CEA WORKS

1

2.1 Physiology of CEA Crops

3. Temperature

3.1 Daytime and nighttime temperature effects

2

Plant growth and development

- Growth = irreversible increase in size (volume) and/or dry mass
  - Growth is the result of cell division and cell expansion
- Development = change in number of organs (leaf, shoot, flower, etc.)
  - New organs develop and mature

3

Optimum temperatures for crop production

- Varied with different growth stages (age, sink/source)
- Varied with PAR (lower temperature at lower PAR)
- Increase with increasing CO_2 conc.
- Varied depending on objectives (whole plant growth, flowering, carbohydrate translocation... etc)

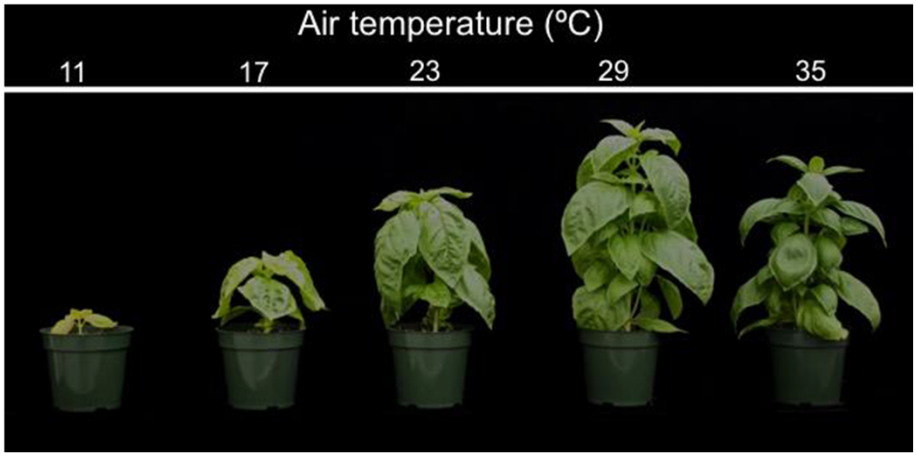
4

Optimum temperatures (examples)

	Germination	Day	Night	Note
Lettuce	20°C (68°F) under light	20-25°C (68-77°F)	12-15°C (54-59°F)	Bolting at higher temperature and long day
Tomato	29°C (84°F)	24-26°C (75-79°F)	15-18°C (59-64°F)	Lower night temperature for seedlings to induce flower buds. Too high temp (>30C) causes poor pollination
Basil	28°C(82°F)	25-28°C (77-82°F)	20-23°C (68-73°F)	
Strawberry	--	20-25°C (68-77°F)	10-15°C (50-59°F)	Fruit becomes large and flavorful at lower night temp.

5

Basil plants grown under different temperatures

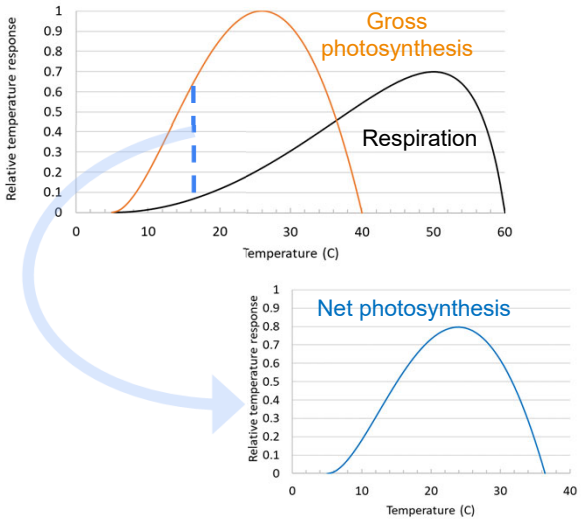


Sweet basil 'Nufar' (*Ocimum basilicum*) plants grown at different air temperatures for 3 weeks. (Walters, 2015; Iowa State University) (PI: Chris Currey)

6

Effect of temperature on photosynthesis and respiration

- Gross photosynthetic rate and respiration rates increase as increasing temperature.
- Respiration rate increases almost exponentially in the range of ambient temperatures.
- Temperatures giving the maximum rate are different for both processes.
- The difference of the two – net photosynthetic rate is maximal at a temperature slightly below that for maximum gross photosynthetic rate.



