Managing light, temperature, and humidity in the greenhouse

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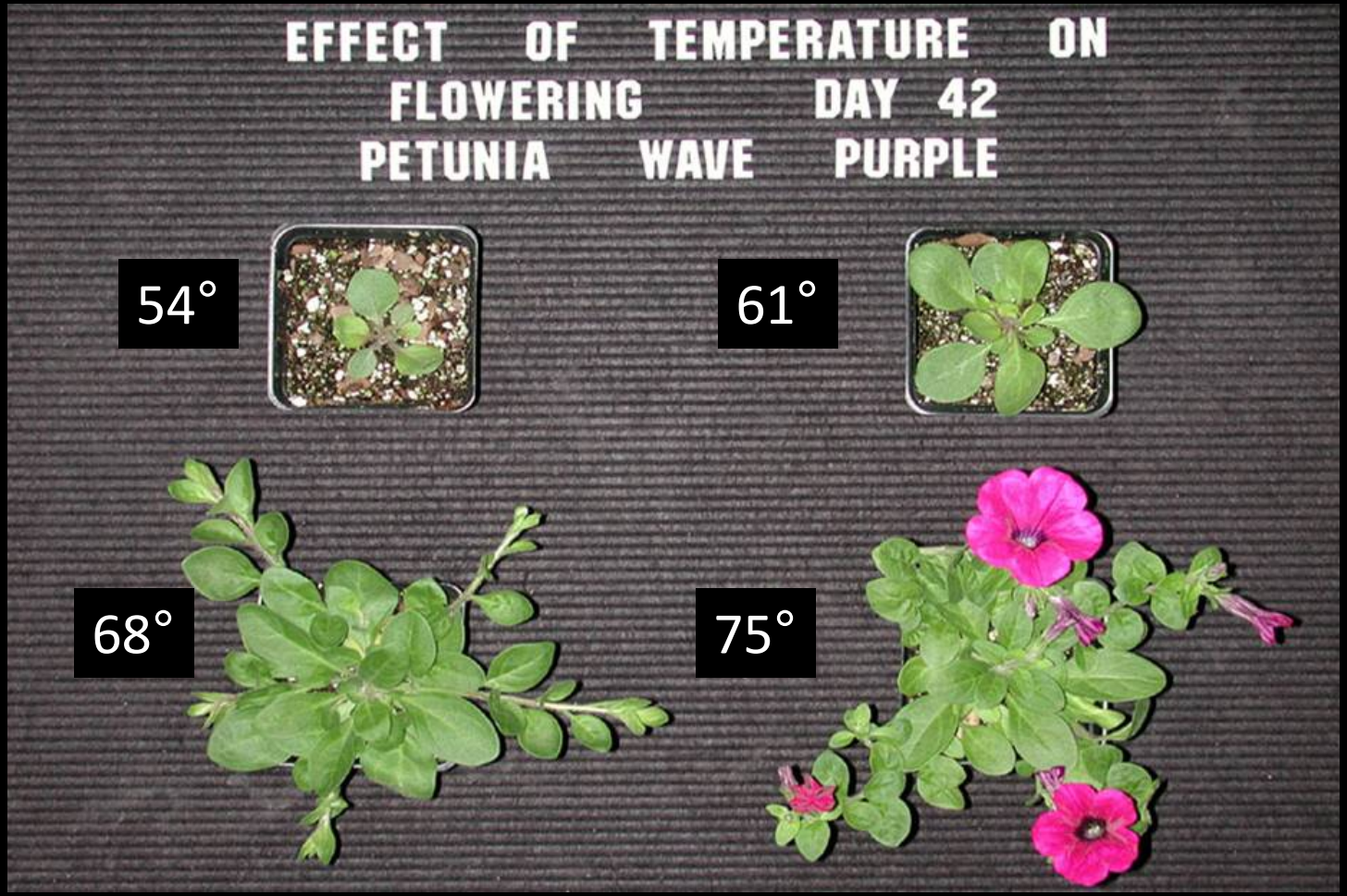
Outline

- Temperature
- Heat loss and saving heat
- Cooling
- Humidity
- Light

Average Daily Temperature (ADT) Affects:

- Crop timing
- Flower size
- Leaf size
- Root growth
- Time to flower
- Time to unfold a leaf


