Plants are 80-95% Water
(Watermelon = 90-91% M.C.)

- Water shortages early in crop development = delayed maturity, reduced yields, production gaps
- 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

Is a Rain Barrel Enough?

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

Basic Watering Facts

- Plants need 1.0”-1.5” of water per week
  - 624 - 935 gallons (83-125 cu. ft.) per 1,000 sq.ft.
  - 27,154 - 40,731 (3,360 – 5,445 cu. ft.) per acre
- 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”

Irrigation Definitions

- Saturation
  - When all soil pore space is filled with water
- Field capacity
  - When a soil is sufficiently wet, its capillary forces can hold no more water
  - Soil M.C. varies with soil texture, ranging from 15-45% by volume
- Permanent wilting point
  - Soil moisture content at which plants can no longer get water from the soil and will wilt and die
  - Soil M.C. ranges from 5-25% by volume
- Plant available water
  - The portion of the soil water that can be taken up by plants; ranges by crop from 20-75% of the water holding capacity of the soil
Irrigation Definitions

- **Field capacity** = 15-45% water by volume
- **Wilting point** = 5-25% water by volume

**Plant available water depends on:**
- Soil structure & texture
- Soil organic matter
- Plant rooting depth
- Soil type
- Water infiltration

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

If you take care of your soil, the soil will take care of your plants.

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

Benefits of Cover Crops / Compost

- Improves drainage & aeration of heavy clay soils
- Increases moisture-holding ability of sandy soils
- Increases earthworm and soil microbial activity that benefit plant growth
- Improves soil structure and makes it easier to work
- Contains nutrients needed for plant growth

USDA Soil Texture Classes

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  - 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**
  - Gritty, smooth, sticky
- **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

Effective Rooting Depth of Selected Vegetables

<table>
<thead>
<tr>
<th>Shallow (6-12&quot;)</th>
<th>Moderate (18-24&quot;)</th>
<th>Deep (&gt;30&quot;)</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>Potato</td>
<td>Tubér set and enlargement</td>
</tr>
</tbody>
</table>

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

Reference: irrigationtraining.tamu.edu/docs/irrigation-training/south/crop-guidelines/estimatedwaterrequirementsvegetablecrops.pdf

Evapotranspiration (ET)

- Rate of water loss changes as plant grows and sets fruit
- Peak water use is during bloom, fruit set and ripening
- Factors that affect ET
  - Type of crop or vegetation cover
  - Stage of crop growth
  - Temperature, wind, relative humidity
  - Soil moisture content
  - Mulches and ground covers

Soil & Climate Properties

- Soils store 0.25”-2.5” of water per foot of depth
  - 1.2” of water per foot of depth is common
    (Check Dunklin County USDA-NRCS Soil Survey)
- Intake rate by soil type:
  - Malden-Canalou-Bosket = 2.0”- 6.0” per hour
  - Crowley = 0.2”-0.6” per hour, rest is runoff
- Summer E.T. rate can be 0.25” per day
  - Can be as high as 0.30” per day with low humidity & high temperature with wind
**Physical & Chemical Properties**  
(from USDA Soil Survey – Dunklin County, MO)

<table>
<thead>
<tr>
<th>Property</th>
<th>Soil pH</th>
<th>EC (dS/m)</th>
<th>ECe (dS/m)</th>
<th>P (ppm)</th>
<th>Ca (ppm)</th>
<th>Mg (ppm)</th>
<th>K (ppm)</th>
<th>Na (ppm)</th>
<th>NH4 (ppm)</th>
<th>SO4 (ppm)</th>
<th>Cl (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>0.042</td>
<td>0.044</td>
<td>0.045</td>
<td>56.5</td>
<td>6.5</td>
<td>5.5</td>
<td>4.5</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>56.5</td>
<td>6.5</td>
<td>5.5</td>
<td>4.5</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sedimentary</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>56.5</td>
<td>6.5</td>
<td>5.5</td>
<td>4.5</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Reference: solildatamart.nrcs.usda.gov/Manuscripts/MO069/0/dunklin_MO.pdf

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**Watermelon Production**

- Soil pH = 5.8 to 6.6
- Seed germinates at soil temperatures of 68-95°F
- Use uniform, disease free, certified seed with at least 85-90% germination, or vigorous transplants
- Plant seed 0.5-1.0 inch deep, at 1-2 lbs./acre, depending upon seed size, germination and plant spacing
- Transplants:
  - 3.5’ x 10’ spacing = 1,245 plants per acre (35 sq. ft./plant)
  - 2.5’ x 10’ spacing = 1,742 plants per acre (25 sq. ft./plant)

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**Overhead Irrigation**

- Watermelons need system capable of delivering 1” of water every 4 days at <2.0” per hour
- 25-45 psi system operating pressure
- 5-6 feet spacing between hills and 10 feet between rows
- Center pivot
- Linear move
- Traveling gun
- Permanent set
- Portable pipe with sprinklers