7

Plant physiological responses affected by daytime temperature

- Photosynthesis (gross photosynthetic rate, net photosynthetic rate)
- Respiration rate
- Transpiration rate (through changes in humidity)
- Development rate (leaf, flower; through 24-h average temperature effect)

8

Plant physiological responses affected by nighttime temperature

- Respiration rate
- Nonstomatal transpiration rate (through changes in humidity)
- Development rate (leaf, flower; through 24-h average temperature effect)
- **Flower and fruit size*
- **Produce quality (acidity in fruit)*

*these responses are likely through 24-h average temperature effects

9

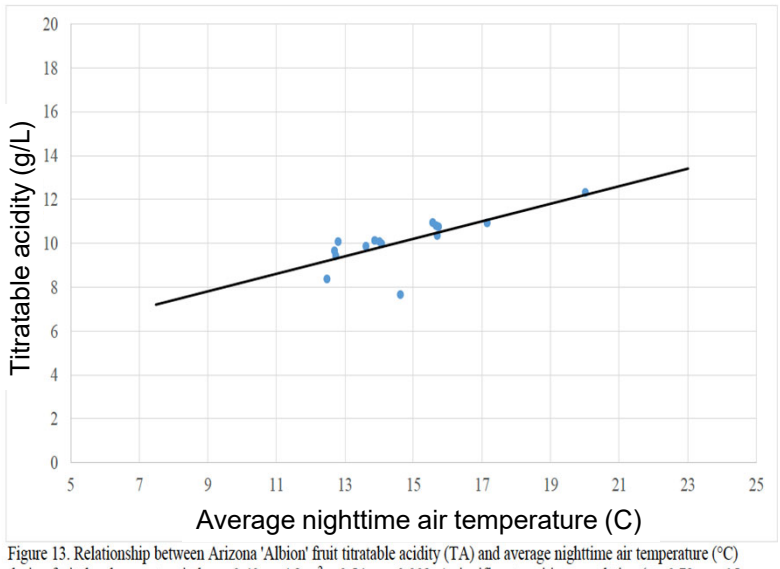
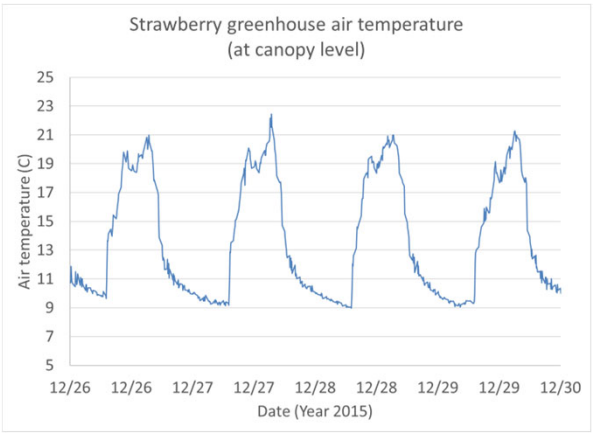


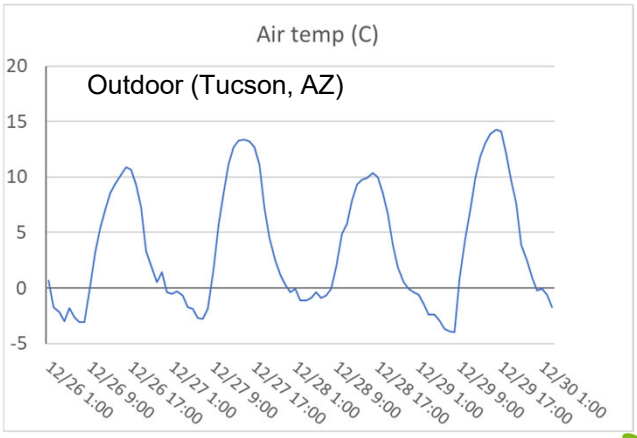
Figure 13. Relationship between Arizona 'Albion' fruit titratable acidity (TA) and average nighttime air temperature (°C) during fruit development period. $y = 0.40x + 4.2$, $r^2 = 0.54$, $p = 0.002$. A significant positive correlation ($r = 0.73$, $n = 15$, $p = 0.002$) between TA and average nighttime temperature was found.

