

Year-Round Production: See the Light at the End of the (High and Low) Tunnel

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Why would I want to extend my season?

- Year-round income
- Higher yields
- Higher quality
- Higher prices
- Keep workers employed
- Local foods



Why might I not want to extend my season?

- NO vacation...
Year-round work
- Increased management
- Higher production costs to start
- Plastic disposal issues



How can I extend my season?

- Plastic mulch
- **Row covers/low tunnels**
- **High tunnels or hoop houses**

Advantages of Row Covers

- Protect plants from frost
- Protect plants from drying wind
- Protects plants from insects
- Enhance early maturity
- Increase early yield
- Improve quality

Types of Row Covers

1. Floating covers

- Made of spun-bounded polyester and spun-bounded polypropylene
- So lightweight they 'float'

2. Hoop-supported covers (low tunnels)

- Made of clear or white polyethylene
- Too heavy to 'float', supported

Floating Row Covers

- Vary in weight (0.3-2 ounces/square yard)
- The heavier the cover, the greater the frost protection
- Sizes range from widths of 3-60' and lengths of 20-2550'
- Larger covers = More labor efficient
- Durability related to weight and material



Lightest Covers

- Used as insect barriers
- Exclude egg-laying moths on Cole crops
- Exclude flea beetles on eggplant & radish
- Can prevent viruses spread by insects
- Easily damaged, not reusable, nearly no effect on temperature

Medium-weight Covers

- Most common
- Used to enhance maturity, improve quality and yield
- Also insect barrier
- Used on:
 - Melons
 - Lettuce
 - Squash
 - Potatoes
 - Peas
 - Carrots
 - Radishes
 - Cut flowers
 - Cucumbers
 - Raspberries
 - Strawberries
 - Sweet corn

Heavier-weight Covers

- Greater than 1 oz/sq. yard
- Used mainly for frost and freeze protection
- Also when extra durability required
- Can be re-used for 3-4 or more seasons

Row Cover Installation

- Manually or mechanically
- Lay immediately after transplanting or seeding
- Weigh down or bury edges
- Allow enough slack in cover for crop to grow
- Weed control can be a huge problem- use with plastic or other mulches

Pollination



- Self-pollinating (leafy) crops can remain covered most of season
- Row covers can increase the temp too much ($> 86^{\circ}$ F for > 3 hours) for tomatoes & peppers \rightarrow blossom drop
- Cover must be removed at flowering for insect pollinated crops (squash, cucs, melons); like hardening-off

Hoop-Supported Row Covers

- Structure usually 14-18” high and wide enough to cover 1 bed
- Commonly used with black plastic
- Not permeable to air and water
- More labor intensive
- Types of low tunnels:
 - Slitted row covers
 - Punched row covers
 - Teepee-like row covers



Slitted Row Covers

- Pre-cut slits for hot air to escape
- Slits remain closed at night to prevent heat loss



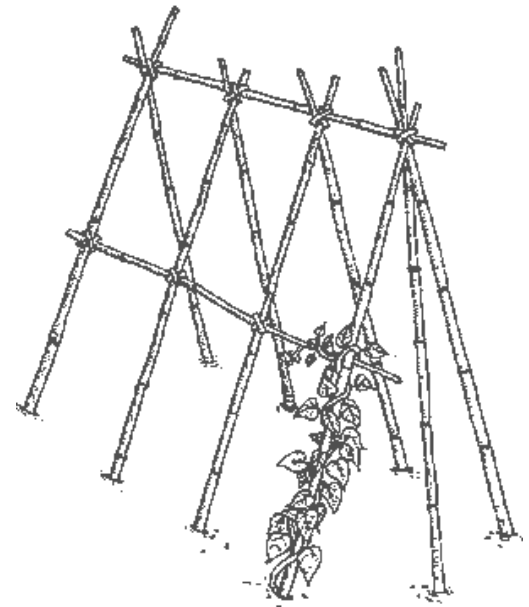
Photo courtesy of ATTRA.