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**Overhead Irrigation Use**

- Apply water at rate to avoid puddling and runoff
- Water early morning (4 a.m. to 8 a.m.)
  - Less evaporation loss (no sun, calmer winds)
  - Knocks dew and guttation fluid off leaf blades
  - Lets plant leaves dry before evening to discourage fungal growth and infection

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**Overhead Irrigation Rates**

- From planting until plants begin to run
  - Apply 0.5” whenever soil in top 6” becomes dry
- From time plants begin to run until first bloom
  - Apply 0.75” every five days during dry weather
  - If wilting occurs before noon, increase irrigation frequency
- From first bloom until harvest
  - Apply 1.0” every four days during dry weather
  - When more than 95°F, frequency may need to be increased to every three days to avoid stress

Reference: www.caes.uga.edu/applications/publications/files/pdf/309998.2.PDF

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**Drip Irrigation**

- Drip tape or drip pipe with emitters
  - Point use gives less runoff, less evaporation, easier weed control, saves 30%-50% water
  - 6-20 psi operating pressure means smaller pumps & pipes
  - Can fertilize through system
  - Do field work while irrigating
  - Can automatically control
  - Susceptible to clogging
  - Must design system to elevation
  - 2.3 feet of head = 1 psi pressure
  - Requires diligent management
  - Cost = $1,200 - $1,500 for 1st acre; $900 - $1,100/acre for rest

Reference: UNIVERSITY OF MISSOURI Extension

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Dec. 4, 2013
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

Example Layout of Drip Irrigation System

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 Tape for Watermelons

- Space plants 2.5-3.0 feet apart in beds and 8-10 feet between beds = 25-35 sq. ft./plant
  - Icebox watermelons = space 2 feet apart in beds and 5 feet between beds
  - Install drip tape (8 to 10 mil thickness; 8 to 12 inch dripper spacing) 1” below ground under plastic and 3” from the centerline of the bed
  - Design system to use 80% or less of your available water

Know the Soil Rooting Depth & How Water Will Re-Distribute

<table>
<thead>
<tr>
<th>Hours Required to Apply 1” of Water to Mulched Raised Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip Tube Flow Rate</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>24</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>42</td>
</tr>
<tr>
<td>48</td>
</tr>
</tbody>
</table>
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

Friction Loss - PVC Plastic Pipe

<table>
<thead>
<tr>
<th>Pipe Diameter, inches</th>
<th>0.75&quot;</th>
<th>1&quot;</th>
<th>1.5&quot;</th>
<th>2&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>PSI Loss per 100 ft. of pipe</td>
<td>2.4</td>
<td>8.8</td>
<td>18.6</td>
<td>31.6</td>
</tr>
</tbody>
</table>

Friction Loss – PVC Layflat Hose

Tensiometers

- Reading is a measure of the energy needed to extract water from the soil
- Work better in sandy soils than gypsum moisture blocks
- Read gauge of 0 (wet) to 100 (dry)
- Place at appropriate depth (8" & 16")
- Cost: $70-90, plus $50 for service unit

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 Deficit (inches per foot of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.1, 0.2, 0.3, 0.4, 0.6, 0.7</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.3, 0.4, 0.6, 0.7, 0.9, 1.1</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>0.4, 0.5, 0.8, 0.9, 1.1, 1.4</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0.5, 0.7, 0.9, 1.0, 1.3, 1.7</td>
</tr>
<tr>
<td>Loam</td>
<td>0.2, 0.5, 0.8, 1.0, 1.6, 2.4</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.

Water Source Quality

- 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
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>Physical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td>50-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Chemical</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

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: 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
- Backflow prevention is critical
- Use proper equipment and procedures
  - Inject upstream of filters
  - Allow for complete mixing
  - Pressurize system before injection
  - Flush lines at the end of injection to remove residue

Typical Chemigation System (electrically-driven)

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</td>
<td>Suspended clay and silt</td>
</tr>
<tr>
<td>White precipitate</td>
<td>Carbonate precipitation</td>
</tr>
<tr>
<td>Reddish precipitate (red rust color)</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>Clearwater 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 needs "contact time"
  - 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, and maintains solubility or dissolves Fe, Mn, and Ca precipitates
- 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/B1130_2.PDF

**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
  – 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

End of Season Maintenance: Winterizing Irrigation Equipment

• Park pivots in a safe location
• Remove brush and branches near equipment
• Lower the water levels in underground piping
• Drain roll-up hoses, travelers, and big guns
• Check for water pockets in drip lines and tape
• Drain or pump down underground pipelines
• Drain the pumping plant
• Inspect and lock down electrical power supplies
• Catalogue improvements and repairs on each system with a winter work list

Irrigation Resources on the Web

• This presentation and related resources extension.missouri.edu/webster/publications
• Irrigation System Planning & Management Links extension.missouri.edu/webster/Irrigation/

Questions??