McKean (2019)

10

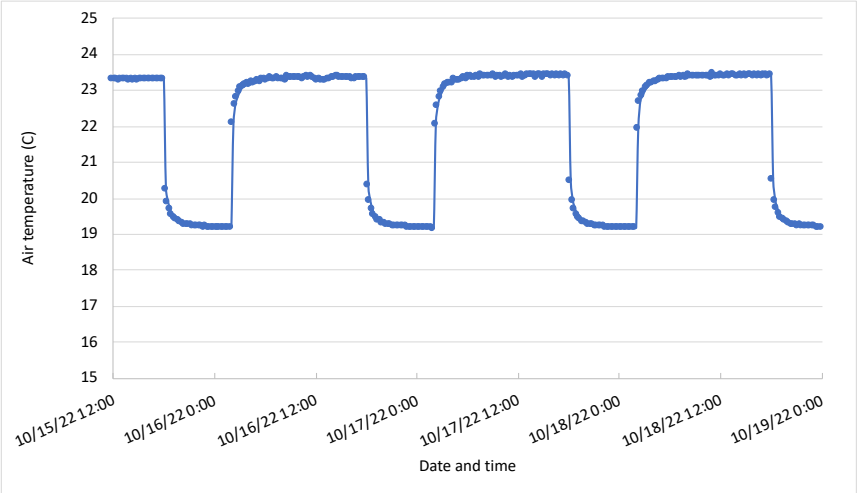
Greenhouse temperature examples





11

Growth chamber temperature examples



12

Leaf temperature is not the same as air temperature – Why?

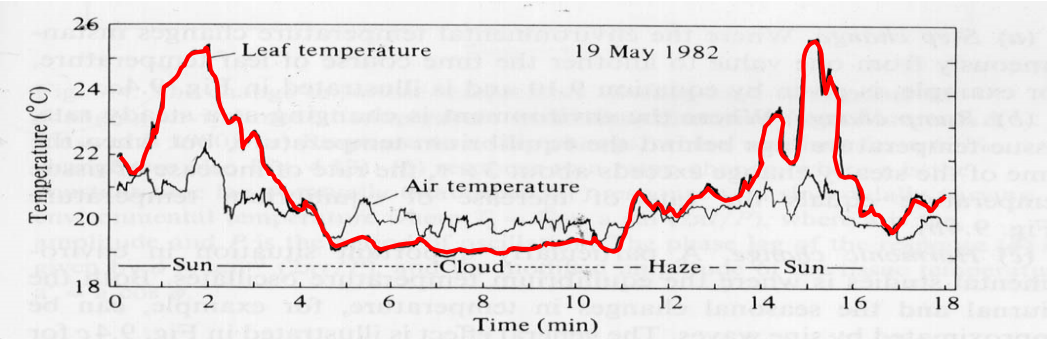
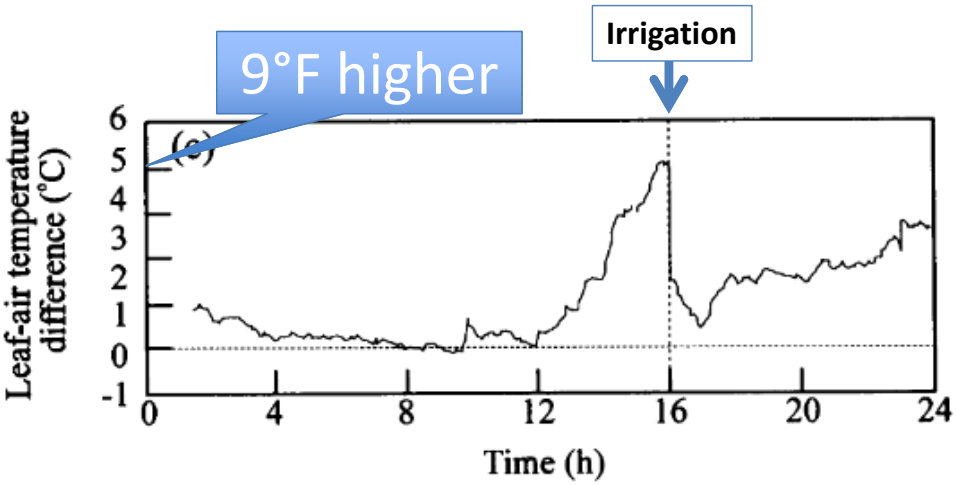


Fig. 9.3. Temperature fluctuations of an apple leaf (approx. 10 cm²) in the field. Temperatures measured with 42-gauge copper–constantan thermocouples.

