Drip Irrigation Considerations in High Tunnel Production Systems

by
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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

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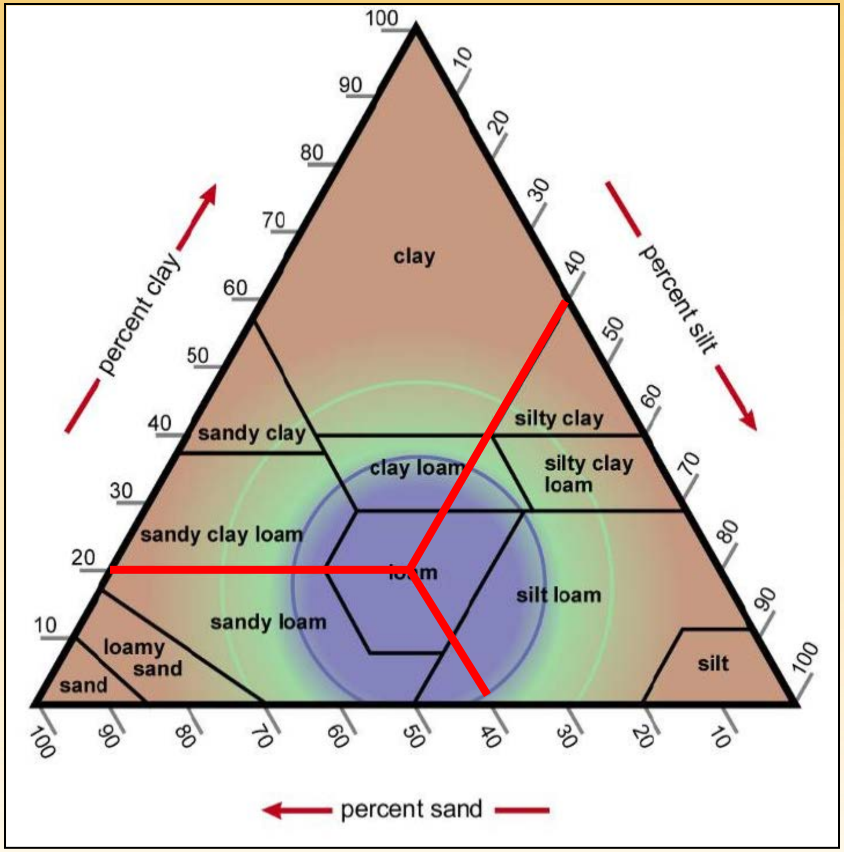
If you take care of your soil, the soil will take care of your plants.

- Available Water Holding Capacity depends on:
  - Soil texture
  - Organic matter
  - Rooting depth