Punched Row Covers

- Small holes punched ~ 4" apart to ventilate
- Retain more heat than slitted covers
- Best for northern areas
- Must be carefully monitored to avoid overheating
- Used for peppers, tomatoes, eggplant, most cucurbits

Teepee-like Row Covers

- Use two 3'-wide plastic sheets, stapled together at top
- Common for trellised crops
 - Cherry tomatoes
 - Long beans
 - Bitter melons
- More expensive
- Most work done



Survival of Cool Season Crops

Very Hardy	Hardy	Semi-Hardy
Leeks (5-20 °F)	Cabbage (12-20 °F)	Lettuce (20-25 °F)
Parsnips (tops 15 °F, roots 0 °F)	Broccoli (18-22 °F)	Cauliflower (25-28 °F)
Spinach (8-12 °F)	Brussels Sprouts (15-20 °F)	Carrots (tops 10 °F, roots 30 °F)
	Rutabaga (10-15 °F)	Beets, Chard (15-25 °F)
	Kale (10-15 °F)	Peas (15-25 °F)
	Mustard (10-15 °F)	

From 'Season Extension'
by Debbie Roos and
Doug Jones

High Tunnels or Hoophouses

- An arched frame covered with clear plastic
- High enough to stand in or drive tractor through
- Solar heated, no heating costs
- Crops grown in ground with drip irrigation
- Range in price from \$1.50-\$3.00 or less per square foot
- Some growers say structures pay for themselves in one season, others 2-3

Features of High Tunnels

(depending on the model)

- **Tractors can be driven through them**
- **Can be moved from field to field**
- **Can be fully opened on hot days**
- **Can be completely closed on cool days early or late in the season**



Photos courtesy of Haygrove Tunnels.

Features of High Tunnels

(ALL models)

- Produce higher quality crops than those grown in the field
- Produce crops earlier → hit market when prices are high
- Allow production of certain crops year-round



Photo courtesy of Matt Kleinhenz,
The Ohio State University.

Caveats:

- While tunnels provide *some* protection from low temps, do not protect against frost like greenhouses do
- Generally allow planting 3 weeks earlier than outdoor planting of warm season crops
- Also, extend season ~4 weeks in Fall

Location and Site Preparation

- Locate near house (short walk on cold day)
- Level ground from side to side
(no more than 3% slope from end to end)
- Make sure drainage is good
- Avoid wet, shady areas, and obstructions to ventilation

Advice from Alison and Paul Wiediger, Au Naturel Farm, KY. They grow winter vegetables in 8,500 square feet of tunnels.

Orientation

- Orient your house to capture the most light in the winter
- For locations south of 40° latitude, the ridge should run N to S
- Dr. Lewis Jett, West Virginia University, says tunnels should be oriented perpendicular to the prevailing winds
 - Sunlight is less important than ventilation

Design and Construction

- There are many resources to help with the design and construction (see 'Resources')
- Most designs use heavy-gauge galvanized metal bows attached to metal posts driven into the ground 4-6' apart
- Strength is important
- The most critical components for strength are the end walls

End Wall Design

- End walls with:
 - Wood end-posts from two 2- by 6” boards
 - Corrugated fiberglass panels for end-wall glazing
 - Industrial steel frame doors with heavy-duty latches
- Have proven long-lasting for the Noble Foundation

Covering

- 6-mil greenhouse grade, UV-treated polyethylene most economical (will last 3-5 years)
- Do NOT use plastic that is not UV-treated (will fall apart in half a season)
- Roll-up sides allow for easy, effective ventilation
- Tape plastic to 1" pipe that runs length of tunnel
- A sliding "T" handle is attached to the edge of the pipe so plastic can be rolled to hip board
- Camlocks to hold plastic in place



Photos courtesy of Matt Kleinhenz,
The Ohio State University.

