Basics of Plant Growth in Greenhouses: Temperature, Light, Moisture, Growing Media, etc
The law of limiting factors

• “Too much or too little of any one factor can limit the growth of a plant even if all other factors are at or near the optimum level required by that plant”
Environmental Factors

• Light
• Temperature
• Gases
What do plants need?

• Light
  – Plants need light to grow
  – Photosynthesis
    • The conversion of light (+ carbon dioxide and water) into energy (sugar)

\[
\text{+ 6 CO}_2 + 6 \text{ H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]
Measuring Light

• Most CO greenhouses will receive sufficient light for veggie crops
• If growing flowers or bedding crops:
  – Supplemental lights may be needed
• Handheld light meters are available
The effects of too little light

- Slow growth
- Spindly, slender growth and elongation of stems
- Yellowing
- Growth is softer, succulent, sometimes larger leaves
- Plants bend drastically toward light source
Too little light

- Possible solutions
  - Provide artificial lighting
  - Plan for optimum greenhouse location
The effects of too much light

- Slow growth
- Leaf burn
- Light green color
- Small and thick leaves

Citrus

Peace Lily
Too much light

• Possible solutions
  – Shading
  – Grow plants suited for light levels you have
  – Plan for optimum greenhouse location
Know the sun’s path in all seasons

Temperature

- Controls most everything in the plant
  - Rate of water uptake
  - Rate of nutrient uptake
  - Photosynthesis
  - Cell division
Air Temperature

• Optimum high
  – 85°F
  – Above 90 growth slows

• Warm season plants
  – Tomatoes
  – Peppers
  – Cucumber

• Optimum low
  – Between 50°F and 60°F

• Cool season plants
  – Spinach
  – Cole crops
  – Peas
Air Temperature

- Many hobby greenhouses have inadequate or *missing* heating and ventilation (cooling) systems.
- Yes, they are expensive but make the difference between success and failure.
Air Temperature

• Measure at plant height
• Gradient may be seen
  – Cooler temps near walls, doors, vents
• Germinating seeds have special requirements
Soil Temperature

• More critical than air temperature, however, very closely related to the temperature of the air.

• Roots grow slower at temperatures below $45^\circ F$
  – Can’t take up water and nutrients
Gases

- Oxygen
- Carbon dioxide
- Harmful gases
- Wood preservatives
Soil oxygen

- Pore space is important for respiration
- Compaction
- Water-logging
Carbon Dioxide

- Fresh air exchange
- Especially in winter

\[
\text{CO}_2 + 6 \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]
Harmful Gases

• Natural gas
  – Leaky heating system
  – Epinasty

• Ethylene
  – Reduced blooms
  – Epinasty
Wood preservatives

• Don’t use treated wood if certified organic
• Direct toxicity (roots in contact)
• Fumes given off
• Common preservatives
  – Pentachlorophenol
  – Creosote
• Can paint over with special paint (B-I-N)
Growing media

- Soils
- Artificial soils
Soil preparation

• Planting directly into ground in most hoophouses
• Need to prepare the soil
  – Weed control
  – Organic matter
  – Nutrients
Soil Prep-New Site

- Remove existing vegetation
- Reduce weed seedbank levels
- Increase OM & fertility levels
- Grading/slope for drainage
  - May need to tile perimeter
Soil Health

• Consider immediate & long term health
• Increase OM with annual compost applications
  – Carbon based compost
  – Mature compost
  – Limited animal manure compost
Why limited animal manure compost?

• High nitrate levels
• Limited leaching in hoophouse
  – Especially with drip irrigation
  – Buildup of soluble salts and excess nutrients in soil
  – Too much nitrates in plants (leafy greens)? Human health affected?
Soil health approaches

• Add compost to build OM to 10-15%
• Soil testing for nutrients, EC, & pH
• Incorporate green manures & cover crops
  – Year prior to production is best
• As needed: sidedressing w/ needed nutrients
Soil testing

• EC and pH pens
  – EC measurement of soluble salts
  – K, Na, Cl, NO$_3$, NH$_4$
  – <$100 for handheld meter
  – Calibration is important

• Full nutrient analysis
  – Send off to lab for best quality analysis
  – Many labs to choose from
  – Check “Alternative Soil Testing Laboratories” publication by ATTRA
• Effects of high EC?
  – Restricted water uptake and wilting
  – Reduced root growth
  – Poor seed germination
  – Leaf margin burning
  – Reduced flowering & yields

• Different testing methods
  – Saturated paste, dilutions (1:2 or 1:5)
# EC levels