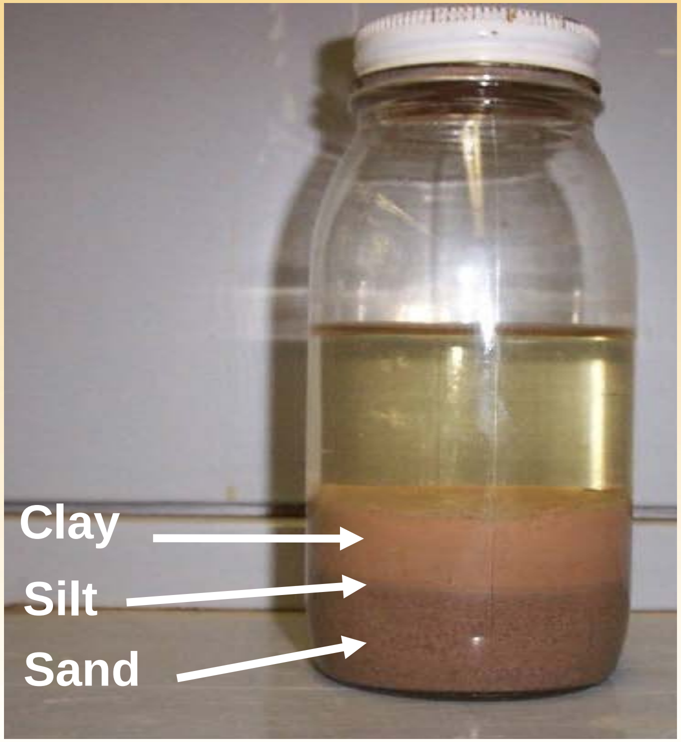
USDA Soil Texture Classes

- 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



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

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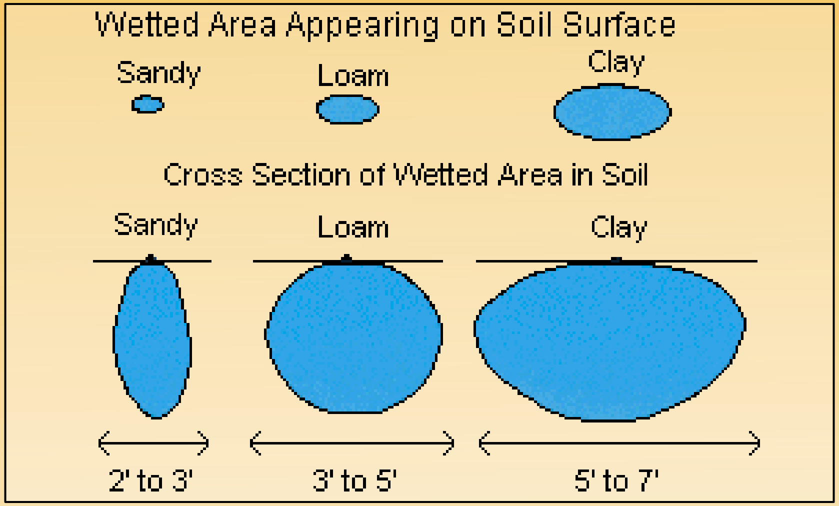
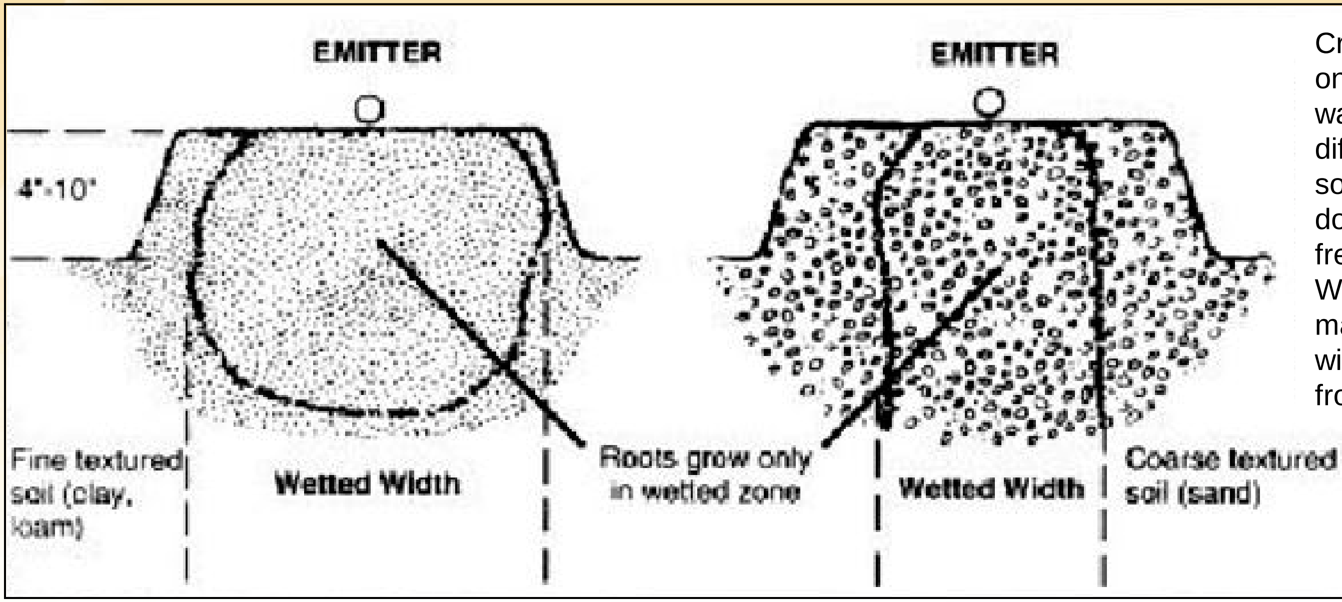
Know the Soil Rooting Depth & How Water Will Re-Distribute





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

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

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

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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

Low	**Medium Low**	**Medium**
Spinach	Peas, Green	Cabbage
Lettuce	Beans, Kale	Broccoli
Radish		Pepper

Medium High	**High**	**Very High**
Tomato	Sweet Corn,	Muskmelon
Asparagus	Vine Squash	Watermelon
		Pumpkin

Plant Water Requirements

(Estimated design rates for southwest Missouri)

