Long Term Soil and Water Management in the High Tunnel

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Outline

• Introduction
• HT management practices in the Midwest
• Site preparation
• Water and irrigation management
• Fertility management
• Soil soluble salts management
• Conclusion
Site Selection and Preparation

• Site preparation is much like preparing a field for production (1-2 years in advance) – but you are planning out for several years
  – Removal of existing cover
  – Reduce weed seed bank
  – Cover crop
  – Soil test and amend as needed – compost, minerals, other amendments
  – Select well drained soils; provide for drainage if needed
Water and Irrigation Management

Compare and contrast water management in a high tunnel and in the field
Assess the Water Source

- Irrigation is necessary in the high tunnel
- Water quality is important, especially for long term
  - Alkalinity
  - Hardness
  - Pollutants
- Operation of drip irrigation systems – must have good quality water
- Issues related to salts buildup can be related to water quality
Soil Moisture and Irrigation

- Drip irrigation advantages
  - Efficient use of water
  - Great way to deliver soluble nutrients
  - Keeps plants dry
- Drip irrigation challenges
  - Important to know the system, and ensure adequate wetting depth for wide ranging root systems
  - May not provide sufficient water to leach away soil salts
Soil Fertility Management

- Fertility management is a balance of managing the following:
  - Physical characteristics
  - Chemical characteristics
  - Biological characteristics
Soil Fertility Management

• Why is the tunnel environment different than the field?
  – Raised beds and drip irrigation tend to concentrate root systems
  – Nutrients are delivered via fertigation, and are readily available and mobile
  – The nutritional status of the soil and the plant are dynamic and can change rapidly
  – Excess nutrients often remain in the rooting zone following a cropping cycle, and can accumulate
Fertility Management

• Successful fertility management in the high tunnel is related to several key components:
  – **Soil Testing.** Soil testing to determine the nutrient availability (pH) and balance is perhaps even more important than it is in the field.
  – **Compost.** Compost seems to be the most important soil fertility management tool for the high tunnel.
  – **Rotations.** The variation in crops grown in the tunnel will influence whether cover crops are needed to maintain soil fertility and health.
Soil Testing

- Standard Field Soil Test
  - Conducted on a dry sample
  - Soil pH is tested on a separate sample.
  - Nitrate-nitrogen is not usually analyzed but can be if requested, which is a good idea for high tunnels.
  - The amount of K, Ca and Mg extracted are used to calculate an estimate of the total cation exchange capacity (CEC). The balance of the three elements is also calculated.
  - Phosphorus amount is estimated
  - Organic matter content is estimated
  - Micronutrients can be requested
  - Each lab will have an interpretation of the soil test
Soil Testing

• Saturated Media Extracts (SME) test (MU greenhouse media test)
  – Conducted on a saturated soil sample
  – total soluble salts as electrical conductivity
  – soluble nitrogen as nitrate and ammonium nitrogen.
  – In addition the P, K, Ca, Mg, Na and Cl in parts per million (ppm) are commonly reported.
  – The micronutrients Fe, Mn, Zn, Cu, B and Mo may also be reported if requested.

• For rapid growth conditions with frequent irrigation, ie conditions often found in a high tunnel, the SME provides a picture of available nutrients at one moment in time
Soil Testing

• Where is SME testing indicated?
  – Where nutrients applied as water-soluble fertilizers
    • Conventional greenhouse bench crops
  – Where nutrient content exceeds retention capacity
    • High proportion of “free salts”
  – Soils with accumulated nutrient salts
    • Irrigated desert soils
    • Long-term high tunnels
Soil Testing

• Startup high tunnel
  – Essentially same as open-field soil management
  – Routine field soil test most appropriate
  – Optimize pH, OM, major & micronutrient reserves
Soil Testing

• Established houses (1 + years)
  – Salt buildup can be a problem if not uncovered
    • Monitor total salt level to avoid desiccation damage
  – Open field soil N management does not apply
    • Monitor nitrate level to avoid over-fertilizing
  – Field soil test to address potential deficiencies
  – EC (SME) to monitor total nutrient salt buildup
  – Available nitrogen to address nitrate buildup
Soil Testing

• Continuously-covered houses, usually 3+ years
  – Saturated Media Extraction + Organic matter
    • Water soluble (nutrient intensity) mgt. system
    • UVM interpretation guidelines
  – N-P-K recommendations to adjust SME levels
    • UVM guidelines
Soil Testing

optimal soil nutrient levels for greenhouse tomatoes or lettuce using the SME test

- pH: 5.8 – 6.8
- nitrate-N: 125 – 200 ppm
- P: 8 – 13 ppm
- K: 175 – 275 ppm
- Ca: > 250 ppm
- Mg: > 60 ppm
- soluble salts: 1.5 – 3.0 (mmhos)

# Soil Testing

General interpretation guidelines for greenhouse growth media analyzed by the Saturated Media Extract Method.