13

Air temperature vs. leaf temperature

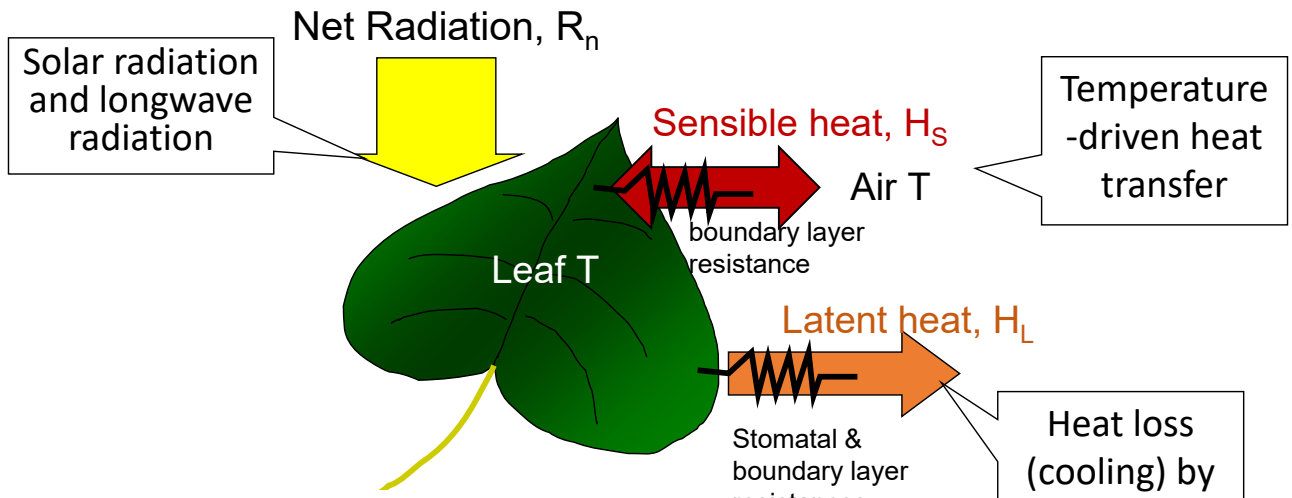


Difference between leaf and air temperatures of eggplant seedlings grown under controlled environment inside a growth chamber (constant air temperature and radiation).

(Shibuya et al., 1997. Environ.Control Biol. 35:227-234)

14

Main components affecting leaf temperature



- ✓ When input > output, leaf temperature increases.
- ✓ When input < output, leaf temperature decreases.
- ✓ When input = output, leaf temperature does not change.

15

Air temperature vs. plant temperature

- Plant temperature is NOT the same as air temperature.
- Even under the constant air temperature, leaf temperature varies at a large extent, depending on many factors.
- **Leaf temperature** is more important than air temperature, to understand physiological processes occurring in leaves (photosynthesis, transpiration).
- However, accurately measuring leaf temperature is not easy (e.g. emissivity errors; sensor maintenance).
- Even within the same plant, tissue temperature varies (e.g., lower vs. upper leaves; difference within the leaf)

CEA WORKS

16

Summary

- Temperature is a critical environmental factor affecting plant growth and development.
- Plant growth systems such as greenhouse and growth room have daytime temperature and nighttime temperature set points, selected based on expected effects of these temperatures.
- Plant net photosynthetic rate exhibits optimum temperature where the rate reaches maximum.
- Plant respiration rate increases almost exponentially over the range of typical growing temperatures.
- Leaf temperature can be very different from air temperature.

17

CEA WORKS

THANK YOU

18