Vegetable Crop (mature)	*Gallons per 100 Feet of Row per Week*
Minimum for plant survival	100
Lettuce, spinach, onions, carrots, radishes, beets	200
Green beans, peas, kale	250
Tomatoes, cabbage, peppers, potatoes, asparagus, pole beans	300
Corn, squash, cucumbers, pumpkins, melons	400-600

Vegetable Crops & Growth Period Most Critical for Irrigation Requirements

Crop[1]	Most Critical Period
Broccoli, Cabbage, Cauliflower, Lettuce	Head development
Carrot, Radish, Beet, Turnip	Root enlargement
Sweet Corn	Silking, tasseling, and ear development
Cucumber, Eggplant, Pepper, Melon, Tomato	Flowering, fruit set, and maturation
Bean, Pea	Flowering, fruit set, and development
Onion	Bulb development
Potato	Tuber set and enlargement

[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

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

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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

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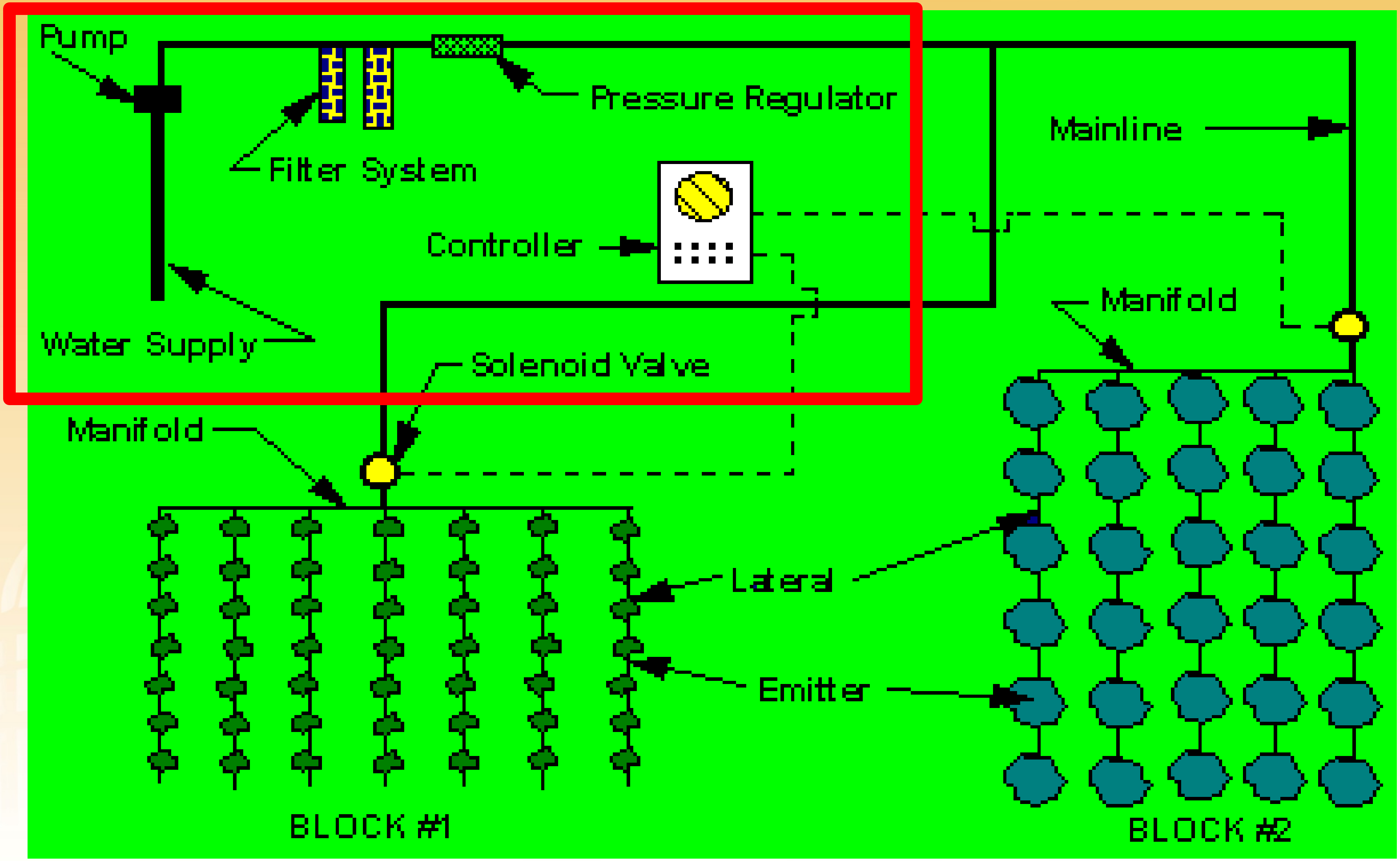
Drip Irrigation – Pros & Cons

- 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

	Number of Bathrooms in Home			
	1	**1.5**	**2**	**3**
Bedrooms	**Flow Rate (Gallons Per Minute)**			
2	6	8	10	--
3	8	10	12	--
4	10	12	14	16
5	--	13	15	17
6	--	--	16	18

Source: http://extension.missouri.edu/p/G1801

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Pump Cycling Rate, Max.

