Trickle Irrigation Primer

Matt Stasiak
Peninsular Agricultural Research Station
University of Wisconsin-Madison
College of Agriculture and Life Sciences
What Do Plants Need? How Do They Get It?

- Water
- Light Energy
- Air (CO$_2$ & O$_2$)
- Temperature
- Absence of toxins
- Nutrients
What Do Plants Need?  
How Do They Get It?

- Water
- Light Energy
- Air (CO₂ & O₂)
- Temperature
- Absence of toxins
- Nutrients

Precipitation
- NE WI 30-32” / year

Conservation
- Weed control
- Mulching

Irrigation
- Supplemental
Water Cycle

Soil
Plant
Environmental Management

all contribute to amount of moisture available for plant use

http://upload.wikimedia.org/wikipedia/commons/thumb/8/80/Surface_water_cycle.svg/260px-
Factors Limiting Moisture Supply

- Soil Type
- Root Distribution
- External Stress
  - Wind
  - Humidity
  - Temperature
  - Precipitation Frequency
- Irrigation Amount & Frequency
Soil Type

Texture
- Sand: .05-1 mm
- Silt: .002-.05 mm
- Clay: <.002 mm

Micro-particles
Micropores

Soil Classification

- Clay
- Clay loam
- Sandy loam
- Silt loam

Sand
Silt
Soil Type

Water Availability

Soil Water Content

- Sand
- Loam
- Clay

Legend:
- Bound Water
- Available Water
- Field Capacity
The role of organic matter

Physical & chemical process bind clay-silt-sand together.

Organic matter and soil structure
- Soil flora and fauna activity dependant on organic matter.
- Bacteria, fungi, algae, earthworms, beetles, etc.
- Fungal threads, gums fats & waxes bind particles together.

Macro-particles and macropores
- Soil clods & granules
- Soil aeration and permeability

Surface vegetation or mulch
Mulching
### Mulching

Improvement in surface water infiltration after two seasons of ‘mow and throw’.

<table>
<thead>
<tr>
<th>Infiltration Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>(seconds/inch)</td>
</tr>
<tr>
<td>2007</td>
</tr>
<tr>
<td>2008</td>
</tr>
<tr>
<td><strong>Control</strong></td>
</tr>
<tr>
<td>7.4</td>
</tr>
<tr>
<td>13.1</td>
</tr>
<tr>
<td><strong>MULCH</strong></td>
</tr>
<tr>
<td>8.9</td>
</tr>
<tr>
<td>5.9</td>
</tr>
</tbody>
</table>
Soil Moisture in Herbicide Strip With and Without Side Delivered Mulch

30% increase
Root Distribution

Natural Distribution

Soil Type

Poor distribution in heavy (clay) soils.
More extensive in coarse soils.

Physical Limitations

Hard pans
Bedrock

Plant Species & Cultivar
External Stress -

- Wind
- Humidity
- Temperature
- Precipitation
  Frequency
External Stress -

Rainfall Distribution – Door County, WI

Inches Precipitation

<table>
<thead>
<tr>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug.</th>
<th>Sept.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3.50</td>
<td>3.00</td>
<td>3.00</td>
<td>3.50</td>
</tr>
</tbody>
</table>
External Stress -

Rainfall Distribution – Door County, WI

Inches Precipitation

April | May | June | July | Aug. | Sept.

2012
## Irrigation Amount & Frequency

<table>
<thead>
<tr>
<th></th>
<th>Acre-inches</th>
<th></th>
<th>Actual irrigation required due to inefficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Consumptive Use</td>
<td>Irrigation Requirement</td>
</tr>
<tr>
<td>April</td>
<td>0.81</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>3.33</td>
<td>1.28</td>
<td>2.56</td>
</tr>
<tr>
<td>June</td>
<td>4.56</td>
<td>3.19</td>
<td>6.38</td>
</tr>
<tr>
<td>July</td>
<td>5.32</td>
<td>4.97</td>
<td>9.94</td>
</tr>
<tr>
<td>August</td>
<td>4.39</td>
<td>3.91</td>
<td>7.82</td>
</tr>
<tr>
<td>Sept</td>
<td>2.07</td>
<td>0.52</td>
<td>1.04</td>
</tr>
<tr>
<td>October</td>
<td>0.54</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>21.02</td>
<td>13.87</td>
<td>27.74</td>
</tr>
</tbody>
</table>

