High Tunnel Selection and Construction Considerations

By: David A. Dickey and Jason D. McAfee
Introduction

• What are high tunnels?

– High tunnels are passively heated and ventilated, plastic-covered structures that provide an intermediate level of environmental protection and control compared to open field conditions and heated greenhouses. (Source: Hightunnels.org)
# Differences between high tunnels and greenhouses

<table>
<thead>
<tr>
<th>High tunnels</th>
<th>Greenhouses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Simple-low cost structure</td>
<td>• Higher initial investment in structure, utilities and equipment</td>
</tr>
<tr>
<td>• Passively heated and ventilated</td>
<td>• Heaters, fans and cool cells</td>
</tr>
<tr>
<td>• Usually one layer of plastic</td>
<td>• Higher R-values</td>
</tr>
<tr>
<td>– Relatively low R-value</td>
<td>– Glass, multi layers of plastic with inflation</td>
</tr>
<tr>
<td>• Used for season extension</td>
<td>• Year round production</td>
</tr>
<tr>
<td>• In ground production</td>
<td>• Typically container production</td>
</tr>
<tr>
<td>• Low operating cost</td>
<td>• High energy consumption</td>
</tr>
<tr>
<td>• Site may or may not need leveling</td>
<td>• Higher maintenance operating cost</td>
</tr>
<tr>
<td></td>
<td>• Site will likely need leveling and/or construction of a pad</td>
</tr>
</tbody>
</table>
Differences between high tunnels and greenhouses

High tunnels

Greenhouses
Advantages of high tunnels relative to field production

• Season extension/off season production
• Reduced moisture on foliage from rainfall and dew
  – Lower disease potential
• Increased growth rates and production
  – Increased heat unit accumulation and retention
  – More even light distribution
  – Reduced plant stress
• Exclude insect pests and some animals
  – Plant health and food safety
• Controlled water application
• Higher quality products
Site selection considerations

• Available space (dimensions)
• Direction of prevailing winds
  – Natural and man made wind breaks?
• Sunlight and shade
  – Incidence of sun’s rays
  – Tree lines and other structure
• Soil structure
  – Rock may prevent or alter installation of ground anchors
• Consider locating tunnel over soil with adequate texture, fertility and internal drainage
Site selection considerations

• Slope and external drainage
  – Prevent water infiltration from runoff
  – Will the site need to be leveled?
  – May choose high tunnel type that follows contour of the land

• Access to water for irrigation

• Ease of access to site
  – Transporting materials to and from the tunnel
  – Access to site and inside tunnel with equipment
Site selection and preparation
Suggested tools and equipment for high tunnel construction

- Cordless screwdriver, hammer drill and bits
- Sledge hammer
- 100’ to 300’ tape measure
- String level or transit
- Ladder
- Auger
- Level
- Lift or tractor bucket
- Pry bar
- Skill saw
- Metal cut off saw
- Nylon string
- Ratchet and appropriate sockets
- Duct tape
- Bracing
- Trailer for flat work surface and bench
Components of high tunnels

- Most tunnels share three structural elements in common:
  - Steel hoops covered by greenhouse grade plastic
  - Passive ventilation through roll-up side curtains
  - Sited on field soil

http://www.hort.cornell.edu/hightunnel/structures/index.htm
High tunnel terminology

- Rib (arch)
- Perlin
- Polyester curtain cord
- Polyethylene cover
- Hip board
- Base board
Grower decisions

- Types of tunnels
  - Stationary vs. movable
  - Single bay vs. multi-bay
  - Architecture types and utility
  - Manufacturers
- Plastic
  - Advantages vs. costs of various types
- Ventilation
  - Side walls (curtains)
  - End walls
High tunnel types

- **Stationary Tunnel**
  - Fixed location
  - Long term

- **Movable Tunnel**
  - Relocate
  - Seasonal rotation considerations
High tunnel types