EFFECT OF TEMPERATURE ON
FLOWERING DAY 42
PETUNIA WAVE PURPLE
54°
61°
68°
75°

Cold Sensitive Crops

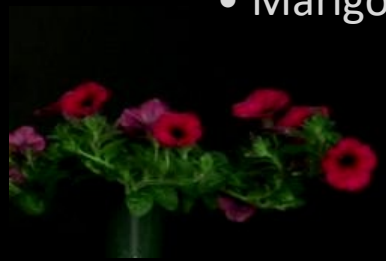
- African violet
- Alocasia
- Angelonia
- Banana
- Begonia (fibrous)
- Blue salvia
- Caladium
- Canna
- Celosia
- Coleus
- Hibiscus
- New Guinea impatiens
- Peppers
- Phalaenopsis orchid
- Poinsettia
- Portulaca
- Purple fountain grass
- Tomato
- Torenia
- Vinca (*Catharanthus*)






Cold Tolerant Crops

- Ageratum
- Alyssum
- Broccoli
- Campanula
- Cineraria
- Cyclamen
- Easter lily
- Gaillardia
- Lettuce
- Leucanthemum
- Marigold (French)
- Miltoniopsis orchids
- Nemesia
- Osteospermum
- Pansy
- Petunia
- Rudbeckia
- Scabiosa



Measuring Air Temperature

- Sensor must be shaded
- Sensor must be aspirated
  - Air moved across
- Sensor should be at or near plant height in a representative greenhouse location (center)

Good

What's wrong?

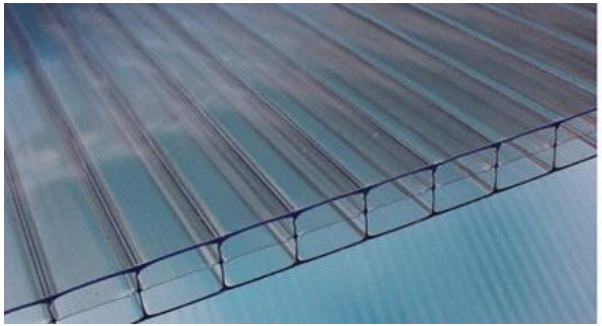
Reducing heat loss

- In a poly house use an anti-condensation IR reflective material
- In double poly houses, this anti-condensation and IR reflective poly is the inner layer

Reducing heat loss

Consider double-layer glazing

- R-value (insulative value)
  - single poly: 0.9
  - Double poly: 1.6



Install a heat curtain

- Approximately 80% of heat is used at night
- Retractable curtains not only reduce heat loss but also increase plant temperature by reflecting IR
- Closed-weave curtains can reduce heat loss by 30 to 50% at night

Reducing heat loss

- Insulate curtain walls to 12” below the greenhouse floor and up to bench height.
- Add another layer of insulation to the north wall.

Reducing heat losses to infiltration

- Seal all the little holes around fans, pads, vents and doors.
- Patch leaks in poly

Conventional Fuel Sources
cost comparison

Source	Price	Efficiency	Cost MBtu
Electricity	$0.11 / kwh	100%	$32.23
Propane	$2.00 / gallon	75%	$28.80
Natural Gas	$1.00 / therm	75%	$13.30
Fuel Oil	$2.50 / gallon	75%	$24.00

Cooling

Passive cooling

- Little to no energy

Vents

- Ex: Roll up walls and roof vents

Shade

Shading

- Spray on shade compound
- Curtains
  - Manual or retractable

Reduces incoming solar radiation

Cooling

Active Cooling

- Forced air ventilation
- Fan and pad (evaporative cooling pad)

Forced Air Ventilation

Fan number and size

- 0.8 cfm per ft^2 greenhouse surface area
  - As rated at 0.1 inches of static water pressure
  - Spaced no more than 25 feet apart

Motorized louvers are better than gravity operated (prevented wind from blowing open when greenhouse heating)