Horsepower Rating	Cycles / Hour
0.25 to 2.0	20
3 to 5	15
7.5, 10, 15	10

Pressure Tank Selection

	Average Pressure, psi*		
Tank Size, gallons	40	50	60
	Pumping Capacity, GPM		
42	5	4	3
82	11	8	6
144	19	14	10
220	29	21	15
315	42	30	22

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

Pressure Tanks

Larger tank

Multiple tanks

OR

Variable-speed pump controller

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)

PVC Casing

Steel Casing

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

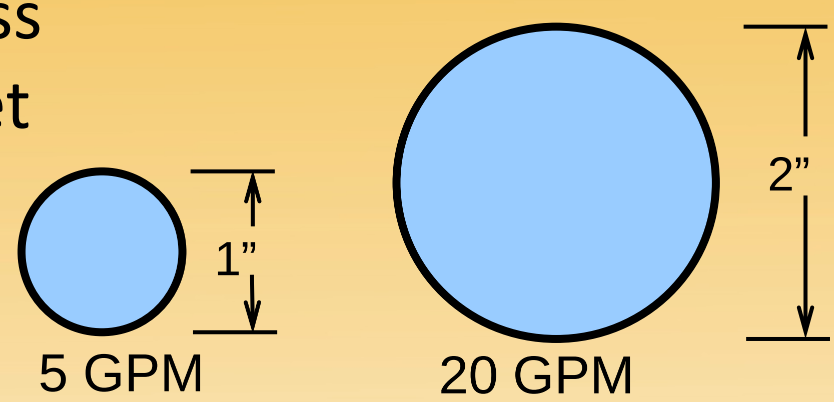
Plugging Potential of Drip Irrigation Systems

Factor	Moderate (ppm)*	Severe (ppm)*
Physical		
Suspended solids	50-100	>100
Chemical		
pH**	7.0-7.5	>7.5
Dissolved solids	500-2000	>2000
Manganese	0.1-1.5	>1.5
Iron	0.1-1.5	>1.5
Hardness***	150-300	>300
Hydrogen sulfide	0.5-2.0	>2.0

* 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 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

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Plastic Pipe Friction Loss

	Pipe Diameter, inches			
	0.75"	**1"**	**1.5"**	**2"**
GPM	**PSI Loss per 100 ft. of pipe**			
5	2.8	0.8	0.1	--
10	11.3	3.0	0.4	0.1
15	21.6	6.4	0.8	0.2
20	37.8	10.9	1.3	0.4
25	--	16.7	1.9	0.6
30	--	--	2.7	0.8

