Drip Irrigation Considerations in High Tunnel Production Systems

by
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Natural Resource Engineering Specialist

for
High Tunnel Micro-Irrigation Workshop
Camdenton, MO
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What is a High Tunnel?

• Unheated greenhouse; same as “hoop house”
  – Not for year-round protection or production
• Uses solar heat (back-up heaters optional)
• No electricity (fans, heaters, vents, etc.)
• Vented through sidewalls or end walls
• Drip irrigated
• Ground culture
• Single layer of plastic (6-mil)
High Tunnels - Advantages

• Extends growing season 2-4 weeks
  – Night-time temps indoors average 4 degrees F higher than outdoors
  – Increases production & marketing opportunities
  – Offers shelter from wind, hail and insects, and can reduce disease pressure
  – Gives ability to control water supply

• Many designed as “drive through” for use of field equipment
High Tunnels - Disadvantages

• Labor-intensive; requires regular monitoring of temperatures
• Heavy rain, snow or wind can damage them
• High humidity early in growing season can lead to increased disease problems
• Construction requires more startup costs compared to conventional outdoor production
  – $3-$5 per sq. ft. to build high tunnel
  – Less costly than $20 per sq. ft. for greenhouse
• Have to water crops, even when it rains
High Tunnels - Location

• Place on level, well-drained, accessible site
• For stationary unit, plan to amend the soil each season or year to maintain fertility
• Orient perpendicular to the prevailing winds on your farm
  – All ventilation is manual, so you depend on the wind to ventilate
  – Face end wall toward winter wind
  – In Missouri, for our S-SW summer winds, use north-south orientation
Checking Soil Drainage

- Perched water table
- Fragipan on upland soils
- Standing water after a rain

Photo credit: truebluesam.blogspot.com/2011/05/clay-pan-soils.html
If you take care of your soil, the soil will take care of your plants.

• Available Water Holding Capacity depends on:
  – Soil texture
  – Organic matter
  – Rooting depth
USDA Soil Texture Classes

- **Particle size**
  - Sand = 2.0-0.05 mm
  - Silt = 0.05-0.002 mm
  - Clay = <0.002 mm

- **Characteristics**
  - Sand adds porosity
  - Silt adds body to the soil
  - Clay adds chemical & physical properties
Determining Soil Texture

• By feel
  – Sticky, gritty, floury

• Using the jar method
  – Fill a 1-quart jar ¼ full of soil
  – Fill the jar with water to ¾ full
  – Add 1 teaspoon of dishwashing detergent
  – Shake very well to suspend soil
  – Place on a flat surface and allow soil to settle for 2 days
  – Measure % thickness of each layer relative to all

Clay
Silt
Sand
Benefits of Adding Compost

• Improves drainage & aeration of heavy clay soils
• Increases moisture-holding ability of sandy soils
• Increases earthworm & soil microbial activity that benefit plant growth
• Improves soil structure & makes it easier to work
• Contains nutrients needed for plant growth
Know the Soil Rooting Depth & How Water Will Re-Distribute

Cross-sections of beds on different soils show water distribution differences. On sandy soils, irrigation must be done in small, more frequent, applications. Wetted width should match bed width. Bed widths usually range from 24-36 inches.
## Effective Rooting Depth of Selected Vegetables

<table>
<thead>
<tr>
<th>Shallow (6-12”)</th>
<th>Moderate (18-24”)</th>
<th>Deep (&gt;36”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beet</td>
<td>Cabbage, Brussels Sprouts</td>
<td>Asparagus</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Cucumber</td>
<td>Lima Bean</td>
</tr>
<tr>
<td>Carrot</td>
<td>Eggplant</td>
<td>Pumpkin</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Muskmelon</td>
<td>Sweet Potato</td>
</tr>
<tr>
<td>Celery</td>
<td>Pea</td>
<td>Watermelon</td>
</tr>
<tr>
<td>Greens &amp; Herbs</td>
<td>Potato</td>
<td>Squash, Winter</td>
</tr>
<tr>
<td>Onion</td>
<td>Snap Bean</td>
<td></td>
</tr>
<tr>
<td>Pepper</td>
<td>Squash, Summer</td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td>Sweet Corn</td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>Tomato</td>
<td></td>
</tr>
</tbody>
</table>