Forced Air Ventilation

Source: Aldrich and Bartok, 1994

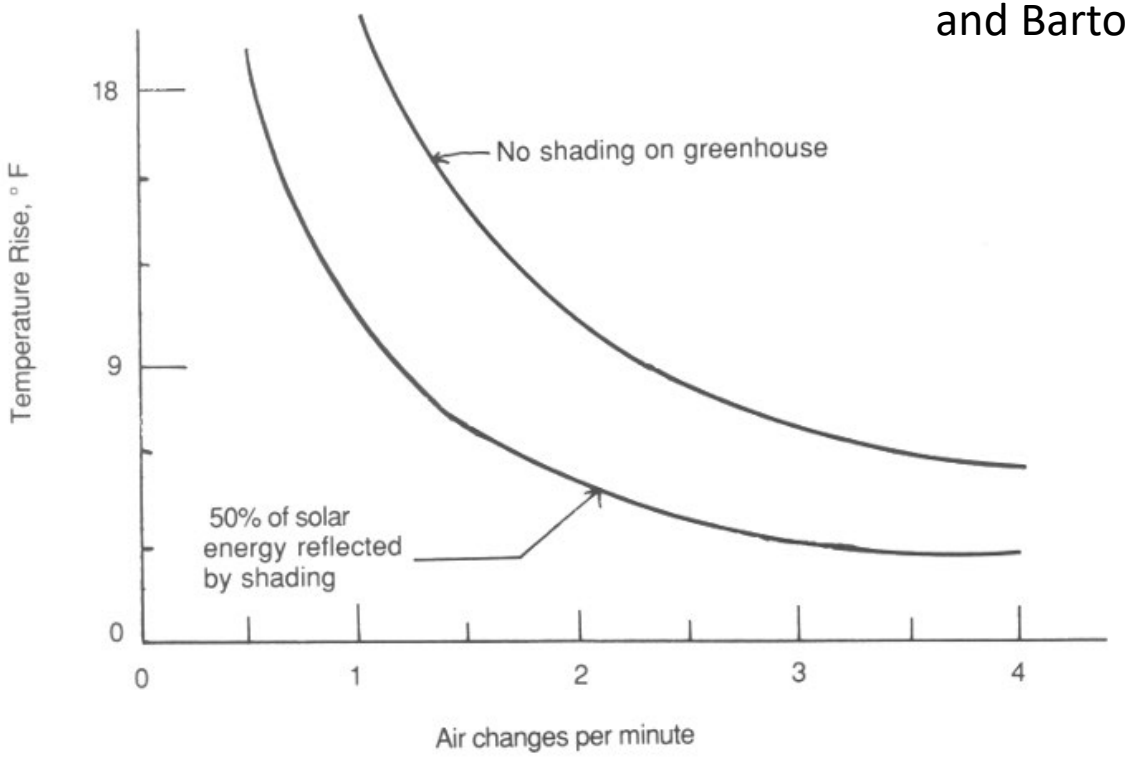


Figure 4–3. Temperature rise in greenhouses as a function of air exchange rate. Solar intensity is 280 Btu/hr.-ft.^{2} on a horizontal surface at solar noon. The greenhouse is full of actively growing crops.

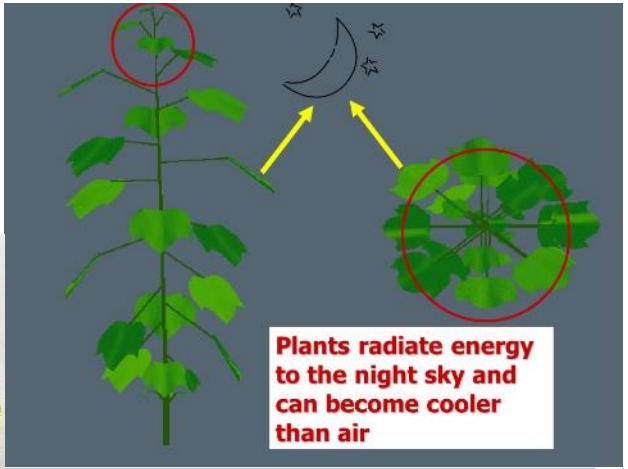
Evaporative Cooling Pads

- Cooling below outdoor temperature is possible
- Degree of cooling depends on humidity (driving force for evaporation)
- 4” thick pad requires 0.5 gallon water per minute per linear ft.
- 6” thick pad requires 0.75 gallon water per minute per linear foot
- Algaecide often added to cooling pad water

Relative Humidity

Too high

- Reduces plant transpiration
  - Decreasing nutrient uptake (esp. Ca) / photosynthesis
- Condensate droplets on ceiling
  - Water puddles/algae
  - Reflects light
- Condensation on leaf surfaces
  - Promotes foliar disease
- Edema (ivy geraniums, sweet potato vine, tomato)



Relative Humidity

Too low

- Plant stress
  - May transpire quicker than roots can take up water →wilting
  - Slower growth
- Plants especially sensitive during propagation/rooting
- Favors spider mites

