What We’ll Cover

• Soil moisture
• Irrigation scheduling
• Drip irrigation of vegetables
• Water quality
• Fertilizer injection
• Maintenance of irrigation systems
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
If you take care of your soil, the soil will take care of your plants.

- Plant Available Water depends on:
  - Soil structure & texture
  - Water infiltration rate
  - Soil organic matter
  - Soil type
  - Plant rooting depth

![Soil Composition Pie Chart]

- 5% O.M.
- 25% Water
- 25% Air
- 45% Mineral Matter
- 50% pore space
- 50% solid
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
Available Water Holding Capacity for Several Soil Types

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Available Water Holding Capacity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Inches per Inch of Soil</td>
<td>In Inches per Foot of Soil</td>
</tr>
<tr>
<td>Loamy fine sand</td>
<td>0.08-0.12</td>
<td>0.96-1.44</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0.10-0.18</td>
<td>1.20-2.16</td>
</tr>
<tr>
<td>Loam</td>
<td>0.14-0.22</td>
<td>1.68-2.64</td>
</tr>
<tr>
<td>Silt loam</td>
<td>0.18-0.23</td>
<td>2.16-2.76</td>
</tr>
<tr>
<td>Clay loam</td>
<td>0.16-0.18</td>
<td>1.92-2.16</td>
</tr>
</tbody>
</table>

Reference: Midwest Vegetable Production Guide for Commercial Growers
http://www.btny.purdue.edu/pubs/id/id-56/
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
- Plant Available Water** = % 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

References:
* [websoilsurvey.nrcs.usda.gov/app/](http://websoilsurvey.nrcs.usda.gov/app/)
** [www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html](http://www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html)
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
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”
# 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](irrigationtraining.tamu.edu/docs/irrigation-training/south/crop-guidelines/estimatedwaterrequirementsvegetablecrops.pdf)
Scheduling Irrigation

- Appearance of plants - wilt
- “Feel” method - handful of soil
- Screwdriver method - force into soil
- Calendar method - daily, 3rd day
- “Checkbook” method
  - Tally total rainfall + irrigation against daily water use of plants
- Tensiometers
  - Read scale of 0 (wet) to 100 (dry)
- Moisture resistance blocks
  - Buried at depths in soil, check with meter
Appearance of Plants

- It’s getting too dry when you see:
  - Purple-blue wilting leaves
  - Grass that leaves footprints
  - Folded or rolled leaves
- Don’t wait to see wilting before watering
"Feel" Method