Average consumptive use and net irrigation requirement for orchards in the Willamette Valley in acre-inches. OSU Agricultural Experiment Station Circular 628
'Drip' Advantages & Disadvantages

- Lower water usage
  50% less than sprinkler
- Lower energy requirement
  Operating pressure and volume
- Efficiency - only what ‘crop’ needs
- Less potential for disease damage
- Reduced weed pressure & mowing costs
- More readily adaptable to hilly terrain
'Drip' Advantages & Disadvantages

- Management, initial investment & operating costs
- Only what ‘crop’ needs
  Limited application volume can also be a negative
- No frost protection
- Clogging
  Particulates, algae, mineral precipitates
Irrigation Amount & Frequency

How much?
- Species & cultivar
- Plant age

When?
- Critical periods
- Timing

Where?
- Placement

Supplemental Irrigation in a Humid Climate
How much?

Differences between species
Annual crop – apple - hop
Roots spread & depth
Down to to 15 ft
3-6’ beyond drip line
Vine age
### How much?

<table>
<thead>
<tr>
<th>CROP</th>
<th>GAL/PLANT/DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hop</td>
<td>1</td>
</tr>
<tr>
<td>Dwarf Apple</td>
<td>1</td>
</tr>
<tr>
<td>Grape</td>
<td>1</td>
</tr>
<tr>
<td>Melons</td>
<td>3</td>
</tr>
</tbody>
</table>
How much?

Newly planted vines 7 gallons of water/week. Best to split into 2 applications. ‘Rule of Thumb’. Increase volume by 50% each year. (more vigorous, greater increase) Amount needed for vines varies with age.
Distribution System

Emitters

- **Point source**
  Historically used in low density crops (1-2 gph)

- **Inline**
  T-tape, ‘drip-in’
  Increased use in high density orchards (0.2-0.3 gph per foot)

12” ----- 24” ----- 36” ----- 48”
Emitter Placement

Need to supply 25% root volume

• Young vines.
  1-2 feet from the crown.
  3-4 feet of slack at installation.

• Mature vines.
  Maintain distance from crown to avoid root rot.
  Additional emitters or lines may be required.
# Application Interval

<table>
<thead>
<tr>
<th>CROP</th>
<th>TREE AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hop</td>
<td>1</td>
</tr>
<tr>
<td>Dwarf Apple</td>
<td>2</td>
</tr>
<tr>
<td>Grape</td>
<td>2</td>
</tr>
<tr>
<td>Melons</td>
<td>-</td>
</tr>
</tbody>
</table>
Application Interval

1st year

Hops
888 vines/acre
(3.5x14’ spacing)

Need to supply:
1 gal/vine/day = 7 gal/week

Using:
1 gph emitter per vine

point source emitters
Application Interval

1st year

Hops
888 vines/acre
(3.5x14’ spacing)

Need to supply:
1 gal/vine/day = 7 gal/week

Using:
1 gph emitter per vine

\[
\frac{7 \text{ g/wk}}{1 \text{ gph}} = 7 \text{ hr/week}
\]

3-4 hrs at 2x per week
Application Interval

1st year

Hops
888 vines/acre
(3.5x14’ spacing)

Need to supply:
1 gal/vine/day = 7 gal/week

Using:
0.735 gph per vine
(3.5/2*.42)

In-line emitters

2’ spacing, 0.42 gph
Application Interval

1st year

Hops
888 vines/acre
(3.5x14’ spacing)

Need to supply:
1 gal/vine/day = 7 gal/week

Using:
0.735 gph per vine
(3.5/2*.42)

\[
\frac{7 \text{ g/wk}}{.735 \text{ gph}} = 9.5 \text{ hr/week}
\]

5 hrs at 2x per week
When?

Critical Periods
- Young plants
- Flowering
- Avoid water logging

In Midwest - typically June through early September
When?

Start early before soil dries
- Increase lateral spread
- Avoid ‘catch up’

Timing

Pan evaporation
Tensiometers
Electrical resistance
Dry Soil > Resistance
Water Availability

Scheduling with pan evaporation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation/week</td>
<td>2.2 inches</td>
</tr>
<tr>
<td>Rainfall/week</td>
<td>0.7 inches</td>
</tr>
<tr>
<td>Net water loss/week</td>
<td>1.5 inches</td>
</tr>
</tbody>
</table>

75-100% replacement depending on crop

Best in arid climates and coarse (sandy soils)
Tensiometers

- Measure energy status of soil water.
- ‘Soil Moisture Tension’ (negative pressure).
- Expressed as bars or centibars.
# Water Availability