Most of the active root system for water uptake may be in the top 6”-12”
Soil Properties

• Soils store 1.5”-2.5” of water per foot of depth (check county NRCS Soil Survey)
• Intake rate = 0.2”-2.0” per hour, rest is runoff
• Available Soil Moisture* = % of soil water between field capacity & permanent wilting point = ranges by crop from 25% to 75%
• Summer E.T. rate can be 0.25” per day or more
  – E.T. affected by radiation, humidity, air temperature, wind speed

*Reference: www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html
Plants are 80-95% Water

• Water shortages early in crop development = delayed maturity & reduced yields
• Water shortages later in the growing season = quality often reduced, even if yields not hurt
• Short periods of 2-3 days of stress can hurt marketable yield
• Irrigation increases size & weight of individual fruit & helps prevent defects like toughness, strong flavor, poor tipfill & podfill, cracking, blossom-end rot and misshapen fruit
Water Needs Vary Widely

- By species & within species by age of crop
- By soil type and time of year
- By location: outdoors vs. indoors

Example: Tomatoes in high tunnels
- 12 oz./plant/day when first set
- Climbs gradually to 75 oz./plant/day upon maturity

Example: Greenhouses (container production)
- A general rule is to have available from 0.3 to 0.4 gallons/sq. ft. of growing area per day as a peak use rate

- Size irrigation system for peak use
### Relative Water Needs of Plants

<table>
<thead>
<tr>
<th>Low</th>
<th>Medium Low</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinach</td>
<td>Peas, Green</td>
<td>Cabbage</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Beans, Kale</td>
<td>Broccoli</td>
</tr>
<tr>
<td>Radish</td>
<td></td>
<td>Pepper</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Sweet Corn, Vine Squash</td>
<td>Muskmelon</td>
</tr>
<tr>
<td>Asparagus</td>
<td></td>
<td>Watermelon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pumpkin</td>
</tr>
</tbody>
</table>
**Plant Water Requirements**

(Estimated design rates for southwest Missouri)

<table>
<thead>
<tr>
<th>Vegetable Crop (mature)</th>
<th>Gallons per 100 Feet of Row per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum for plant survival</td>
<td>100</td>
</tr>
<tr>
<td>Lettuce, spinach, onions, carrots, radishes, beets</td>
<td>200</td>
</tr>
<tr>
<td>Green beans, peas, kale</td>
<td>250</td>
</tr>
<tr>
<td>Tomatoes, cabbage, peppers, potatoes, asparagus, pole beans</td>
<td>300</td>
</tr>
<tr>
<td>Corn, squash, cucumbers, pumpkins, melons</td>
<td>400-600</td>
</tr>
</tbody>
</table>
# Vegetable Crops & Growth Period Most Critical for Irrigation Requirements

<table>
<thead>
<tr>
<th>Crop</th>
<th>Most Critical Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli, Cabbage, Cauliflower, Lettuce</td>
<td>Head development</td>
</tr>
<tr>
<td>Carrot, Radish, Beet, Turnip</td>
<td>Root enlargement</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>Silking, tasseling, and ear development</td>
</tr>
<tr>
<td>Cucumber, Eggplant, Pepper, Melon, Tomato</td>
<td>Flowering, fruit set, and maturation</td>
</tr>
<tr>
<td>Bean, Pea</td>
<td>Flowering, fruit set, and development</td>
</tr>
<tr>
<td>Onion</td>
<td>Bulb development</td>
</tr>
<tr>
<td>Potato</td>
<td>Tuber set and enlargement</td>
</tr>
</tbody>
</table>

1 For transplants, transplanting & stand establishment represent a most critical period for adequate water.

Reference: irrigationtraining.tamu.edu/docs/irrigation-training/south/crop-guidelines/estimatedwaterrequirementsvegetablecrops.pdf
The Two Major Factors in Irrigation System Planning