<table>
<thead>
<tr>
<th>Moisture deficiency</th>
<th>Coarse (loamy sand)</th>
<th>Sandy (sandy loam)</th>
<th>Medium (loam)</th>
<th>Fine (clay loam)</th>
<th>Moisture deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>in/ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in/ft.</td>
</tr>
<tr>
<td>0.0</td>
<td>(field capacity)</td>
<td>(field capacity)</td>
<td>(field capacity)</td>
<td></td>
<td>.0</td>
</tr>
<tr>
<td></td>
<td>Leaves wet outline on hand when squeezed.</td>
<td>Appears very dark, leaves wet outline on hand, makes a short ribbon.</td>
<td>Appears very dark, leaves wet outline on hand, will ribbon out about one inch.</td>
<td></td>
<td>.2</td>
</tr>
<tr>
<td>0.2</td>
<td>Appears moist, makes a weak ball.</td>
<td>Quite dark color, makes a hard ball.</td>
<td>Dark color, forms a plastic ball, slicks when rubbed.</td>
<td>Dark color, will slick and ribbons easily.</td>
<td>.4</td>
</tr>
<tr>
<td>0.4</td>
<td>Appears slightly moist, sticks together slightly.</td>
<td>Fairly dark color, makes a good ball.</td>
<td>Dark color, forms a hard ball.</td>
<td>Quite dark, will make thick ribbon, may slick when rubbed.</td>
<td>.6</td>
</tr>
<tr>
<td>0.6</td>
<td>Appears too dry, will not form a ball under pressure.</td>
<td>Slightly dark color, makes a weak ball.</td>
<td>Fairly dark, forms a good ball.</td>
<td>Fairly dark, makes a good ball.</td>
<td>.8</td>
</tr>
<tr>
<td>1.0</td>
<td>Dry, loose, single-grained flows through fingers. (wilting point)</td>
<td>Lightly colored by moisture, will not ball.</td>
<td>Lightly colored, small clods crumble fairly easily.</td>
<td>Will ball, small clods will flatten out rather than crumble.</td>
<td>1.0</td>
</tr>
<tr>
<td>1.2</td>
<td>Very slightly color due to moisture, loose, flows through fingers. (wilting point)</td>
<td>Slightly dark, forms weak ball.</td>
<td>Slight color due to moisture, powdery, dry, sometimes slightly crusty, but easily broken down in powdery condition. (wilting point)</td>
<td>Somewhat darker due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)</td>
<td>1.2</td>
</tr>
<tr>
<td>1.4</td>
<td>Lightly colored, small clods crumble fairly easily.</td>
<td></td>
<td></td>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td>1.6</td>
<td>Slight color due to moisture, powdery, dry, sometimes slightly crusty, but easily broken down in powdery condition. (wilting point)</td>
<td></td>
<td></td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.8</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>
Screwdriver Method

• Keep a record of rainfall received
• Check soil moisture with long (10”) screwdriver
• Irrigate if screwdriver only goes in a few inches
## Calendar Method

<table>
<thead>
<tr>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
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<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
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<td>26</td>
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<td>29</td>
<td>30</td>
<td>31</td>
<td></td>
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</tr>
</tbody>
</table>
# Soil Water Balance

## “Checkbook” Method

### SOIL WATER BALANCE SHEET

(Make copies as needed)

Field: _______________  Crop: _______________  Emergence date: _______________

Pumping Capacity: _______ gpm per acre = _______ net application inches per day

Available Water Capacity: _______ inches in root zone of: _______ inches

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Vegetative %</th>
<th>Critical Growth %</th>
<th>Maturing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable</td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ inches</td>
</tr>
<tr>
<td>Soil Water Deficit</td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ inches</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week after emergence</th>
<th>Date</th>
<th>Soil water field reading</th>
<th>Maximum temperature</th>
<th>Add</th>
<th>Subtract</th>
<th>Soil water deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
<td>Rainfall</td>
<td>Net irrigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Soil Water Balance

• Example
  – Tomato crop, with root system in top 12” of soil
  – Soil – clay loam, with a water holding capacity of 0.30” per inch and available water of 1.8” per inch in the top 12” of soil
  – Midsummer - Estimated daily ET is 0.25”
The table below shows the daily water balance for a soil system, including water deposits, withdrawals, and the resulting balance:

<table>
<thead>
<tr>
<th>Day</th>
<th>Water Deposits (in.)</th>
<th>Water Withdrawals (in)</th>
<th>Balance (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0 (rainfall)</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0.25</td>
<td>-0.25</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0.25</td>
<td>-0.50</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0.25</td>
<td>-0.75</td>
</tr>
<tr>
<td>5</td>
<td>0.5 (rainfall)</td>
<td>0.25</td>
<td>-0.5</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0.25</td>
<td>-0.75</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0.25</td>
<td>-1.0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0.25</td>
<td>-1.25</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0.25</td>
<td>-1.50</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0.25</td>
<td>-1.75</td>
</tr>
<tr>
<td>11</td>
<td>2.0 (irrigation)</td>
<td>0.25</td>
<td>0</td>
</tr>
</tbody>
</table>
Tensiometers

• Reading is a measure of the energy needed to extract water from the soil
• Place at appropriate depth
• Cost: $70-90, plus $50 for service unit
# Soil Water Deficits for Typical Soils & Soil Water Tensions