Quonset (hoop-house) tunnels

- Single bay (structure is a single component)
- Composed of rounded steel arches that create a single bay that range 12-40 feet wide
- Arches are 11-12 gauge steel spaced 4-6 feet apart
- Two types of arches:
  1. Arches beginning at ground level give the tunnel a rounded structure
  2. Or the arches can sit upon straight, 4-6 foot-tall sidewalls
     - Add height and allow taller crops to be grown in the rows along the walls

http://www.hort.cornell.edu/hightunnel/structures/index.htm
High tunnel types

Gothic style tunnels

• Single bay
• Have peaked roofs
  – steeper roofs help manage snow loads
• Gothic high tunnels tend to be taller than hoop-house tunnels
  – creates a more stable temperature regime during warmer months
• Require additional bracing (purlins) to withstand winds
High tunnel types

- **Multi-bay**
  - Used to cover larger acreages
  - Consist of several spans of arches connected by gutters at the roof seams
  - Do not have purlins or braces and are not designed to withstand snow loads or high winds
  - Require removal of plastic during potential wind storms and offseason during periods of snow
  - Popular in Europe and California
  - Tall enough to cover fruit trees
  - Accommodate tractors and other large equipment

http://www.hort.cornell.edu/hightunnel/structures/index.htm
http://farmtek.wordpress.com/2012/03/15/you-should-own-a-hi-tunnel/
http://www.tunneltech.ca/
Pros and cons of high tunnel architectures

• Quonset
  – Rounded roofline of these structures provides more surface area for snow accumulation
  – Provide less space utility for using heavy equipment (tractors) and growing crops next to side walls
  – Least expensive

• Gothic
  – Taller structure provides more surface area for wind related damage but steeper roof orientation makes it easier to handle snow loads
  – Vertical arches on sides allow more space utility for using heavy equipment and growing crops next to side walls
  – More costly than quonset tunnels

• Multi-bay
  – Best for large scale production especially tree fruits
  – Provide good space utility and ease of access for heavy equipment
  – Plastic roof cannot be left on year round
  – Expensive
What should you choose?

Considerations:

• **Size**
  – Narrower tunnels are easier it is to ventilate
  – A tunnel >30 feet wide may not have optimal lateral airflow for cooling
  – Taller, wider tunnels are more efficient at holding accumulated heat

• **Trellising**
  – Both single bay types (gothic and quonset) allow for vertical trellising (indeterminate tomatoes, cucumbers)
  – Multi-bay tunnels are better suited for crops that can be horizontally trellised (determinate tomatoes, peppers) or crops that need no trellis (strawberries)

• **Snow load/wind**
  – Gothic types are best for withstand snow loads and wind compared to multi-bay tunnels

• **Mobility**
  – In-ground posts make stationary tunnels harder to move
  – Movable tunnels can be relocated to fresh soil annually
  – Crops can benefit from soil health and reduced disease and pests
  – However, movable tunnels carry greater risk of wind damage

http://www.hort.cornell.edu/hightunnel/structures/index.htm
What type of material should you use for the roof?

- Four to six mil, 4-year, greenhouse-grade polyethylene is suitable plastic for covering a high tunnel.
- Infrared light additives provide excellent diffusion and absorb and re-radiate infrared heat back down to the crop during the evening hours.
- Different types:
  - Standard types can range in light transmission 80-90%.
  - Anti-condensate film is ideal for preventing water droplets from dropping on plants:
    - Drip control additive is incorporated throughout the film.
    - Prevents water droplets from falling on plants (disease).
Spring frosts by region

One single layer of poly provides one hardiness zone of protection
High tunnel temperature control

• When to warm?
  – Evening until morning

• When to cool?
  – Morning until evening

• Why?

