Carbon Use Efficiency: Adaptation to Changing Environments

10 chamber gas exchange system

Jonathan Frantz and Bruce Bugbee

Crop Physiology Lab
Utah State University
12 chamber system in greenhouse
Carbon use efficiency

Animals

weight gain

Food input
Carbon use efficiency

Animals

- weight gain
- food input

Humans

- Work output
- Food input
Carbon use efficiency

ANIMALS

weight gain
-----
food input

5 to 20%

PLANTS

weight gain
-----
gross photosynthesis

~ 60%
LETTUCE

Constant temperature from planting

Temperature (°C)

Carbon Use Efficiency

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

20 22 24 26 28 30 32 34 36
CUE ~ 0.6


Whole plant dry weight (g C)
Sunny days

Cloudy days

- **Net Photosynthesis**
- **Respiration**

The graphs show the diurnal variations in net photosynthesis and respiration for sunny and cloudy days. The x-axis represents time of day, and the y-axis represents the intensity of photosynthesis or respiration.
Carbon use efficiency

![Graph showing the relationship between PPF (µmol m\(^{-2}\) s\(^{-1}\)) and Carbon Use Efficiency (% of control). The graph displays a curve that increases as PPF increases, reaching 60% at certain PPF values. The inset image shows a 1st day after treatment view.](image)
Carbon use efficiency

![Graph showing carbon use efficiency vs. PPF (µmol m⁻² s⁻¹). The x-axis represents PPF, and the y-axis represents carbon use efficiency (% of control). The graph includes data points for the 1st and 2nd day after treatment.]
Carbon use efficiency

Carbon Use Efficiency (% of control) vs. PPF (µmol m⁻² s⁻¹)

- 1st day after treatment
- 2nd day after treatment
- 3rd through 9th day after treatment
TOMATO - vegetative growth

Carbon Use Efficiency (% of control)

12th day after treatment
2nd day after treatment
1st day after treatment

PPF (µmol m⁻² s⁻¹)

0 100 200 300 400 500 600 700
TOMATO

Rate of adaptation to low light

Carbon Use Efficiency (% of control)

PPF (μmol m⁻² s⁻¹)

1st day after treatment
2nd day after treatment
12th day after treatment
Days after shade treatment

Relative CUE (% of control)

Rate of adaptation to 75% shade

TOMATO
Days after shade treatment

0  5  10  15  20

0  20  40  60  80  100

TOMATO

Relative CUE (% of control)

LETTUCE

Rate of adaptation to 75% shade
• Most shade adaptation occurred within two days during vegetative phase

• Up to 12 days were required for complete adaptation

• species adapted differently
Lettuce respiration

$R_{dark}$ (% of control) vs. PPF ($\mu$mol m$^{-2}$ s$^{-1}$)

- 1st day after treatment
- 2nd day after treatment
- 3rd through 9th day after treatment
LETTUCE

$P_{\text{net}}$ (% of control) vs. PPF (µmol m$^{-2}$ s$^{-1}$)

1st day after treatment

2nd to 9th day after treatment
LET T U C E

Quantum Yield (mol C fixed mol photons abs⁻¹) vs. PPF (µmol m⁻² s⁻¹)

Days 3 through 9
Day 2
Day 1
Pre-treatment
area A - area B = Daily Carbon Gain

Respiration occurs in both the day and night
Photosynthesis (umol m\(^{-2}\) s\(^{-1}\))

Respiration (mol m\(^{-2}\) d\(^{-1}\))

\[
\text{area A} - \text{area B} = \text{Daily Carbon Gain}
\]

\[
\text{area A} + \text{area C} = \text{Daily Gross Photosynthesis}
\]

\[
\text{Carbon Use Efficiency} = \frac{\text{Daily Carbon Gain}}{\text{Daily Gross Photosynthesis}}
\]