Range for High Tunnel Strawberries = 20-30 Centibars

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Soil Water Tension in Centibars (cb)</th>
<th>Soil Water Deficit (inches per foot of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Loam</td>
<td>0</td>
<td>0.2</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.**
Electrical Resistance Sensor

- Measures the electrical resistance between electrodes imbedded in a gypsum block
- More or less permanent installation in the soil, at appropriate depth
- Cost: $30-80 for sensor, $280 for meter
Soil Water Monitoring Sensors
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

Photo credit: rainwaterbarrel.org

Photo credit: www.lakesuperiorstreams.org
### 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>
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**
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”
Calculating Irrigation Water Needs

- 1” of water = 27,154 gallons per acre
- 1 acre = 43,560 sq. ft.
- 0.25”/day pan evaporation rate = 1.75”/week
- Formula for 1.5” of water per week:
  - Gallons/100 ft. of row/day = (66 x 80% of Pan Evaporation Rate x Row width in feet)
- Example for 5 twin rows 100 ft. long x 2 ft. wide
  - GPD/100 ft. = (66 x 0.25 x .80 x 2) = 26.4 gallons
  - Gallons per day = 26.4 x (5 beds x 2 plant rows) = 264 gallons per day = 1,848 gallons per week
  - 264 GPD ÷ (30 GPH/100 ft. drip tape) x 10 rows = 0.88 hours/day = 53 minutes/day
# 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>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>
# Gallons per 100 Feet of Row per Day

<table>
<thead>
<tr>
<th>Row Width, Inches</th>
<th>Pan Evaporation Rate, Inches/Day</th>
<th>Gallons/100 ft. of row/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50</td>
<td>5 8 11 13 16 18 21 24 26</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>8 12 16 20 24 28 32 36 40</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>11 16 21 26 32 37 42 48 53</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>13 20 26 33 40 46 53 59 66</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>16 24 32 40 48 55 63 71 79</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>18 28 37 46 55 65 74 83 92</td>
</tr>
<tr>
<td>48</td>
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<td>21 32 42 53 63 74 84 95 106</td>
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<td>24 36 48 59 71 83 95 107 119</td>
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<td>60</td>
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<td>26 40 53 66 79 92 106 119 132</td>
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<td>66</td>
<td></td>
<td>29 44 58 73 87 102 116 131 145</td>
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<tr>
<td>72</td>
<td></td>
<td>32 48 63 79 95 111 127 143 158</td>
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<td>78</td>
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<td>34 51 69 86 103 120 137 154 172</td>
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<tr>
<td>84</td>
<td></td>
<td>37 55 74 92 111 129 148 166 185</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td>40 59 79 99 119 139 158 178 198</td>
</tr>
<tr>
<td>96</td>
<td></td>
<td>42 63 84 106 127 148 169 190 211</td>
</tr>
</tbody>
</table>

\[\text{Gallons/100 ft. of row/day} = (66 \times 80\% \text{ of Pan Evaporation Rate} \times \text{Row width in feet}) = 1.5” \text{ per week}\]
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
Advantages of Plastic Mulch, Raised Beds & Drip Irrigation

- Soils warm up faster (+5°F)
- Soil moisture is conserved
- Nutrient leaching is prevented
- Weeds are controlled
- Raised beds encourage earlier maturity and improves soil drainage
- Drip irrigation increases fruit quality and quantity
- Fertilizer can be injected through the irrigation system
### Water Source Quality

**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
- Pump to tank on hill = limited use

**Poor**
Static water table

Cone of depression

Initial cone of depression

Existing wells

Long-term cone of depression

High-capacity well
Water Quality Analysis

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

Resource: soilplantlab.missouri.edu/soil/water.aspx

Domestic suitability test = Hardness, pH, nitrate-N, sulfate, chloride, sodium, carbonate, bicarbonate, iron, manganese, copper, electrical conductivity, total dissolved solids
## 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
Good Agricultural Practices - Irrigation Water