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Drip Irrigation Components

Vacuum Breaker

Backflow Preventer

Filter

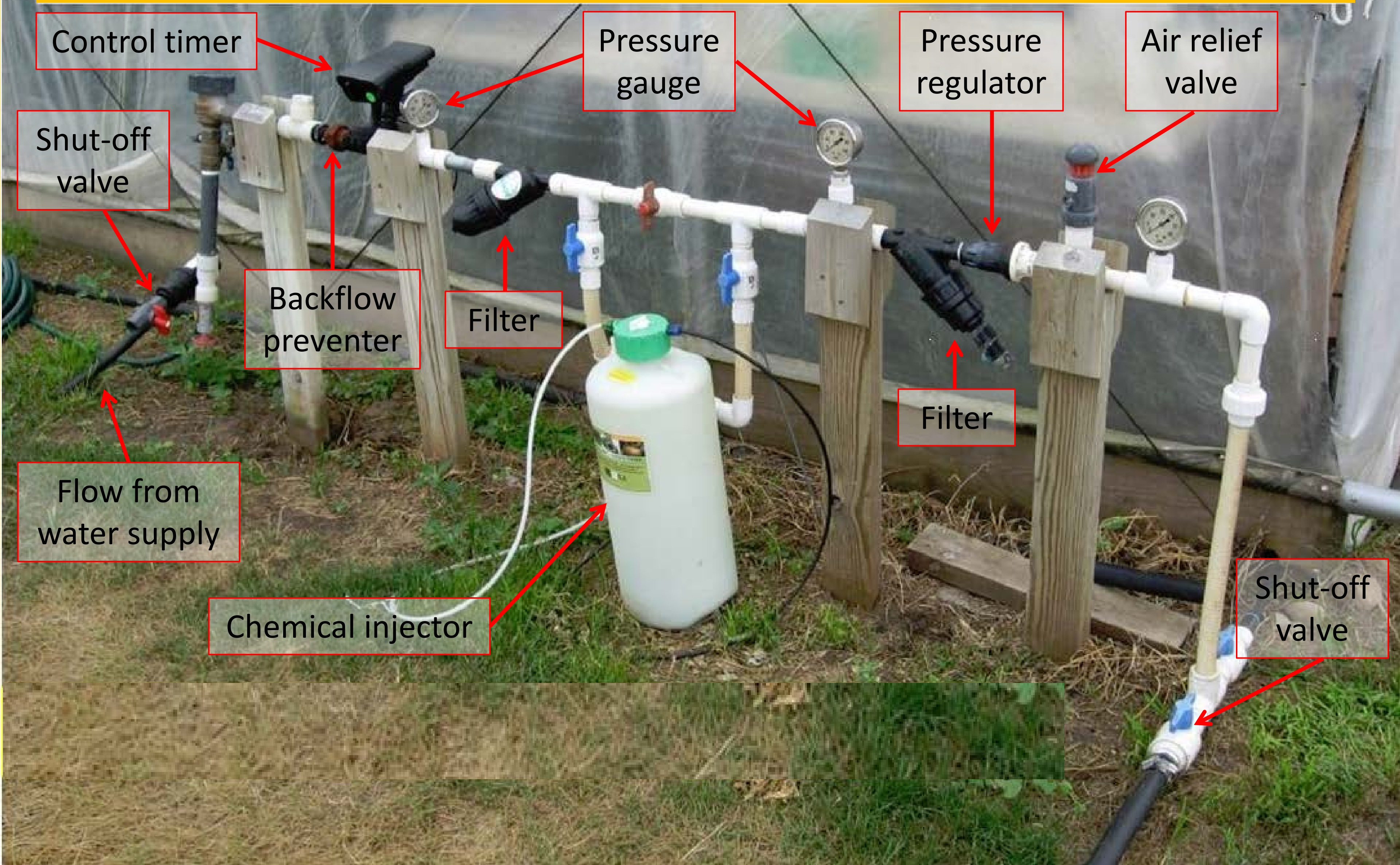
Pressure Regulator

Manifold to Drip Tape Connectors

Manifold Pipe

Drip Tape

Drip Irrigation Control Assembly

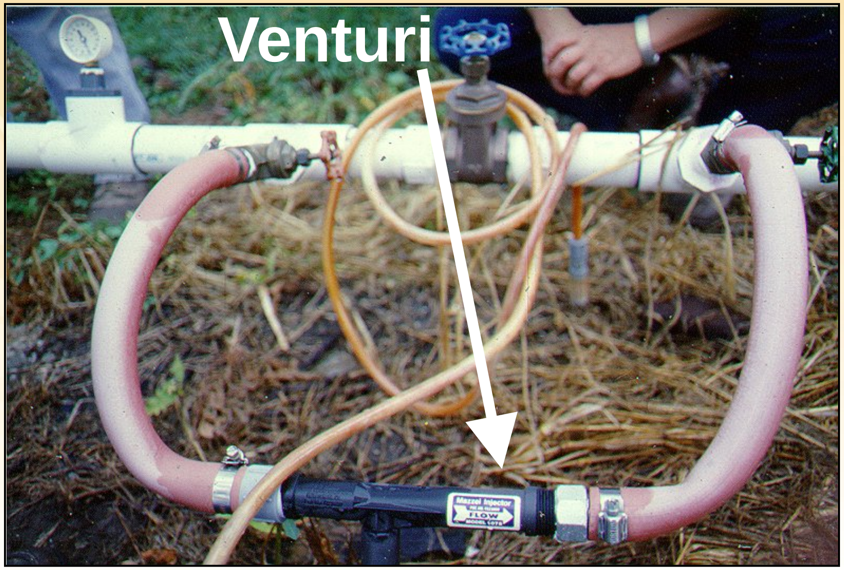


Fertigation

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

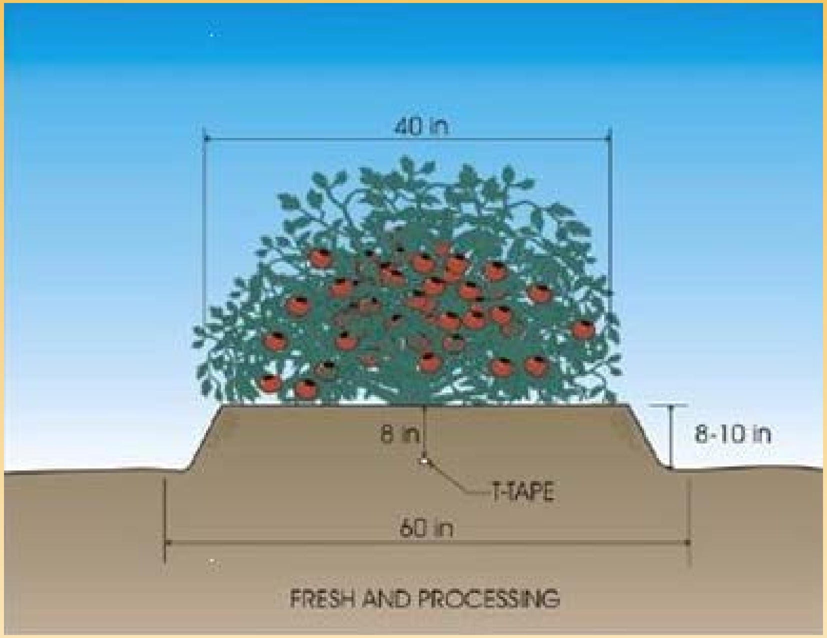
- Wall thickness = 6, 8, 10, 15-mil; 1-2 year life
- Surface or sub-surface installation