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Optimum</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble salts (dS/m)</td>
<td>0-.75</td>
<td>2.0-3.5</td>
<td>5.0+</td>
</tr>
<tr>
<td>Nitrate-N (ppm)</td>
<td>0-39</td>
<td>100-199</td>
<td>300+</td>
</tr>
<tr>
<td>Phosphorus (ppm)</td>
<td>0-2</td>
<td>6-10</td>
<td>19+</td>
</tr>
<tr>
<td>Potassium (ppm)</td>
<td>0-59</td>
<td>150-249</td>
<td>350+</td>
</tr>
<tr>
<td>Calcium (ppm)</td>
<td>0-79</td>
<td>200+</td>
<td></td>
</tr>
<tr>
<td>Magnesium (ppm)</td>
<td>0-29</td>
<td>70+</td>
<td></td>
</tr>
</tbody>
</table>

Soil Testing – MU Soil Testing Laboratory

• Standard soil test
  – [http://soilplantlab.missouri.edu/soil/trucksoil.aspx](http://soilplantlab.missouri.edu/soil/trucksoil.aspx)
  – Cost: $12.50 plus extra charge for micronutrients and nitrogen

• SME testing (Greenhouse media testing)
  – [http://soilplantlab.missouri.edu/soil/greenhouse.aspx](http://soilplantlab.missouri.edu/soil/greenhouse.aspx)
  – Cost: $20 plus extra for micronutrients

• Compost testing
  – [http://soilplantlab.missouri.edu/soil/compost.aspx](http://soilplantlab.missouri.edu/soil/compost.aspx)
  – Cost: $40 for complete package
Soil Testing

• Summary of high tunnel soil testing
  – For newer houses, routine field soil analysis with addition checks on EC and available nitrogen
  – Continuously covered high-EC houses can be effectively managed using SME testing system and field soil testing as indicated
  – Field soil and SME testing systems access greatly different pools for most nutrients and are reported on a different basis. Each requires discreet interpretation and recommendation systems.
Organic Matter

• Crop production is often focused on fertigation to provide water and soluble nutrients – “feed the plant”

• A better long term strategy is focusing on long term soil health – “feed the soil”
  – Soil organic matter management
  – Maintenance of the soil food web
Organic Matter in the High Tunnel

• What happens to organic matter in the high tunnel?

Source: http://www.conservationwebinars.net/webinars/soil-health-in-high-tunnel-production
• Compost applications
  – Compost seems to be the most important soil fertility management tool for the high tunnel
  – Consider plant based compost rather than manures or manure compost; what about worm compost?
  – Consider a compost analysis to characterize the compost and to develop application rates
  – Annual recommended application rates vary - 12 to 40 gallons per 100 square feet = 26 to 86 cu yd/acre or about 10 to 40 ton/acre
Crop Rotations

• Conflict between the need to rotate crops and economic realities
• Consider focusing on early and late plantings of cool season and warm season crops
• Effective rotations can take the place of cover cropping
• Crop family groups
  – lettuce and related leafy greens for baby leaf salad mix (multi harvest) or as heading crops (single harvest);
  – Brassicas for salad and cooking greens;
  – Solanaceous crops (tomato, pepper, eggplant);
  – Root crops (turnip, carrots, beets, radish) and
  – Cucurbits (cucumber, summer squash)
Cover Crops

• Cover crops
  – In general, once the structure is built, the production area is very valuable and the time between cash crops is short.
  – If a diverse crop rotation can be maintained, it is not essential to use tunnel cover crops.
  – If there is time in the schedule:
    • Buckwheat, Japanese millet or cowpeas are short term, warm season cover crops that break down quickly.
    • Oats can also be tilled in after a short time of grown and will grow in cool seasons
    • Use winter cover crops with caution, esp. for early plantings
Foliar Testing

• Useful as a monitoring tool in the dynamic high tunnel environment
• Useful as a diagnostic tool in the event of issues

Magnesium deficiency
Soil Soluble Salt Levels

• What are soluble salts?
  – soluble forms of elements found in the soil - Ca++, Mg++, K+, Na+, NH4+, H+, HPO4-, SO4-, NO3-, Cl-
  – These forms move up and down in the soil profile in response to water movement
  – In the high tunnel environment, soluble salts can accumulate in the rooting zone
Soil Soluble Salt Levels
Salinity in the High Tunnel

• High tunnel soils are similar to desert soils – no flushing rains!

