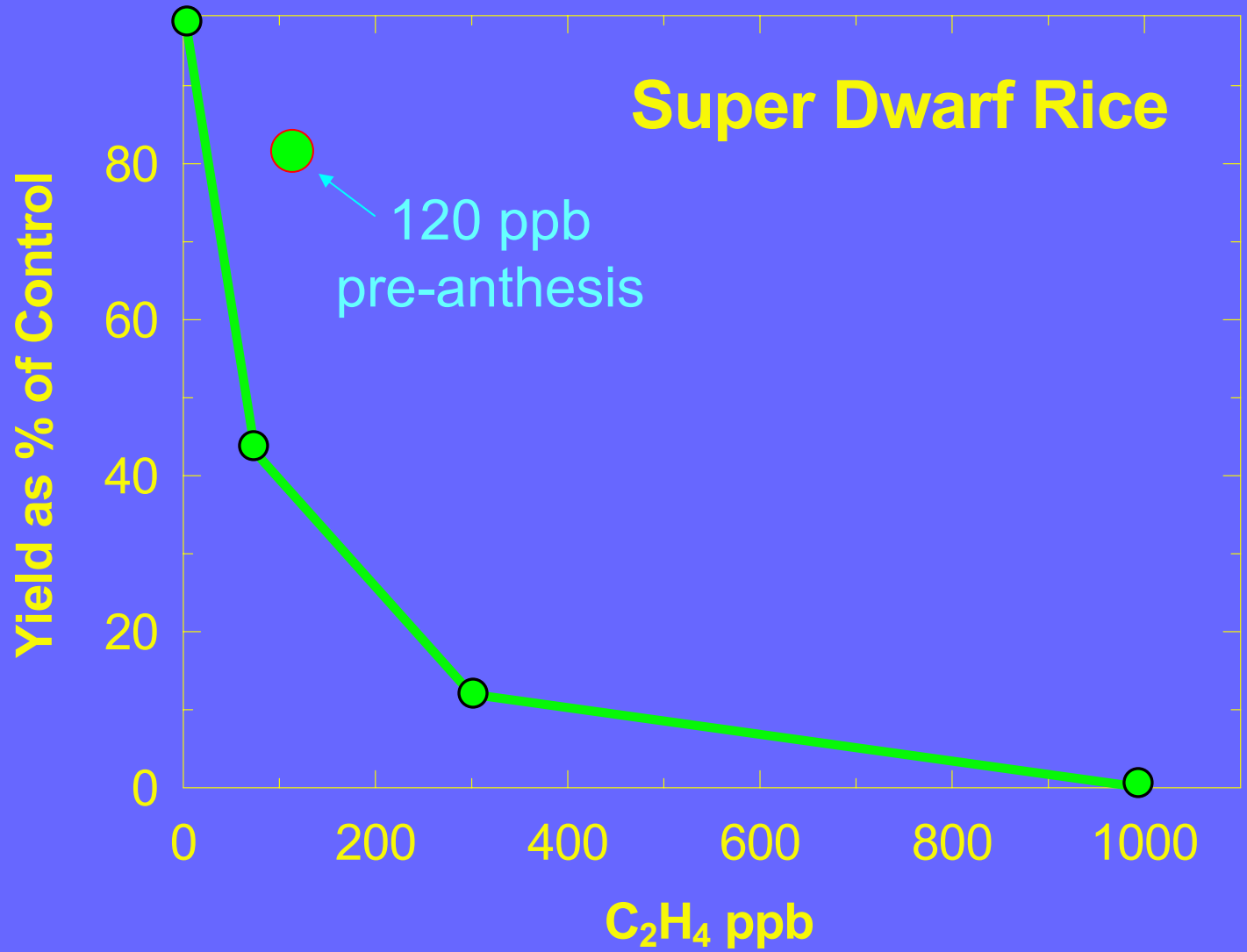
Sensitivity of Crops to Ethylene

Control 50 ppb

Control 30 ppb

Arabidopsis ethylene mutant


12 chamber gas exchange system


Super Dwarf Rice
120 ppb
pre-anthesis
Yield as % of Control
0
20
40
60
80
0
200
400
600
800
1000
C2H4 ppb