• Natural ventilation is BETTER

• Roll-up and drop down side wall systems SAVE MONEY
  – Temperature inside the structure can be maintained within a degree or two of outside during the warm season
  – Natural ventilation provides uniform temperature throughout the high tunnel
  – Opening the sidewall allows easy accessibility for moving plants into or out of the high tunnel

http://www.extension.org/pages/27782/natural-ventilation-in-high-tunnels
Ventilation

• Manually rolled side walls
  – Time consuming
  – Labor intensive
  – Inexpensive
  – Cost vs. time
Ventilation

Roll-up side walls

- Plastic is attached to a piece of steel tubing with clips
- To open the vent, the tubing is rolled up with a hand crank
- Opening the vent introduces cool air at the bottom or ground level of the tunnel
- Roll up side walls save time compared to manual system

http://www.growerssupply.com/farm/supplies/cat;10551;gs1_vent_openers_1;gs1_side_wall_curtain.html
Raising and lowering side walls

Drop-Down side walls

- Introduces cool air at the top of the curtain
- Allows it to mix with warm air and moderate before reaching the plants
- Bottom of the curtain wall material is attached to the baseboard and the top is attached to the steel tubing
- System of cables and pulleys attached to a manual winch is used to raise and lower curtain
- Curtain material can be a 4-year copolymer film or it can be a heavier material such as a reinforced polyethylene or polyvinyl
- Similar to ventilation curtains attached to poultry houses
- Roll up side walls save time compared to manual system

http://www.extension.org/pages/27782/natural-ventilation-in-high-tunnels
Raising and lowering side walls

- Manual - pushing the curtain up and lowering by hand
- Drop down system
End walls
End wall considerations

• Ease of access
  – Will heavy equipment be used?

• Type of material used
  – How long will it last?
  – Cost to replace

• Movable tunnel?

• Modifications may be necessary to suit your needs
Economic considerations for selecting high tunnels

*Pay for the tunnel fitting your **specific** production goals, management style and resources……..Consider….

- Crop type(s) and their management requirements
- Space requirement of crop (*Ex. Strawberries Vs. Cherries*)
  - Dimensions \((L \times W \times H)\)
  - *Do you need a 15’ high tunnel for lettuce and strawberries?*
- If trellising is secured to frame extra hardware and/or stronger structure may be required (*Ex. Tomatoes and Cucumbers*)
- Space available at site (may limit size of tunnel)
- Topography of the ground
  - Some models need relatively flat surface while others can follow contour of the land
- Will equipment be used in the tunnel?
  - May determine tunnel height, end wall/door type and side wall height
Economic considerations for selecting high tunnels

• Structural integrity of the tunnel structure and design as related to weather extremes
  – Wind and snow?
• Will customizations and extra material be needed?
  – These will likely add cost
  – Many tunnel kits require outside purchase of base board and end wall materials
• Cost of the tunnel and availability of funds for purchase
• Reasonable expectation of return over time
  – When will the “operation” break even?
• Construction labor costs are variable
  – Dependent on your experience
  – Size and complexity of the tunnel
  – Anchoring system and soil structure
  – Equipment available to aid in construction
Economic considerations for selecting high tunnels

Important: *Think of the tunnel expense(s) and revenue in terms of dollars per square foot under cover*

- Must manage to make best economic use of limited amount of space
- Rule of thumb: *Tunnel cost per square foot decreases as covered area increases*
  - Spread “fixed” costs over a larger area
    - Ex. End walls and doors
    - Extra height may cost more
# Economic considerations for selecting high tunnels

## Cost per Square Foot of High Tunnel Kits from Three Different Companies

<table>
<thead>
<tr>
<th>Tunnel Brand/Model</th>
<th>Farmtek Round Style (Premium)</th>
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<th>Farmtek Round Style (Premium)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td>20'W x 12'H x 24'L</td>
<td>20'W x 12'H x 96'L</td>
<td>30'W x 12'H x 96'L</td>
</tr>
<tr>
<td><strong>Square Footage</strong></td>
<td>480</td>
<td>1920</td>
<td>2880</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>$2,809.65</td>
<td>$6,935.60</td>
<td>$8,121.64</td>
</tr>
<tr>
<td><strong>Cost per Square Foot</strong></td>
<td>$5.85</td>
<td>$3.61</td>
<td>$2.82</td>
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</table>

