Strawberry Irrigation in High Tunnels

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for
Southern Illinois Small Fruit & Strawberry School
Mt. Vernon, IL
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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
The Two Major Factors in Irrigation System Planning

1. How much **water** do you need?

2. How much **time** do you have?
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
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
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.
Rooting Depth of Strawberries

Photo credit: www.hort.cornell.edu/expo/proceedings/2012/Berries/Berry%20Plant%20Structure%20Poling.pdf
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:
* www.nrcs.usda.gov/wps/portal/nrcs/soilsurvey/soils/survey/state/
* websoilsurvey.nrcs.usda.gov/app/
** www.ces.ncsu.edu/depts/hort/hil/hil-33-e.html
Available Water Holding Capacity for Several Soil Types

<table>
<thead>
<tr>
<th></th>
<th></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>

http://www.btny.purdue.edu/pubs/id/id-56/
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
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
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 = limited use
  - Elevation dictates pressure
    (2.3 feet of head = 1 psi pressure)
  - Watch for tank corrosion
Static water table

High-capacity well

Existing wells

Initial cone of depression

Cone of depression

Long-term cone of depression
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>
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<tbody>
<tr>
<td>2</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>--</td>
<td></td>
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<tr>
<td>3</td>
<td>8</td>
<td>10</td>
<td>12</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
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<tr>
<td>5</td>
<td>--</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>--</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Source: [http://extension.missouri.edu/p/G1801](http://extension.missouri.edu/p/G1801)
## Pump Cycling Rate, Max.

<table>
<thead>
<tr>
<th>Horsepower Rating</th>
<th>Cycles / Hour</th>
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</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>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)
- E. coli bacteria

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>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
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

### Pipe Diameter, inches

<table>
<thead>
<tr>
<th>GPM</th>
<th>0.75&quot;</th>
<th>1&quot;</th>
<th>1.5&quot;</th>
<th>2&quot;</th>
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<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>
Example Layout of Drip Irrigation System
Drip Irrigation Components

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

- Control timer
- Shut-off valve
- Backflow preventer
- Filter
- Chemical injector
- Pressure gauge
- Pressure regulator
- Air relief valve
- Shut-off valve

Flow from water supply
Fertigation
Nutrient “Spoon Feeding”
Frost Protection of Plumbing

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

Photo credit: University of Arkansas -- www.youtube.com/watch?v=4J1p2UQo2jE
Rules of Fertigation

- Be sure fertilizer is 100% water-soluble
- Completely pressurize the drip irrigation system before starting fertigation
- Inject fertilizer two elbows ahead of the filter to ensure good mixing
- Inject fertilizer for at least as long as time required to pressurize the entire system
- Use vacuum breaker or backflow preventer to protect water supply

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
Bed Preparation Before Drip Tape

- Have the soil tested for soluble salts
  - Strawberries are very salt-sensitive
  - Makes it harder to extract water from the soil
- Enough soil moisture for seed germination when laying plastic mulch
- Soil temperature at least 50° F
  - Soil well-worked
  - Free from undecomposed plant debris if fumigating
- Install at same time or prior to mulch
Drip Installation (Hand or Mechanical) Prior to Plastic Mulch
Installing the Drip Tape

- 2-row and 4-row beds common in high tunnels
Installing the Drip Tape

• Use 2-3 drip lines per bed, with 4”- 6” dripper spacing
  – Place drip lines between rows
  – Bury 1”- 2” deep in the bed with the drippers (emitters) facing upward
  – Burying protects drip tape from rodents and prevents it from moving in hot or cold temperatures

• Avoid puncturing drip tape during planting
Drip Tape Placement
Manifold Options
Manifold Options
When & How Much Should I Water?

- Strawberries do not thrive in waterlogged soils
- Irrigate about 3-4 hours per week in early fall after transplanting
- No watering in winter when plants are dormant
- Measure soil moisture with tensiometer or “feel method”
  - Tensiometer reading in the 20-30 cb range at a 12” depth
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></td>
<td>2 feet</td>
</tr>
<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>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>36</td>
<td>16</td>
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<tr>
<td>42</td>
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<tr>
<td>48</td>
<td>21</td>
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<td>54</td>
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<td>60</td>
<td>26</td>
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<td>66</td>
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<td>78</td>
<td>34</td>
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<tr>
<td>84</td>
<td>37</td>
</tr>
<tr>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td>96</td>
<td>42</td>
</tr>
</tbody>
</table>

Gallons/100 ft. of row/day = (66 x 80% of Pan Evaporation Rate x Row width in feet) = 1.5” per week
Soil Water Monitoring Sensors
## 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.
## 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

Rust & silt

Algaecide
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)  
  agebb.missouri.edu/mac/links/index.htm

• High Tunnel Construction Considerations (Iowa State)  
  www.public.iastate.edu/~taber/Extension/Tunnelconstruct.pdf

• Growing Strawberries in High Tunnels in Missouri  
  hightunnels.org/growing-strawberries-in-high-tunnels-in-missouri/

• Midwest Vegetable Production Guide for Commercial Growers  
  www.btny.purdue.edu/pubs/id/id-56/

• Plasticulture (Penn State)  
  extension.psu.edu/plants/plasticulture

• Horticultural Engineering (Rutgers University)  
  aesop.rutgers.edu/~horteng/

• Noble Foundation  
  www.noble.org/
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/
Structure Suppliers

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

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  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

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