• Pathogens that contaminate the surface of produce are difficult to remove

• Irrigation water can be a vehicle for foodborne pathogens
  – E. coli 0157:H7 in spinach
  – Salmonella in peppers

• GAPs program looks at food safety practices
  – Irrigation water quality
  – Manure management
  – Worker hygiene
  – Harvesting, transportation & storage practices
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 flowrate 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><strong>0.8</strong></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>
Example Layout of Drip Irrigation System
Drip Irrigation Components

- Vacuum Breaker
- Backflow Preventer
- Pressure Regulator
- Filter
- Manifold to Drip Tape Connectors
- Manifold Pipe
- Drip Tape
Filter Selection

• Screen filter
  – 150-200 mesh, 3/4” to 6” dia.
  – Slotted PVC, perf. or mesh stainless steel or nylon mesh
  – Manual or automatic flush

• Disc filter
  – Stack of grooved wafers
  – Provides more filter area than screen of same size
  – Cannot handle sand well
Filter Selection

- Sand media
  - 14” to 48” diameter
  - Use swimming pool filter for smaller systems
  - Use pairs of canisters for larger systems
  - #16 silica sand = 150-200 mesh screen
  - Work best at < 20 GPM flow per square foot of media
  - Follow with screen filters
  - Backflush to clean
Drip Irrigation Control Assembly

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

- Fertigator
- 150-mesh filter
- Shut-off valve
- Flow from water supply
- 10 psi Pressure regulator
- Flow to high tunnel

Photo credit: University of Arkansas -- www.youtube.com/watch?v=4J1pZUQo2jE
Design Considerations:

Drainage of the System

• If possible, design system to allow for gravity drainage
• Bury supply lines and manifolds below the frost line
• Include drains whenever possible
  – Upstream and downstream of each control valve
  – At each low point in the system
  – Allow for air entry at high points in the system
  – Make sure that drains are accessible
  – Make sure that water from drains has somewhere to go!
• Include a port for compressed air – install downstream of backflow prevention and pressure regulators/vacuum breaks
Layout of Drip Irrigation System
Beginning of Season Maintenance

- Check controls and clean filters
- Flush the system
- Leak check the system
- Check emitters and wetting patterns
Beginning of Season Maintenance:

Check Controls & Clean Filters

- Place controls in system, if removed
- Check each component for proper function as per manufacturer’s guidelines
- Make sure that filters are clean
- Replace cartridges or media if needed
Beginning of Season Maintenance:

Flush the System

- Flush mainline for 20 minutes, with manifold valves closed
- Flush each manifold for 5-10 minutes
- Open ends of each lateral in a zone
- Flush laterals in each zone until water runs clear
Beginning of Season Maintenance:

Leak Check the System

- Close lateral ends
- Run system with water for 20 min to remove air
- Check pressure throughout the system – note any areas with more than 20% variation in flow rate, and correct
- Walk field, noting plugged emitters, leaks and breaks; repair any problems
Growing Season Maintenance:

**Fertigation**

- Drip irrigation can supply soluble materials such as fertilizers by chemigation
- Analyze water source for precipitate potential through water/fertilizer interactions
- Test fertilizers for solubility, especially P sources
- Use vacuum breaker or backflow preventer to protect water supply
Growing Season Maintenance:
Fertigation Procedure

• Completely pressurize the drip irrigation system before starting fertigation
• Inject fertilizer two elbows upstream of the filter to ensure good mixing
• Inject fertilizer for at least as long as time required to pressurize the entire system
• Flush lines at the end of injection to remove residue

Typical Chemigation System
(electrically-driven)
Fertigation Injector Options

- Venturi
- Venturi bypass
- Piston
- Metering pump
- Hydraulic unit
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”, 6”, 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 Tape Placement