50-80 lbs sodium/acre

700 lbs sodium/acre

Source: http://www.conservationwebinars.net/webinars/soil-health-in-high-tunnel-production
Soil Soluble Salts Levels

Plants affected by high salt concentrations often appear dark green in the early stages, but rapidly develop marginal yellowing and necrosis of older leaves.

Soil Soluble Salt Levels

• Soluble salt levels in high tunnels can be a problem
  – Many fertilizers and manures are high in potential salts; low quality water can contribute soluble salts
  – Faster mineralization in the high tunnel environment, especially under black plastic
  – Carryover of available nitrogen (Nitrate)
  – Enhanced evaporation “wicks” salts to the surface
  – No natural rainfall to wash (leach) excess nutrients
  – Irrigation usually not sufficient to leach excess salts
Soil Soluble Salt Levels

• Addressing high soil soluble salt levels
  – Monitor soluble salt levels in the soil
  – Place tunnels on soils that are well drained, to promote leaching
  – Avoid over application of nutrients
  – Use nutrients with low salt indices; limit use of animal manures
  – Use irrigation water that is low in salt levels
  – Consider using a sprinkler system to establish seedlings or maintain cover crops
  – Rotate into crops that are less sensitive to salts
  – Leach out salts
Soil Soluble Salt Levels

Salt Indexes of Various Fertilizers

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Salt Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Nitrate (34-0-0)</td>
<td>102</td>
</tr>
<tr>
<td>Sodium Nitrate (16-0-0)</td>
<td>100</td>
</tr>
<tr>
<td>Urea (45-0-0)</td>
<td>73</td>
</tr>
<tr>
<td>Ammonium Sulfate (21-0-0)</td>
<td>69</td>
</tr>
<tr>
<td>Calcium Nitrate</td>
<td>65</td>
</tr>
<tr>
<td>Diammonium Phosphate (18-46-0)</td>
<td>29</td>
</tr>
<tr>
<td>Monoammonium Phosphate (11-55-0)</td>
<td>27</td>
</tr>
<tr>
<td>Superphosphate (0-45-0)</td>
<td>10</td>
</tr>
<tr>
<td>Superphosphate (0-20-0)</td>
<td>8</td>
</tr>
<tr>
<td>Potassium Chloride (0-0-60)</td>
<td>116</td>
</tr>
<tr>
<td>Potassium Nitrate (14-0-47)</td>
<td>74</td>
</tr>
<tr>
<td>Potassium Sulfate (0-0-54)</td>
<td>46</td>
</tr>
</tbody>
</table>

Adapted from: Foth & Ellis, Soil Fertility 2nd Ed.
Soil Soluble Salt Levels

Plant response to salinity levels
The table below illustrates the effects of salinity level on various vegetable crops.

<table>
<thead>
<tr>
<th>Salinity Level (mmhos/cm)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.40</td>
<td>Negligible salinity; salt sensitive cultivars of beans and carrots may exhibit effects</td>
</tr>
<tr>
<td>0.40-0.80</td>
<td>Very slightly saline; 25-50% decrease in yields of carrots, onions, peppers, lettuce</td>
</tr>
<tr>
<td>0.81-1.20</td>
<td>Moderately saline; seedling injury possible; 25-50% decrease in yields of broccoli, potatoes</td>
</tr>
<tr>
<td>1.21-160</td>
<td>Saline; beets tolerant</td>
</tr>
<tr>
<td>1.61-3.20</td>
<td>Strongly saline</td>
</tr>
<tr>
<td>Greater than 3.2</td>
<td>Very strongly saline</td>
</tr>
</tbody>
</table>

*Adapted from the Agriculture Analytical Services Laboratory, The Pennsylvania State University; based on a 1:2 soil:water test.
Soil Soluble Salt Levels

- Leaching out salts
  - Movable tunnels to uncover production areas
  - Removal of plastic cover, in response to soil test report – at least 12” of rain needed to leach
  - Use of irrigation to leach salts
    - As a guideline, to leach salts away from the top 12” of soil:
      - 6” of water will leach away 50% of salts
      - 12” of water will leach away 80% of salts
      - 24” of water will leach away 90% of salts
Summary

• Develop a water and soil management plan
  – Test water source annually (or more)
  – Soil test annually, SME test at least annually (more often if indicated)
  – Apply compost, nutrients, and amendments as needed
  – Foliar testing is useful to monitor a fertility program and to diagnose issues
  – Use rotations and cover crops as possible
  – Monitor soil soluble salts levels
  – Keep records!!!!!
Any Questions?

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