<table>
<thead>
<tr>
<th>Testing Methods</th>
<th>Saturated Paste</th>
<th>1:2 dilution</th>
<th>1:5 dilution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.7</td>
<td>0-0.25</td>
<td>0-0.12</td>
<td>Very low</td>
<td></td>
</tr>
<tr>
<td>.7-2.0</td>
<td>0.25-0.75</td>
<td>0.12-0.35</td>
<td>Good for germination</td>
<td></td>
</tr>
<tr>
<td>2.0-3.5</td>
<td>0.75-1.25</td>
<td>0.35-0.65</td>
<td>Desirable for growth</td>
<td></td>
</tr>
<tr>
<td>3.5-5.0</td>
<td>1.25-1.75</td>
<td>0.65-0.9</td>
<td>Slightly high, too high for seedlings</td>
<td></td>
</tr>
<tr>
<td>5.0-6.0</td>
<td>1.75-2.25</td>
<td>0.9-1.1</td>
<td>Reduced growth, marginal burn</td>
<td></td>
</tr>
</tbody>
</table>

1 dS/m = 1 mmho/cm = 1 mS/cm

Adapted from A. Rangarajan, Cornell University
Relative EC tolerance

<table>
<thead>
<tr>
<th>Non Tolerant (0-2 dS/m)*</th>
<th>Slight Tolerant (2-4 dS/m)</th>
<th>Moderately Tolerant (4-8 dS/m)</th>
<th>Tolerant (8-16 dS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>carrot</td>
<td>cabbage</td>
<td>broccoli</td>
<td>swiss chard</td>
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<tr>
<td>onion</td>
<td>celery</td>
<td>muskmelon</td>
<td>beet</td>
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<td>pea</td>
<td>lettuce</td>
<td>spinach</td>
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</tr>
<tr>
<td>radish</td>
<td>pepper</td>
<td>squash</td>
<td></td>
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<tr>
<td>green bean</td>
<td>sweet corn</td>
<td>tomato</td>
<td></td>
</tr>
<tr>
<td>potato</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*saturated paste extract

Adapted from A. Rangarajan, Cornell University
Artificial soils

Media serves the following functions:

– Provide water
– Supply nutrients
– Permit gas exchange to and from the roots
– Provide support for plants

Consists of Organic & Inorganic portions
Components

Organic
- Peat moss
- Manures
- Leaf mold/composts
- Wood by-products
- Bark
- Coir
- Straw

Inorganic
- Sand
- Gravel
- Perlite
- Vermiculite
- Rock wool
Soilless Media

- The amount of air and water held in a medium is determined (prior to placing the seed or plant in the container) by
  - The container
  - How the medium is handled
    - Compaction
    - Moisture content
    - Pot filling technique
  - Watering practices used by grower

**Diagram from: Water, Media, and Nutrition for Greenhouse Crops, Chapter 5  Ball Publishing**
What about Polymers?

• What about the addition of water holding polymers to media?
  – Do they work?
    • Appear to ‘work well’ in containerized systems?
    • Do not work well with turfgrass
  – How do they work?
    • Polymers hold several hundred times their weight in water and then release it slowly back to the plant.
    • Wet the crystals first, before incorporation into the media
    • ¼ cup absorbs 5 gallons of water
  – Are they economical??????
Nutrition & watering
Nutrients

Macro
Nitrogen
Phosphorus
Potassium
Calcium
Magnesium
Sulfur

Micro
Iron
Boron
Manganese
Copper
Zinc
Molybdenum
Chlorine
Others
Effect of pH on availability

Field Soil

Artificial Media
Greenhouse fertilization

• In-ground vs. containerized plants
  – Leaching
• Compost (nutrient test if possible)
• Organic options?
• Soil testing is key (know what you’re starting with!)
Water

Number one area where mistakes are made

• Everybody “thinks” they know how to water
• OVERWATERING IS EXTREMELY COMMON!
Water related problems

• Symptoms of underwatering
  – Foliage off color
  – Foliage wilts
  – Stunting
  – Marginal or interveinal chlorosis
  – Premature leaf senescence
Water related problems

• Common symptoms of overwatering
  – Foliage yellows or wilts
  – Root system undersized
  – Roots black or dark brown
  – Nutrient deficiency symptoms
  – Pathogens develop
How to Water Properly

• When hand watering always use a water breaker to decrease the force of the water

Photo: UCIPM
Water Based on Need not Calendar

• What are the plants’ irrigation needs?
• Depends on:
  – Frequency
  – Amount
  – Method of water application
  – Type of media
  – Plant cultivar
  – Environmental conditions
  – Water quality
How to Water Properly

• Watering frequency
  – Increase the period between watering to the maximum level that is consistent with good growth.
  – Before watering again, allow soil to drain and dry out to the point where most available water has been used.

• Amount of irrigation
  – Apply 10 – 15% more water to leach salts.
  – The rate of irrigation must be low enough to allow the water to percolate throughout the soil.
Irrigation water testing

- Quarterly, if possible
- Check for EC, pH, hardness, salinity
- Send to testing lab
  - Colorado Analytical Labs
- At home kits
Questions?