- Drip Irrigation Tube
- Plastic Mulch

Diagram showing the placement of drip tape around a plant with dimensions provided.
Manifold Options
Growing Season Maintenance

• Water supply
• Flush physical contaminants
  – Cleaning the filter (150-200 mesh)
  – Flushing the system
• Check for excessive leakage
• Repair breaks or lost emitters
• Fertilizer injection
# Growing Season Maintenance: Water Troubleshooting Guide

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green or slimy matter in surface water</td>
<td>Algae or fungi</td>
</tr>
<tr>
<td>Turbidity (muddy water)</td>
<td>Suspended clay and silt</td>
</tr>
<tr>
<td>White precipitate or film on tape or around emitters</td>
<td>Carbonate precipitation</td>
</tr>
<tr>
<td>Reddish-brown precipitate or slime around emitters</td>
<td>Oxidized (ferric) iron precipitation</td>
</tr>
<tr>
<td>Water initially clear (no oxygen), but turns red/orange in presence of air</td>
<td>Clear water dissolved (ferrous) iron</td>
</tr>
<tr>
<td>Black sandy particles</td>
<td>Iron sulfide precipitation</td>
</tr>
<tr>
<td>Black precipitate</td>
<td>Manganese precipitation</td>
</tr>
<tr>
<td>Reddish brown slime 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>
</tbody>
</table>
Growing Season Maintenance:

Chemical Water Treatment

• Useful to manage both inorganic and organic problems

• Goals of chemical treatment
  – Cause some particles to settle out or precipitate
  – Cause some particles to remain soluble or to dissolve

• Place filtration after chemical treatment

• Backflow prevention is critical
Growing Season Maintenance: Chemical Water Treatment

- **Chlorine**
  - Kills microbial activity (algae, bacteria)
  - Decomposes organic materials
  - Oxidizes soluble minerals, causing them to precipitate out of solution
  - Chlorine (<6 mo. old) needs “contact time”
  - Powdered HTH can plug emitters
Growing Season Maintenance:
Chemical Water Treatment

• Chlorine
  – Chlorine concentration of 10-20 ppm for 30-60 minutes daily
  – Work by sections through the system, flushing out lines after treatment
  – If emitters are plugged, higher concentrations of chlorine may be needed to decompose organic matter
Growing Season Maintenance:

Chemical Water Treatment

• Acid treatment
  – Lowers water pH
  – Help acidify soil for plants (blueberries)
  – Maintains solubility or dissolves manganese, iron, and calcium precipitates
  – Make chemicals work better

• Potassium permanganate
  – Oxidizes iron, causing it to precipitate
Growing Season Maintenance: Chemical Water Treatment

- Acid injection rate calculation
  - Amount of acid needed to treat a system
    - Strength of acid used
    - Buffering capacity of the irrigation water
    - Desired pH of water
  - Perform a titration to determine the acid volume : water volume ratio

- Calibration of injection pumps is critical

Resource: www.caes.uga.edu/applications/publications/files/pdf/B%201130_2.PDF
Growing Season Maintenance:

Chemical Water Treatment

• Calcium salts (carbonates, phosphatics)
  – Water pH >7.5, bicarbonate levels >100ppm
  – Acid injection
    • Target pH 4.0 or lower for 30 to 60 minutes/daily
    • Hydrochloric, phosphoric, or sulfuric acid used
    • Flush and clean injector
  – Water softening (household systems)
Growing Season Maintenance:
Three Steps for Iron Removal

• An oxidizer is added to the water, which induces precipitation of the iron and hydrogen sulfide, and the precipitated contaminant is then filtered out of the water.