Humidity control

- Grow dry
  - Avoid excess watering
  - Avoid watering before sunset
- Air circulation keeps humidity evenly distributed
- Heat plants (ex: bottom heat) keep their temperature above dew point
- Dehumidification
  - Vent / heat – most common
    - Can cost 5-30% of greenhouse energy bill (average 20%)
      - Heat exchanger can recovery about 40% of lost heat
  - Mechanical dehumidifier
    - heat pump / refrigeration - cooling cycling to condense air than reheat air
    - Not typically practical / cost effective in greenhouse

Venting / heating to control humidity

Venting at sundown and sunrise

- Venting/heating cycle should be be done two or three times per hour after sun goes down
  - May not be needed in middle of night if not supplemental lighting (or don't have wet floors)
  - Best would be to monitor with a humidity sensor
- Again in the morning at sunrise

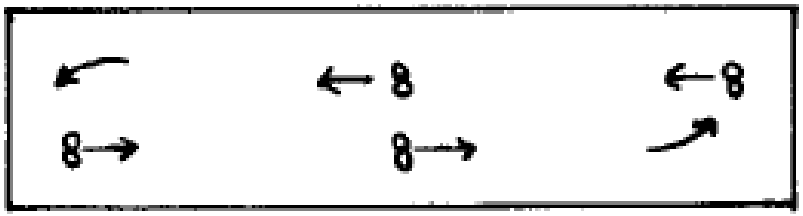
https://ag.umass.edu/greenhouse-floriculture/fact-sheets/reducing-humidity-in-greenhouse

Horizontal Airflow Fans (HAF)

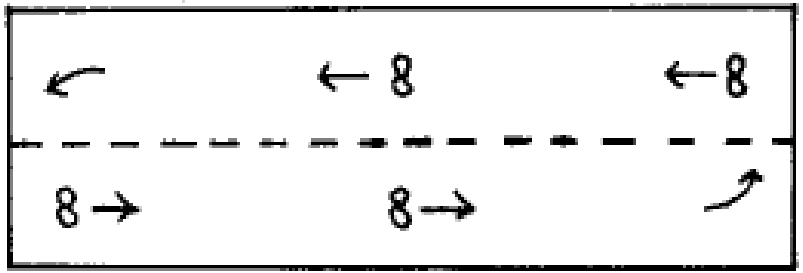
- Provide air circulation
- Increase the uniformity of the greenhouse environment
  - Reduces temperature and humidity gradients

Horizontal Airflow Fans (HAF)

- Minimum of two fans (1 pointing in each direction to mix air) in single span greenhouse
- Add a row of fans for each additional 50’ of greenhouse length
- Total fan capacity in cubic feetper minute (cfm) should equal one-fourth the house volume.
  - 16" dia. circulating fans with 1/15 hp motors will generally be sufficient.