1. How much water do you need?
2. How much time do you have?
Is a Rain Barrel Enough?

- 1” of rain from a 1,600 sq. ft. roof = 1,000 gallons
- Elevation dictates pressure
  - 2.3 feet of head = 1 psi pressure

55 gal. = 1.5 psi
850 gal. = 3.5 psi
31,000 gal. = 23 psi
Basic Watering Facts

• Plants need 1”-1.5” of water per week
  – 624-935 gallons (83-125 cu.ft.) per 1,000 sq.ft.
• Can survive drought on half that rate
• Deep infrequent waterings are better than several light waterings
• Deeper roots require less supplemental irrigation
• Taller plants have deeper roots
  – Lowers tendency to wilt
  – Shades soil surface
  – Controls weeds by competition
  – Makes water “go farther”
Drip Irrigation

• Also known as:
  – Trickle irrigation
  – Micro-irrigation
  – Low-volume irrigation
Drip Irrigation – Pros & Cons

• Low application rate is efficient
  – Saves 30%-50% water
  – Less runoff & evaporation;
    water goes directly to plant roots

• Uniform water application
  – Maintains optimum growing conditions
  – Protects & enhances yield and quality

• Can effectively apply some nutrients in water

• Improves disease & weed control

• Allows field work while irrigating
Drip Irrigation – Pros & Cons

• Solid-set management
  – Variety of emitter spacings
  – Irrigate crops separately
• Works well with plastic mulches
• Moderate labor
  – Easily automated
• No frost protection
• Emitters plug easily
  – Iron, calcium, sand, algae, some fertilizers
• Tube and drip tape damage from rodents, hoe
Example Layout of Drip Irrigation System
Water Source & Quality

• Plan 3-10 gallons per minute per high tunnel
  – Depends on drip flow rate and tubing layout

Good
• Well = check pH & hardness
• Municipal = may be expensive
• Spring = may not be dependable
• River or stream = depends on runoff
• Lake or pond water = sand filters

Poor
• Pump to tank on hill
  – Elevation dictates pressure
    (2.3 feet of head = 1 psi pressure)
  – Watch for tank corrosion
Estimating Water Quantity

- Household water demand
  - GPM = Total count of toilets, sinks, tubs, hose bibs, etc. in home
- Excess is available for irrigation
  - Contact pump installer for capacity data
- Is pressure tank large enough?
  - Stay within cycle limits of pump, OR
  - Run the pump continuously
## Home Water Flow Rates

<table>
<thead>
<tr>
<th>Bedrooms</th>
<th>Number of Bathrooms in Home</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>8</td>
<td><strong>10</strong></td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>--</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>--</td>
<td></td>
<td>16</td>
<td>18</td>
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</tbody>
</table>

Source: [http://extension.missouri.edu/p/G1801](http://extension.missouri.edu/p/G1801)
<table>
<thead>
<tr>
<th>Horsepower Rating</th>
<th>Cycles / Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 to 2.0</td>
<td>20</td>
</tr>
<tr>
<td>3 to 5</td>
<td>15</td>
</tr>
<tr>
<td>7.5, 10, 15</td>
<td>10</td>
</tr>
</tbody>
</table>
## Pressure Tank Selection

<table>
<thead>
<tr>
<th>Tank Size, gallons</th>
<th>Average Pressure, psi*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Pumping Capacity, GPM</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td>82</td>
<td>11</td>
</tr>
<tr>
<td>144</td>
<td>19</td>
</tr>
<tr>
<td>220</td>
<td>29</td>
</tr>
<tr>
<td>315</td>
<td>42</td>
</tr>
</tbody>
</table>

* Cut-in pressure + 10 psi = Avg. Pressure = Cut-out pressure - 10 psi
Pressure Tanks

Larger tank

OR

Variable-speed pump controller

Multiple tanks
Water Quality Analysis

- Inorganic solids = sand, silt
- Organic solids = algae, bacteria, slime
- Dissolved solids (<500 ppm)
  - Iron & Manganese
  - Sulfates & Chlorides
  - Carbonates (calcium)
- pH (5.8-6.8 preferred)
- Hardness (<150 ppm)