Super dwarf tomatoes

Micro-Tom

15 cm tall

Red Robin

20 cm tall

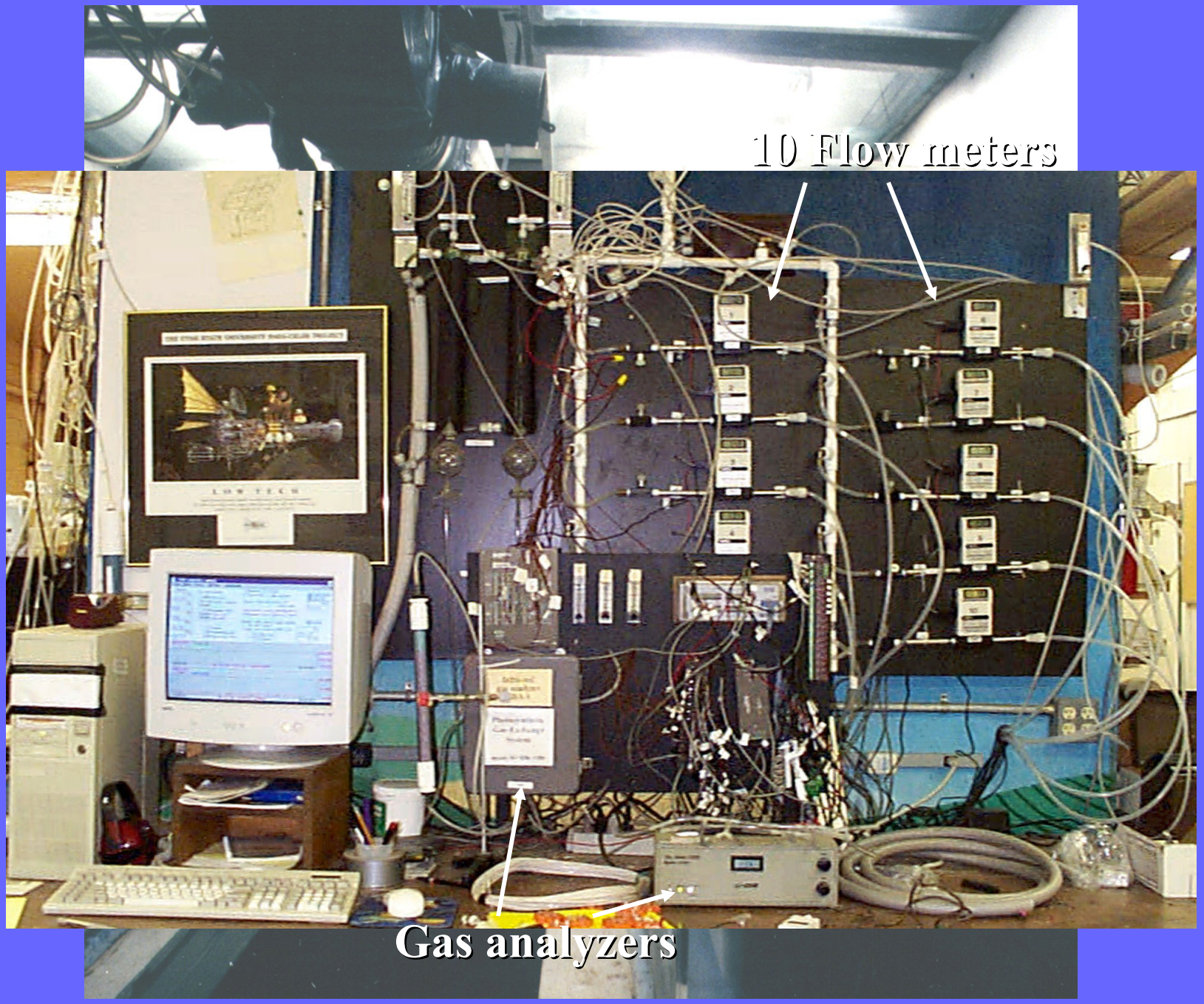
Super Dwarf tomato cultivars

	acidity	sweetness	overall flavor
Micro-Tom	5.0	4.3	4.7
Red Robin	3.0	5.2	4.2
Micro-Tina	4.2	5.7	5.6

Scott, et al. HortScience July 2000

Higher plant sensitivity to light

	PPF ($umol/m^2$ s
Full moonlight	0.05
Potato tuberization	0.6
Poinsettia color	0.1


10 Flow meters
Gas analyzers