• pH control
  – Low pH (2.0) – iron dissolves
  – High pH (7.2+) – iron precipitates
Growing Season Maintenance: Iron Removal Options

- Iron bacteria
  - Chlorine + retention + filtration
- Ferric (red rust) iron
  - Filter, but may require use of coagulant
- Ferrous (clear water) iron < 5 ppm
  - Ion exchange with resin bed, fouls easily
Growing Season Maintenance: Iron Removal Options

- Ferrous (clear water) iron 5+ ppm
  - Aeration + retention + filtration
  - Hydrogen peroxide + retention + filtration
  - Ozone (strong oxidizer) + retention + filtration
  - Chlorine (as a gas, calcium hypochlorite, or sodium hypochlorite at 1 part Cl : 1 part Fe) + retention + filtration (by manganese greensand, anthracite/greensand or activated carbon)

Greensand is then regenerated by using potassium permanganate (at 0.2 parts of pot. perm. : 1 part of iron)

- Oxidizing filter media (pyrolusite ore) + backwash it at 25 to 30 gallons per sq. ft.
- Manganese greensand (high capacity & high flow). Regenerate it with potassium permanganate at 1.5 to 2 oz. per cubic foot of greensand
Growing Season Maintenance: Control Area

• Control area
  – Regularly check each component for proper function as per manufacturer’s guidelines
  – Remember – pressure gauges are your indicators!
Growing Season Maintenance:

**Filters**

- Filters must be cleaned when pressure loss across filter exceeds 5-10 psi
- Screen filter - manual or automatic flush
- Disc filter – flush
- Sand media - backflush to clean
Growing Season Maintenance: Supply Lines and Laterals

- Flush lines at intervals
- Repair breaks and areas of leakage
- Inspect weekly
Growing Season Maintenance: Emitters

- Check frequently for plugging
- Check for lost emitters
- Control weed growth
  - Weeds compete for water
  - Weeds compete for injected fertilizers
  - Weeds interfere with wetting patterns
  - Weeds make maintenance more difficult
Growing Season Maintenance: Emitters

• Root intrusion
  – Cl injection at 100 ppm for 1 hour
  – Injection of trifluralin or copper sulfate

• Soil ingestion
  – Install vacuum relief valves on submains and manifolds, especially at high points
  – Soil surface installations – place emitter orifices up
End of Season Maintenance

• Turn off the water source
• Winterize the control area
• Drain all lines
  – Open manual drains
  – Remove plugs at ends of laterals
  – Use compressed air to remove water if needed
  – Replace end coverings and close drains
End of Season Maintenance:

Turn Off the Water Source

• The main shut off valve must be freeze-proof!
  – Below frost line
  – In heated room
  – Insulated
End of Season Maintenance:

Winterize the Control Area

• Disconnect power if needed
• Remove controls (backflow prevention, filters, gauges, injection equipment)
• Drain water from everything!
• Consider storing controls in a heated protected area
End of Season Maintenance:

Drain All Lines

• Two methods
  – Drain valves
  – Blowing out the system

• Drain valves
  – Open all drain valves, allow water to drain

• Remember to leave all valves open!
End of Season Maintenance:

**Drain All Lines**

- Blowing out the system
  - Use the proper compressor - need a large volume (50-125 cubic feet per minute is usual)
  - Remove backflow prevention
  - Turn on the control valve that is on the zone furthest from the backflow prevention; close down other zones
  - Connect the compressor, slowly increase the pressure, never exceed 50 psi
  - Run until all water is blown out (don’t run longer than 2-3 minutes), then turn off the control valve
  - Repeat procedure for each zone
  - Repeat the entire process again

- Remember to leave all valves open!
Final Thoughts

• Pick a good soil site for the garden or high tunnel
• Plan a reliable water supply
• Test water for problem minerals
• Match irrigation system to crop and time available
• Monitor soil moisture frequently
• Preventative maintenance is cheaper than repairs
• Be prepared for the unexpected
Irrigation Resources on the Web

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

• USDA NRCS Web Soil Survey
  websoilsurvey.sc.egov.usda.gov/App/
Questions??

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

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