Individual



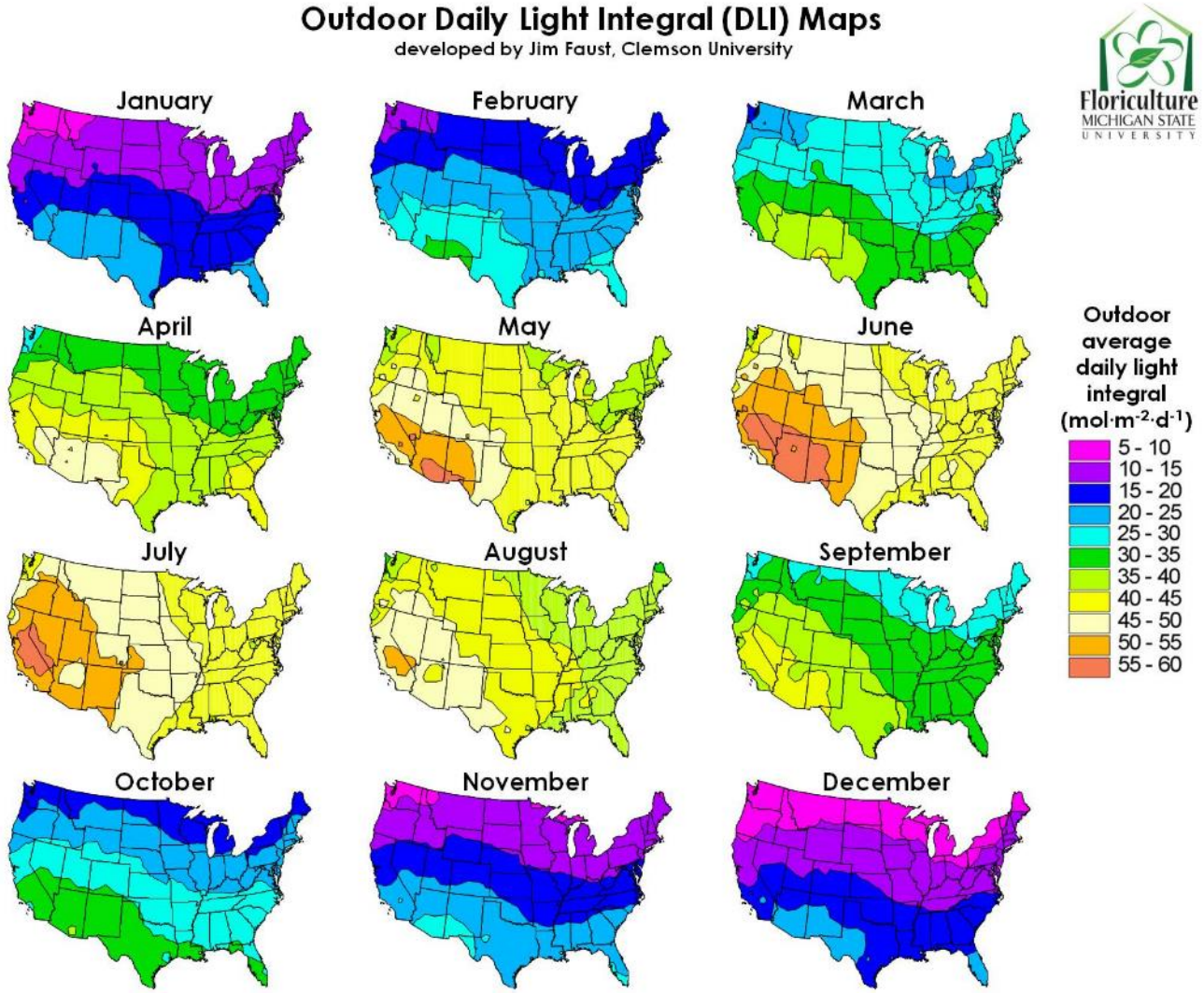
2-row

Source: Aldrich and Bartok, 1994

Light

Naturally light availability

Winter has 4 times less light than summer!