Resource: soilplantlab.missouri.edu/soil/water.aspx
## Plugging Potential of Drip Irrigation Systems

<table>
<thead>
<tr>
<th>Factor</th>
<th>Moderate (ppm)*</th>
<th>Severe (ppm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td>50-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH**</td>
<td>7.0-7.5</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>500-2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Iron</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Hardness***</td>
<td>150-300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>0.5-2.0</td>
<td>&gt;2.0</td>
</tr>
</tbody>
</table>

* ppm = mg/L  ** pH is unitless  *** Hardness: ppm = gpg x 17
Friction Loss Design

• Size piping for 1 psi or less pressure loss per 100 feet
  – Pipe diameter x 2
  = 4X flow rate

• Pipe friction may replace pressure regulators on downhill runs

• Vary flow rate no more than 20% (+/- 10%) within each block of plants

• Manifolds attached to mainline...
  – at center if < 3% slope
  – at high point if 3+% slope
## Plastic Pipe Friction Loss

<table>
<thead>
<tr>
<th>GPM</th>
<th>0.75&quot;</th>
<th>1&quot;</th>
<th>1.5&quot;</th>
<th>2&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.8</td>
<td>0.8</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>11.3</td>
<td>3.0</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>21.6</td>
<td>6.4</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>20</td>
<td>37.8</td>
<td>10.9</td>
<td>1.3</td>
<td>0.4</td>
</tr>
<tr>
<td>25</td>
<td>--</td>
<td>16.7</td>
<td>1.9</td>
<td>0.6</td>
</tr>
<tr>
<td>30</td>
<td>--</td>
<td>--</td>
<td>2.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Drip Irrigation Components

- Vacuum Breaker
- Backflow Preventer
- Manifold to Drip Tape Connectors
- Filter
- Manifold Pipe
- Pressure Regulator
- Drip Tape
Drip Irrigation Control Assembly

- Control timer
- Shut-off valve
- Backflow preventer
- Flow from water supply
- Chemical injector
- Pressure gauge
- Filter
- Pressure regulator
- Air relief valve
- Shut-off valve
Fertigation
Nutrient “Spoon Feeding”
Fertigation

- Apply fertilizer
  - Be sure it’s 100% water-soluble
  - Always inject it two elbows before the filter for good mixing
  - Use backflow preventer
Line Source Drip Tubing

• Heavy wall thickness = can last 7-10 years
• 6-10 times more costly than tape
• Surface or sub-surface installation
• On-line or in-line emitters
  – On-line spacing whatever you choose
  – In-line spacing = 9”, 12”, 18”, 24”, or 48”
  – Non-P.C. emitters = 8-15 psi
  – P.C. emitters give best flow
    uniformity = 10-60 psi
Line Source Drip Tape

- Wall thickness = 6, 8, 10, 15-mil; 1-2 year life
- Surface or sub-surface installation
- Emitters manufactured within the tape wall
  - Common spacing = 4”, 8”, 12”, 16” 18” 24”
  - Max. operating pressure
    = 6-mil @ 10 psi
    = 8-mil @ 12 psi
    = 10-mil @ 14 psi
    = 15-mil @ 25 psi
- More animal damage outdoors
Drip Installation (Hand or Mechanical) Prior to Plastic Mulch
Drip Tape Placement

• Install at same time or prior to mulch
• Single-row crops: tomatoes, cucumbers, muskmelons  
  – Place tape 4”-5” from the center or in the center
• Double-row crops: eggplant, peppers, strawberries  
  – Place tape on center of bed
• Keep emitters up & bury 1-2” deep to reduce shifting
• Avoid puncturing during planting or staking
Drip Tape Placement
Manifold Options

- Various manifold options are shown, including different pipe configurations and materials used for irrigation systems. The images demonstrate how manifolds are set up in the soil to distribute water efficiently to plants.
Manifold Options
When & How Much Should I Water?
# Hours Required to Apply 1” of Water to Mulched Raised Bed