- Emitters manufactured within the tape wall
  - Common spacing = 4”, 8”, 12”, 16” 18” 24”
  - Max. operating pressure
    = 6-mil @ 10 psi
    = 8-mil @ 12 psi
    = 10-mil @ 14 psi
    = 15-mil @ 25 psi
- More animal damage outdoors

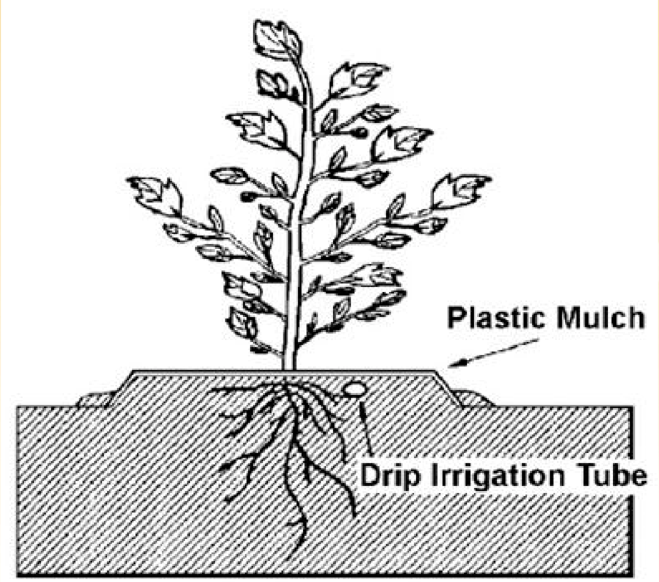
Drip Installation (Hand or Mechanical) Prior to Plastic Mulch

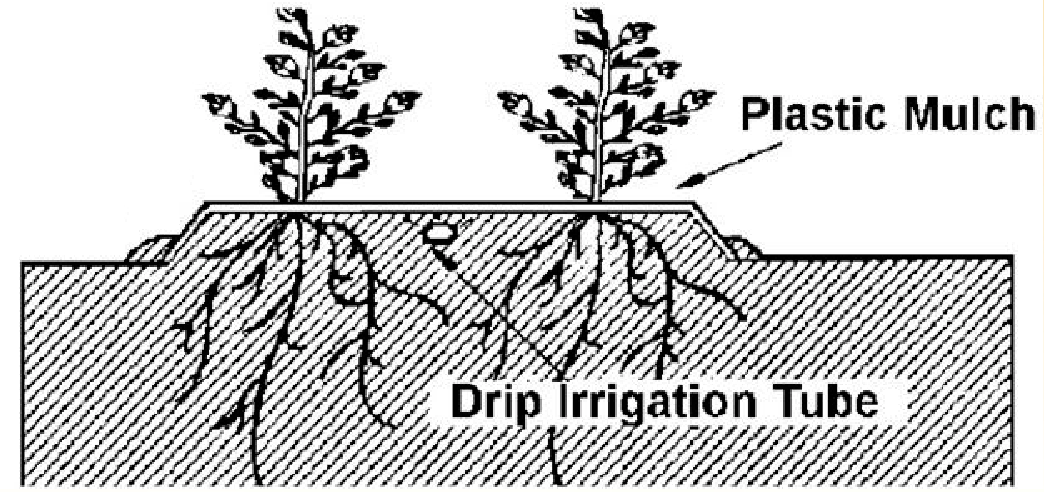
Drip Tape Placement

- 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

Manifold Options

When & How Much Should I Water?