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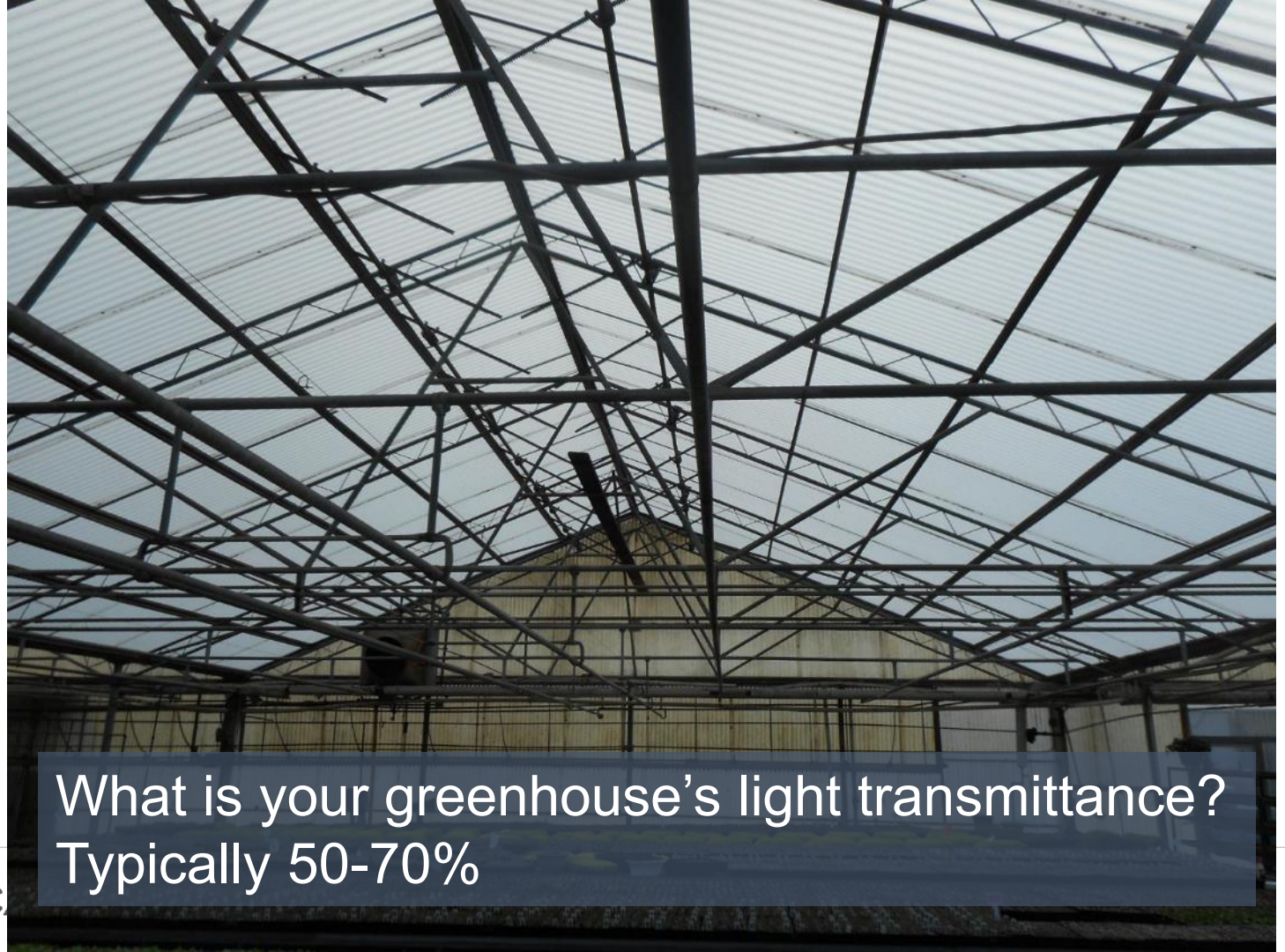
What is your greenhouse’s light transmittance?
Typically 50-70%

How much light do you need?

Flower Crops

- Propagation of plugs and cuttings
  - 8-12 mol m^{-2} d^{-1} (after callus)
- Bedding plants
  - 10-12 mol m^{-2} d^{-1} (species dependent)
- Flowering potted plants
  - 10-12 mol m^{-2} d^{-1} (species dependent)
  - Phalaenopsis orchids (6), potted miniature roses (14)
- Install lighting capacity of 50-100 µmol m^{-2} s^{-1}

Light intensity effects time to flower

Pansy grown for 3 weeks under different lamps

Increasing light intensity

DLI

8 10 12.5 16 19.5 23

How much light do you need?

Vegetables

- Within bounds: 1% more light → 1% more yield

- Lettuce and Herbs
  - 12-17 mol m^{-2} d^{-1}
  - For head lettuce
  - greater light → tipburn
  - Vertical airflow fans important
- Microgreens
  - 12 mol m^{-2} d^{-1}
- Install lighting capacity of 100-200+ µmol m^{-2} s^{-1}

How much light do you need?

Fruiting Crops

- Cucumber
  - 15 mol m^{-2} d^{-1} minimum, >30 mol m^{-2} d^{-1} optimum
- Tomato
  - 20 mol m^{-2} d^{-1} minimum, >30 mol m^{-2} d^{-1} optimum
- Sweet Pepper
  - 20 mol m^{-2} d^{-1} minimum, >30 mol m^{-2} d^{-1} optimum
- Strawberries
  - 17 mol m^{-2} d^{-1} minimum, >20 mol m^{-2} d^{-1} optimum
- Install lighting capacity of 100-200+ µmol m^{-2} s^{-1}

Considerations when choosing new lights

- **Wall-plug efficacy**
- **Initial cost ($/fixture x # of fixtures)**
- Lifespan (often reported to 70% output)
- Bulb replacement cost
- Installation cost
- Shading of fixture
- Uniformity of light plan
- Wavelength/Light quality?

Lamp type	PAR efficacy (µmol/J)	PAR efficacy (mol/kWh)
HPS (single ended)	1.56	5.62
HPS (double ended)	1.59	5.72
LED (bar)	2.39	8.60
HPS (claimed)	**2.10**	**7.56**
LED (bar, claimed)	**3.00**	**10.8**

Highest measured efficacies (so far)

Questions?

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