<table>
<thead>
<tr>
<th>Drip Tube Flow Rate</th>
<th>Width of Mulched Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons per Hour per 100 feet run of drip tape</td>
<td>Gallons per Minute per 100 feet run of drip tape</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>16</td>
<td>0.27</td>
</tr>
<tr>
<td>18</td>
<td>0.30</td>
</tr>
<tr>
<td>20</td>
<td>0.33</td>
</tr>
<tr>
<td>24</td>
<td>0.40</td>
</tr>
<tr>
<td>30</td>
<td>0.50</td>
</tr>
<tr>
<td>36</td>
<td>0.60</td>
</tr>
<tr>
<td>40</td>
<td>0.67</td>
</tr>
<tr>
<td>42</td>
<td>0.70</td>
</tr>
<tr>
<td>48</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Irrigation Hours per Week to Apply 68 oz./day per Tomato Plant

Allow 6 sq.ft. of space per plant

20' x 96' = 300 plants in 5 rows = 2.5 GPM ≈ 1200 gallons/week

26' x 96' = 400 plants in 6 rows = 3.0 GPM ≈ 1600 gallons/week

30' x 96' = 500 plants in 7 rows = 3.5 GPM ≈ 2000 gallons/week

<table>
<thead>
<tr>
<th>Drip tube flow rate</th>
<th>Tomato plants per high tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gph/100 ft¹</td>
</tr>
<tr>
<td>8</td>
<td>0.13</td>
</tr>
<tr>
<td>10</td>
<td>0.17</td>
</tr>
<tr>
<td>12</td>
<td>0.20</td>
</tr>
<tr>
<td>16</td>
<td>0.27</td>
</tr>
<tr>
<td>18</td>
<td>0.30</td>
</tr>
<tr>
<td>20</td>
<td>0.33</td>
</tr>
<tr>
<td>24</td>
<td>0.40</td>
</tr>
<tr>
<td>30</td>
<td>0.50</td>
</tr>
<tr>
<td>36</td>
<td>0.60</td>
</tr>
<tr>
<td>40</td>
<td>0.67</td>
</tr>
<tr>
<td>42</td>
<td>0.70</td>
</tr>
<tr>
<td>48</td>
<td>0.80</td>
</tr>
<tr>
<td>60</td>
<td>1.00</td>
</tr>
</tbody>
</table>

¹Gallons of water per hour per 100 ft. run of drip tape.
²Gallons of water per minute per 100 ft. run of drip tape.

Resource: http://extension.missouri.edu/p/G6462
Soil Water Monitoring Sensors
### Soil Water Deficits for Typical Soils & Soil Water Tensions

**Good Range for High Tunnels = 25-40 Centibars**

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Soil Water Tension in Centibars (cb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>0</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>0</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0</td>
</tr>
<tr>
<td>Loam</td>
<td>0</td>
</tr>
</tbody>
</table>

**1500 cb is approximately the permanent wilting point for most plants, and the soil water deficit values equal the soil’s available water holding capacity.**
## Using a Tensiometer to Monitor Soil Moisture for Tomatoes

### Parts of a Tensiometer
- **Sealing cap**
- **Vacuum gauge**
- **Sealed plastic tube**
- **Porous ceramic tip**

### Soil Moisture Status

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Soil tension (cb)</th>
<th>Soil moisture status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, loamy sand</td>
<td>5–10</td>
<td>Soil at field capacity. Irrigation is not required.</td>
</tr>
<tr>
<td>Sandy loam, loam, silt loam</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Clay loam, clay</td>
<td>20–40</td>
<td>Irrigate tomatoes (50% of soil water is depleted). Provide approximately 2 quarts per plant.</td>
</tr>
<tr>
<td>Sand, loamy sand</td>
<td>20–40</td>
<td></td>
</tr>
<tr>
<td>Sandy loam, loam, silt loam</td>
<td>40–60</td>
<td></td>
</tr>
<tr>
<td>Clay loam, clay</td>
<td>50–100</td>
<td></td>
</tr>
</tbody>
</table>