<table>
<thead>
<tr>
<th>Tunnel Brand/Model</th>
<th>Farmtek Round Style (Economy)</th>
<th>Farmtek Round Style (Economy)</th>
<th>Farmtek Round Style (Economy)</th>
</tr>
</thead>
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<td><strong>Dimensions</strong></td>
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<td>1920</td>
<td>2880</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>$2,421.60</td>
<td>$5,919.09</td>
<td>$7,123.46</td>
</tr>
<tr>
<td><strong>Cost per Square Foot</strong></td>
<td>$5.05</td>
<td>$3.08</td>
<td>$2.47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tunnel Brand/Model</th>
<th>Haygrove Super Solo</th>
<th>Haygrove Multi-Bay</th>
<th>Haygrove Multi-Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td>25 x 200</td>
<td>3 Bays 24 x 303 (.5 Acre)</td>
<td>15 Bays 24 x 303 (2.5 Acre)</td>
</tr>
<tr>
<td><strong>Square Footage</strong></td>
<td>5000</td>
<td>21816</td>
<td>109080</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>$10,293.38</td>
<td>$20,900.00</td>
<td>$75,304.02</td>
</tr>
<tr>
<td><strong>Cost per Square Foot</strong></td>
<td>$2.06</td>
<td>$0.96</td>
<td>$0.69</td>
</tr>
</tbody>
</table>

*Does not include labor cost.*
Economic considerations for selecting high tunnels

**Business planning by the square foot**

**Scenario:** Off season strawberry production under a Haygrove Super Solo High Tunnel (25 x 200)
Plant September 1. Harvest November through May.

**Assumptions:**
- 1900 strawberry plants.
- 5000 square feet covered area.
- Tunnel cost per square foot: $-2.06
- Cost of production per square foot: $0.71
- Season 1 tunnel + production cost per square foot: $2.77
- Average yield per plant: 1.5 lbs.
- Average price per lb.: $3.00

**Calculate:**
- Season 1 gross return per square foot: $1.77
- Season 1 profit per square foot: (-$1.00)
- Season 2 carry over expense per square foot: $1.00

<table>
<thead>
<tr>
<th>Price Per lb.</th>
<th>Yield Per Plant (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>$1.00</td>
<td>$0.19</td>
</tr>
<tr>
<td>$1.50</td>
<td>$0.29</td>
</tr>
<tr>
<td>$2.00</td>
<td>$0.38</td>
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<tr>
<td>$2.50</td>
<td>$0.48</td>
</tr>
<tr>
<td>$3.00</td>
<td>$0.57</td>
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<tr>
<td>$3.50</td>
<td>$0.67</td>
</tr>
<tr>
<td>$4.00</td>
<td>$0.76</td>
</tr>
<tr>
<td>$4.50</td>
<td>$0.86</td>
</tr>
<tr>
<td>$5.00</td>
<td>$0.95</td>
</tr>
<tr>
<td>$5.50</td>
<td>$1.05</td>
</tr>
<tr>
<td>$6.00</td>
<td>$1.14</td>
</tr>
</tbody>
</table>

First season profitability range

**Season 2 carry over expense per square foot**: $1.00

**Season 1 yield/square foot**

<table>
<thead>
<tr>
<th>Price Per lb.</th>
<th>Yield Per Plant (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.00</td>
<td>$0.19</td>
</tr>
<tr>
<td>$1.50</td>
<td>$0.29</td>
</tr>
<tr>
<td>$2.00</td>
<td>$0.38</td>
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</tbody>
</table>

**Season 1 gross return per square foot**: $1.77

**Season 1 profit per square foot**: (-$1.00)
Economic considerations for selecting high tunnels

Business planning by the square foot

Scenario: Off season strawberry production under a Haygrove Super Solo High Tunnel (25 x 200)
Plant September 1. Harvest November through May.