<table>
<thead>
<tr>
<th>Tension (Bars)</th>
<th>% H₂O Filled Space</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oven Dry</strong></td>
<td>10,000</td>
</tr>
<tr>
<td><strong>Wilt Point</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Field Capacity</strong></td>
<td>.33</td>
</tr>
<tr>
<td><strong>Saturation</strong></td>
<td>0</td>
</tr>
</tbody>
</table>

1 Bar (kPa) = \(-.15\)psi  
15 Bars = \(-2\) psi  
10,000 Bars = \(-1450\) psi
Water Availability

Monitor with tensiometers
   Place 1/3 & 2/3 root depth
Sprinkler
   Begin 40-50 cb
Drip
   Maintain between 10-50 cb

Wet - Dry
Sand 10-40
Loam 20-80
Clay 30-100
Well, stream or pond?

- **Particulates**
  Less likely with well water
- **pH, dissolved solids & elements**
  Calcium, Magnesium & Iron
- **All water sources contain bacteria or elements that support bacterial growth**
  Can lead to ‘bacterial slime’
- **Algae from surface water**
Water Source

Filters needed depend on water source

- **Coarse screen filters**
  Protect pumps from surface water trash
- **Fine mesh screen filters**
  Slotted plastic, perforated/mesh stainless, or nylon
Water Source

Filters needed depend on water source

Sand filters for surface water - high ‘organic’ matter
# Prevention of Clogging

<table>
<thead>
<tr>
<th>Water Criteria</th>
<th>Clogging Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>slight</td>
</tr>
<tr>
<td></td>
<td>concentration (ppm)</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
<tr>
<td>suspended solids</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>&lt; 7.0</td>
</tr>
<tr>
<td>dissolved solids</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>manganese</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>iron</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>hardness, as CaCO₃</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
</tr>
<tr>
<td>bacteria (plate count/ml)</td>
<td>&lt; 10,000</td>
</tr>
</tbody>
</table>

Prevention of Clogging

Calcite (scale) formation

\[
\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca(HCO}_3\text{)}_2
\]

- **Soluble**
  - Calcium carbonate
  - Weak acid
  - Calcium bicarbonate

- **Precipitate**
  - pH and temperature dependant
Prevention of Clogging

Acid treatment

Citric, phosphoric, sulfuric, hydrochloric
Prevention of Mg & Ca scaling, bacterial slime (Fe)
  – Continuous injection to lower pH to just below 7.0.

Scale removal

  – ‘Slug’ injection with pH 3.0-4.0.
  – Flush after sitting in line 1-2 hours.

Chlorine injection

Algae, bacterial slime (Fe)
  – Continuous injection to maintain 1-2ppm.
Injectors

- Chemical injection to reduce algae and precipitates.
- Type – venturi, metering, proportioner
- Fertilizer use can be cut by 50%.
- All require backflow prevention to protect water source.
Nitrogen, potassium, magnesium, boron, and zinc can be effectively supplied through fertigation. Benefits over broadcast fertilizing include:

- Increased nutrient absorption
- Reduced fertilizer need
- Reduced leaching
- Reduction in water usage due to the plant's resulting increased root mass's ability to trap and hold water
- Precise timing and application rates
Average Yields from Seven Tart Cherry Orchard Floor Systems, 1995-2000

Production Cost

YIELD (tons/a)

- Herb. Strip
- HS + Fertigation
- Compost
- Mulch
- Cover Crop
- CC + Fertigation
- Bio-System

No Irrigation
Design Considerations

- Field layout
  - Mainline
    - Supply to fields
  - Submain (header)
  - Within field
- Laterals
  - To the tree
- Emitters

Flow Rate
# Flow Rate Determination - per acre

<table>
<thead>
<tr>
<th>CROP</th>
<th>GAL/PLANT/DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TREE AGE</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hop</td>
<td>1</td>
</tr>
<tr>
<td>Dwarf Apple</td>
<td>1</td>
</tr>
<tr>
<td>Grape</td>
<td>1</td>
</tr>
<tr>
<td>Melons</td>
<td>3</td>
</tr>
</tbody>
</table>
Flow Rate Determination - per acre

Mature

Hop
888 vines/acre
(3.5x14’ spacing)

Need to supply:
3 gal/vine/day = 21 gal/week

Using:
1 gph emitter per vine

888 vines/acre x 1 gph = 888 gallons per hour
# Flow Rate Supply

Required main and submain size for various flow rates.