Resource: extension.missouri.edu/explorepdf/manuals/m00170.pdf
# Troubleshooting Guide

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Possible Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reddish-brown slime or particles near emitters</td>
<td>Bacteria feeding on iron</td>
</tr>
<tr>
<td>White stringy masses of slime near emitters</td>
<td>Bacteria feeding on sulfur</td>
</tr>
<tr>
<td>Green or slimy matter in surface water</td>
<td>Algae or fungi</td>
</tr>
<tr>
<td>White film on tape or around emitters</td>
<td>Calcium salts or carbonates</td>
</tr>
<tr>
<td>Presence of silt or clay</td>
<td>Inadequate filtration</td>
</tr>
</tbody>
</table>
Chemigation

• Kill bacteria & slime
  – Chlorine (<6 mo. old) needs “contact time”
  – Powdered HTH can plug emitters
Chemigation

- Control pH with acid
  - Help acidify soil for plants (blueberries)
  - Dissolve Mn, Fe, Ca precipitates
  - Make chemicals work better
Final Thoughts

• Pick a good soil site for the high tunnel
• Anchor high tunnel for stormy weather
• Plan a reliable water supply
• Test water for problem minerals
• Match irrigation system to crop and time available
• Monitor soil moisture frequently
• Be prepared for the unexpected
References

• High Tunnels.org  
  www.hightunnels.org
• Missouri Alternatives Center (click on “H” for high tunnels)  
  http://agebb.missouri.edu/mac/links/index.htm
• High Tunnel Construction Considerations (Iowa State)  
  www.public.iastate.edu/~taber/Extension/Tunnelconstruct.pdf
• Noble Foundation  
  www.noble.org
• Plasticulture (Penn State)  
  http://extension.psu.edu/plants/plasticulture
• Horticultural Engineering (Rutgers University)  
  http://aesop.rutgers.edu/~horteng/
• High Tunnel Tomato Production Guide  
  http://extension.missouri.edu/explorepdf/manuals/m00170.pdf
• Watering and Fertilizing Tomatoes in a High Tunnel  
  http://extension.missouri.edu/p/G6462
Irrigation Resources on the Web

• Irrigation System Planning & Management Links
  extension.missouri.edu/webster/irrigation/

• Missouri Digital Soil Survey
  soils.missouri.edu/
Structure Suppliers

- A. M. Leonard
  www.amleo.com
- Atlas Greenhouse Systems, Inc.
  www.atlasgreenhouse.com
- Conley’s Greenhouse Mfg.
  www.conleys.com
- CropKing, Inc.
  www.cropking.com
- FarmTek
  www.farmtek.com
- Grow-It Greenhouse
  www.shelterlogic.com
- Haygrove tunnels
  www.haygrove.co.uk
- Hoop House Greenhouse Kits
  (Mashpee, MA, USA)
  www.hoophouse.com
- International Greenhouse Company
  www.igcusa.com
- Jaderloon
  www.jaderloon.com
- Keeler Glasgow
  www.keeler-glasgow.com
- Ludy Greenhouses
  www.ludy.com
- Poly-Tex Inc.
  www.poly-tex.com
- Rimol Greenhouse Systems
  www.rimolgreenhouses.com
- Speedling Inc.
  www.speedling.com
- Stuppy Greenhouse Mfg
  (Kansas City, MO, USA)
  www.stuppy.com
- Turner Greenhouses
  www.turnergreenhouses.com
- XS Smith
  www.xssmith.com
Questions??

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Program Complaint Information
To file a program complaint you may contact any of the following:

University of Missouri
- MU Extension AA/EEO Office
  109 F. Whitten Hall, Columbia, MO 65211
- MU Human Resources Office
  130 Heinkel Bldg, Columbia, MO 65211

USDA
- Office of Civil Rights, Director
  Room 326-W, Whitten Building
  14th and Independence Ave., SW
  Washington, DC 20250-9410

Special thanks to Jerry Wright, University of Minnesota Extension, for some of the photos used in this presentation.

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Publications about High Tunnels