Assumptions:
- 1900 strawberry plants.
- 5000 square feet covered area.
- Carry over tunnel cost per square foot - $1.00
- Cost of production per square foot - $0.80
- Season 2 tunnel + production cost per square foot - $1.80
- Average yield per plant - 2.0 lbs.
- Average price per lb. - $3.00

Calculate:
- Season 2 gross return per square foot - $2.28
- Season 2 profit per square foot - $0.48

<table>
<thead>
<tr>
<th>Price Per lb.</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.00</td>
<td>$0.19</td>
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<td>$0.57</td>
<td>$0.76</td>
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<td>$1.33</td>
<td>$2.00</td>
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<td>$3.42</td>
<td>$4.56</td>
</tr>
</tbody>
</table>

Season 2 profitability range

$ Yield/Square Foot
Conclusions

- Evaluate tunnel costs and revenue by the square foot
- Consider crop type(s), management and revenue potential when selecting tunnels and accessories
- Remember high tunnels are not greenhouses
- Natural Resource Conservation Service (NRCS) has a program available 2013
  - Allows growers to apply for cost-share of high tunnels
  - Must meet requirements (no guarantee)
- Structural integrity
  - Snow and wind
- Consider insuring your structure
  - Why?
When disaster strikes!

http://3x5aquaponics.blogspot.com/2011/02/poor-mans-greenhouse-aka-high-tunnel.html

http://www.extension.org/pages/18358/introduction-to-high-tunnels

http://3x5aquaponics.blogspot.com/2011/02/poor-mans-greenhouse-aka-high-tunnel.html
Manufacturers

Ledgewood Farm Greenhouse Frames
Rte 171
Moultonboro, NH 03254
603-476-8829

Rimol Greenhouse Systems Inc.
Northpoint Industrial Park
40 Londonderry Turnpike
Hooksett, NH 03106
877-746-6544

Greenhouse Supply Inc.
12 Acme Road, Suite 212
Brewer, ME 04412
800-696-8511

Haygrove Tunnels
694 Kraybill Church Road
Mount Joy, PA 17552
1-866-HAYGROVE
717-492-4955
harry.edwards@haygrove.com

Farm Tek
1440 Field of Dreams Way
Dyersville, IA 52040
1-800-327-6835

Walker Bros., Inc.
105 Porchtown Rd
Pittsgrove NJ,08318
856-358-6493

Tunnel Tech
1925 Windham Rd. 19
La Salette, Ontario N0E 1H0
519-582-4424

Four Season Tools
9615 Grand View Rd.
Kansas City, MO 64137
816-444-7330
steve@smallfarmtools.com

Other high tunnel suppliers
M. Leonard (Piqua, Ohio)
Atlas Greenhouse Systems, Inc. (Alapaha, Georgia)
Conley’s Greenhouse Mfg. (Montclair, California)
CropKing, Inc. (Seville, Ohio)
GothicArch Greenhouses (Mobile, Alabama)
Grow-It Greenhouse (West Haven, Connecticut)
Hoop House Greenhouse Kits (Mashpee, Massachusetts)
Hummert International (Earth City, Missouri)
International Greenhouse Company (Georgetown, Illinois)
Jaderloon (Irmo, South Carolina)
Keeler Glasgow (Hartford, Michigan)
Ludy Greenhouses (New Madison, Ohio)
Poly-Tex Inc. (Castlerock, Minnesota)
Speedling Inc. (Sun City, Florida)
Stuppy Greenhouse Mfg. (Kansas City, Missouri)
Turner Greenhouses (Goldsboro, North Carolina)
XS Smith (Eatontown, New Jersey)
Zimmerman’s Welding (Versailles, Missouri) 573-378-4770