<table>
<thead>
<tr>
<th>Pipe Flow Rate (gpm)</th>
<th>Minimum Pipe Size (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 4</td>
<td>1/2</td>
</tr>
<tr>
<td>8 - 12</td>
<td>1</td>
</tr>
<tr>
<td>22 - 30</td>
<td>1 1/2</td>
</tr>
<tr>
<td>30 - 50</td>
<td>2</td>
</tr>
<tr>
<td>70 - 110</td>
<td>3</td>
</tr>
<tr>
<td>110 - 190</td>
<td>4</td>
</tr>
<tr>
<td>190 - 450</td>
<td>6</td>
</tr>
</tbody>
</table>

**Sufficient flow?**

- **888 vines/acre x 1 gph = 888 gallons per hour**

- **14.8gal/min.**
  - 1 ACRE

- **7.4gal/min.**
  - 1/2 ACRE
## Flow Rate Supply

Required main and submain size for various flow rates.

<table>
<thead>
<tr>
<th>Pipe Flow Rate (gpm)</th>
<th>Minimum Pipe Size (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 4</td>
<td>1/2</td>
</tr>
<tr>
<td>8 - 12</td>
<td>1</td>
</tr>
<tr>
<td>22 - 30</td>
<td>1 1/2</td>
</tr>
<tr>
<td>30 - 50</td>
<td>2</td>
</tr>
<tr>
<td>70 - 110</td>
<td>3</td>
</tr>
<tr>
<td>110 - 190</td>
<td>4</td>
</tr>
<tr>
<td>190 - 450</td>
<td>6</td>
</tr>
</tbody>
</table>

Sufficient flow?

- **1 ACRE**
  - 888 vines/acre x 1 gph = 888 gallons per hour

- **1/2 ACRE**
  - 14.8gal/min.
  - 7.4gal/min.
# Flow Rate Supply

Required main and submain size for various flow rates.

<table>
<thead>
<tr>
<th>Pipe Flow Rate (gpm)</th>
<th>Minimum Pipe Size (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 4</td>
<td>1/2</td>
</tr>
<tr>
<td>8 - 12</td>
<td>1</td>
</tr>
<tr>
<td>22 - 30</td>
<td>1 1/2</td>
</tr>
<tr>
<td>30 - 50</td>
<td>2</td>
</tr>
<tr>
<td>70 - 110</td>
<td>3</td>
</tr>
<tr>
<td>110 - 190</td>
<td>4</td>
</tr>
<tr>
<td>190 - 450</td>
<td>6</td>
</tr>
</tbody>
</table>

Sufficient flow?

- 888 vines/acre x 1 gph = 888 gallons per hour

- 14.8gal/min. 1 ACRE
- 7.4gal/min. 1/2 ACRE
Water Source

Pump requirements

Needs to be sufficient to bring water to the surface and move against gravity and friction.

Combination of-

- **Flow rate**
  
  Gallons per minute each section to be irrigated.

- ‘Head’ - total energy needed supply emitters
  
  Elevation – water source to highest lateral.
  Friction – supply lines, valves, filters, etc.
Final Thoughts - Design Considerations

Professional Design Engineer

- Water source – well, pond, existing pumps, etc.
- Electrical supply – voltage, etc.
- Total flow rate
- Vine age & cultivar
- Row and plant spacing
- Field dimensions – row lengths
- Terrain
- Automation
- Chemical injection
Suppliers

Roberts Irrigation Company, Inc.
1500 Post Rd
P.O. Box 490
Plover, WI 54467
Ph: 800-434-5224
www.robertsirrigation.net

Trickl-eez Company
4266 Hollywood Rd.
St. Joseph, MI 49085
Ph: 800-874-2553
www.trickl-eez.com

Spring Brook Supply
11291 Lakewood Blvd.
Holland, MI 49424
Ph: 616-396-1956
www.springbrookirrigation.com
Further Information

Designing A Drip/Trickle Irrigation System: Part 1&2 — Water Needs, Emitters, and Management. Albert R. Jarrett Professor of Agricultural Engineering
http://pubs.cas.psu.edu/freepubs/pdfs/F180.pdf
http://pubs.cas.psu.edu/freepubs/pdfs/F181.pdf


http://njaes.rutgers.edu/pubs/publication.asp?pid=FS793

http://njaes.rutgers.edu/pubs/publication.asp?pid=FS795

http://edis.ifas.ufl.edu/hs1202