Hours Required to Apply 1” of Water to Mulched Raised Bed

Drip Tube Flow Rate		Width of Mulched Bed		
Gallons per Hour per 100 feet run of drip tape	Gallons per Minute per 100 feet run of drip tape	2 feet	2.5 feet	3 feet
16	0.27	8.0	10.0	11.5
18	0.30	7.0	8.5	10.5
20	0.33	6.0	8.0	9.5
24	0.40	5.0	6.5	8.0
30	0.50	4.0	5.0	6.0
36	0.60	3.5	4.5	5.0
40	0.67	3.0	4.0	4.5
42	0.70	3.0	4.0	4.5
48	0.80	2.5	3.0	4.0

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

Drip tube flow rate		Tomato plants per high tunnel		
Gph/100 ft[1]	Gpm/100 ft[2]	300	400	500
8	0.13	21	28	35
10	0.17	17	22	28
12	0.20	14	19	23
16	0.27	11	14	18
18	0.30	9	12	16
20	0.33	8	11	14
24	0.40	7	9	12
30	0.50	6	8	9
36	0.60	5	6	8
40	0.67	4	6	7
42	0.70	4	5	7
48	0.80	3.5	5	6
60	1.00	2.8	4	5

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

Resource: http://extension.missouri.edu/p/G6462

Soil Water Monitoring Sensors

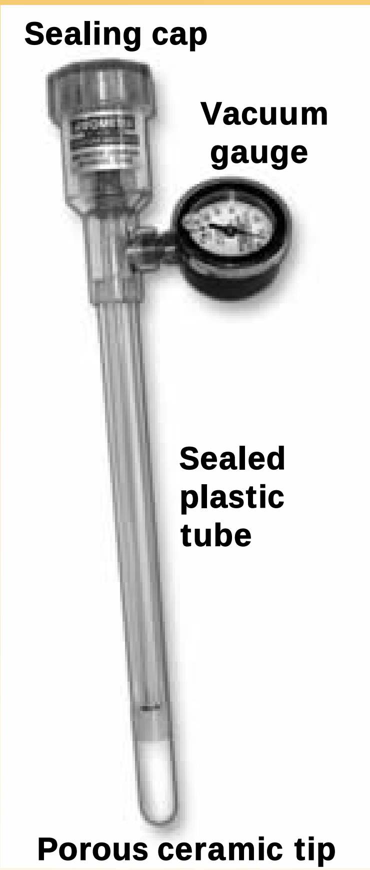
Soil Water Deficits for Typical Soils & Soil Water Tensions

Good Range for High Tunnels = 25-40 Centibars

Soil Texture	Soil Water Tension in Centibars (cb)						
	10	30	50	70	100	200	1500**
	Soil Water Deficit (inches per foot of soil)						
Coarse sand	0	0.1	0.2	0.3	0.4	0.6	0.7
Fine sand	0	0.3	0.4	0.6	0.7	0.9	1.1
Loamy sand	0	0.4	0.5	0.8	0.9	1.1	1.4
Sandy loam	0	0.5	0.7	0.9	1.0	1.3	1.7
Loam	0	0.2	0.5	0.8	1.0	1.6	2.4

***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



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

Resource: extension.missouri.edu/explorepdf/manuals/m00170.pdf

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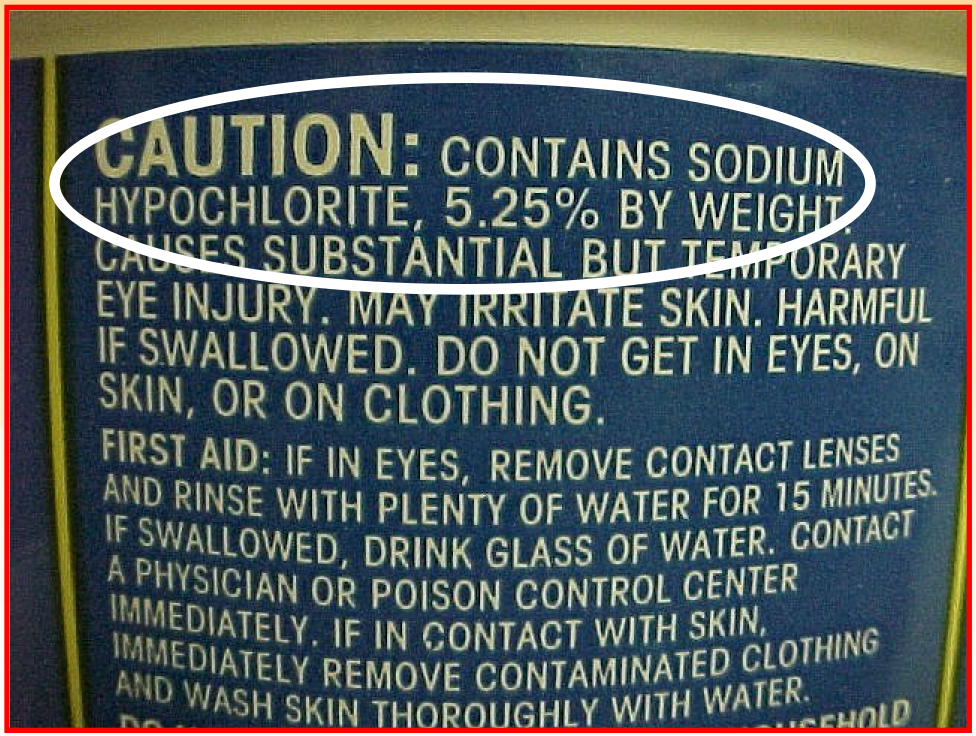
Troubleshooting Guide

Symptom	Possible Causes
Reddish-brown slime or particles near emitters	Bacteria feeding on iron
White stringy masses of slime near emitters	Bacteria feeding on sulfur
Green or slimy matter in surface water	Algae or fungi
White film on tape or around emitters	Calcium salts or carbonates
Presence of silt or clay	Inadequate filtration

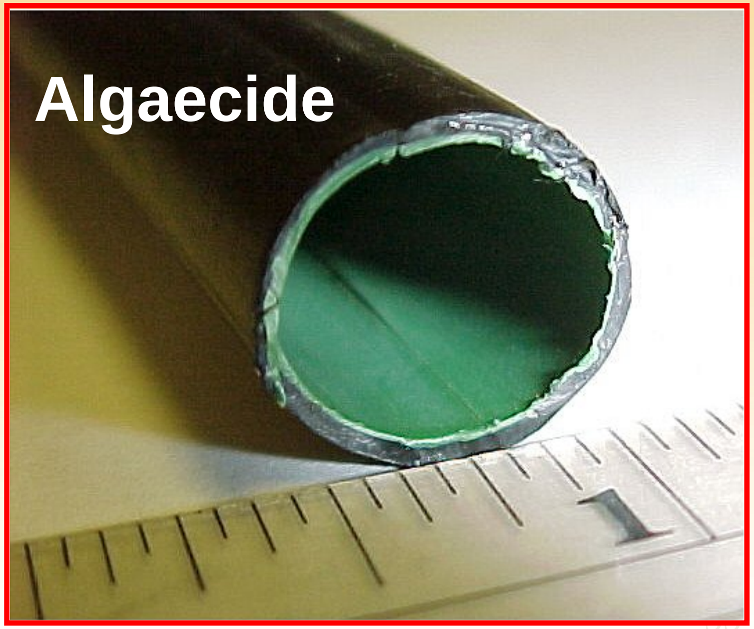
Chemigation

- 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

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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

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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.

Publications about High Tunnels

Four Season Harvest: Organic Vegetables from Your Home Garden All Year Long., Eliot Coleman 1999, 212 pages, Chelsea Green Publishing www.chelseagreen.com

The Hoophouse Handbook by Lynn Byczynski, 2003, 60 pages, Fairplain Publishing, Inc. www.growingformarket.com

The New Organic Grower: A Masters Manual of Tools and Techniques for the Home and Market Gardener. By Eliot Coleman , 1995, 340 pages, Chelsea Green Publishing, www.chelseagreen.com

Season Extension Techniques for Market Gardeners Janet Bachman and Richard Earles 2000, 24 pages, ATTRA, www.attra.org

Solar Gardening: Growing Vegetables Year-Round the American Intensive Way. Leandre and Gretchen Poisson, 1994, 267 pages, Chelsea Green Publishing www.chelseagreen.com

The Winter-Harvest Manual Farming the Backside of the Calendar Eliot Coleman, 2001, 62 pages, www.fourseasonfarm.com