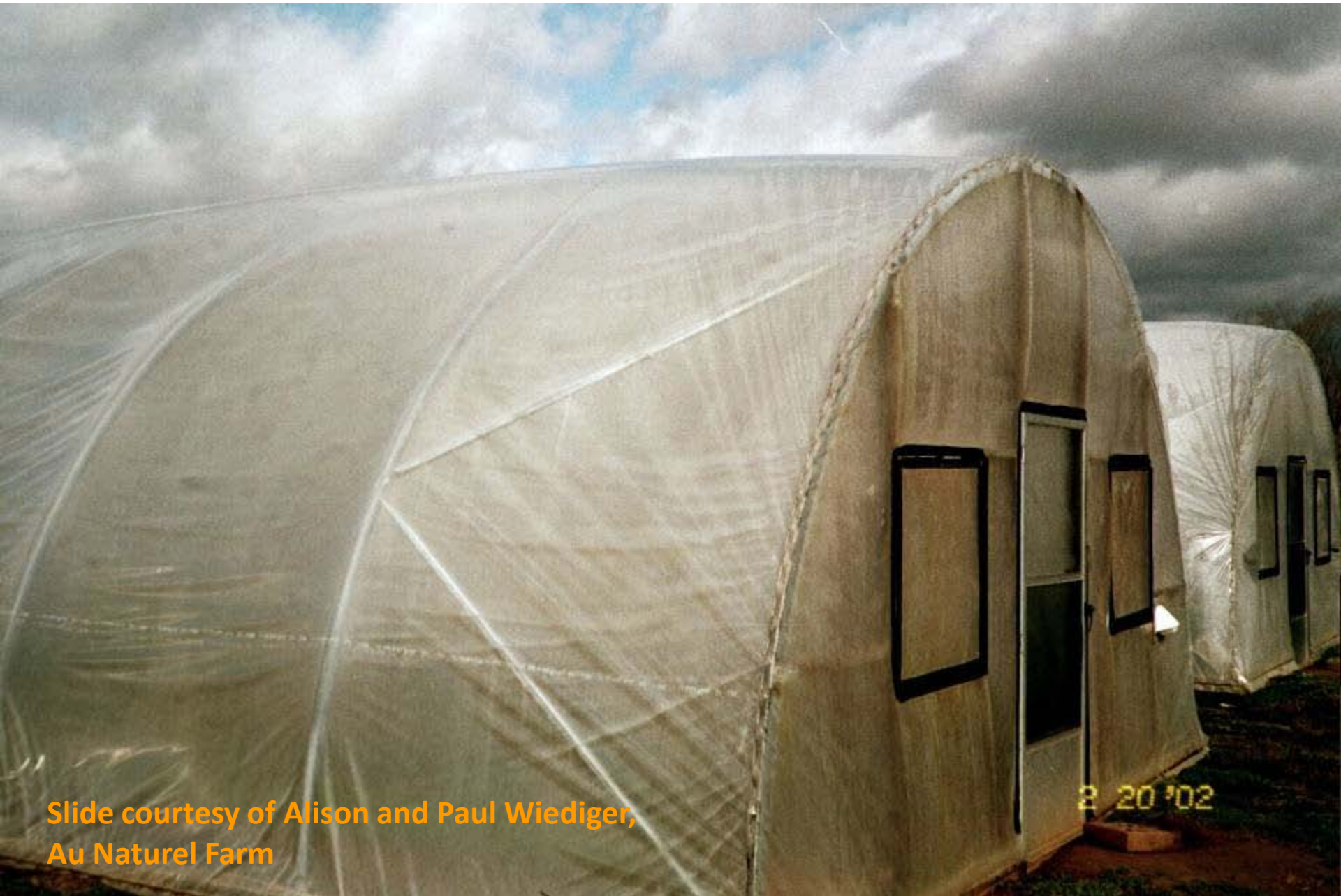




UT High Tunnels

Roll Up Sides





Slide courtesy of Alison and Paul Wiediger,
Au Naturel Farm

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Irrigation

- Essential!
- Can be by hand, by drip or by overhead emitters
- Drip irrigation:
 - Uses water & fertilizer efficiently
 - Reduces weed competition
 - Can work in tunnel while irrigating
 - Decreases disease potential



Photo courtesy of Matt Kleinhenz, OSU.

Floor Covering

- A sheet of landscape fabric or 6-mil black plastic can:
 - Warm the soil
 - Control weeds
 - Reduce loss of soil moisture
 - Acts as barrier against diseases from soil splash



Photo courtesy of Anthony Carver,
Grainger Co. Extension.

Temperature Management

- Critical to success
- Sides must be rolled up on sunny mornings to prevent rapid temperature rise
- On cloudy days, rolling up sides can reduce humidity- disease pressure
- Rolling down sides at night conserves heat
- 20' x 96' common size
- Allows for efficient heating/cooling

Advice from Growers

- The Wiediger's use a 20' x 96' high tunnel plus two 21' x 60' tunnels
- They suggest: Build as large a structure as is practical
- Larger structure = More heat retained inside (air & soil)
- Plants close to walls do not grow as well as plants further away
- Larger tunnel = More interior space
- They use double layer of 6-mil, 4-yr poly for cover & small fan to blow air between layers

Show Me the Money!

- Lynn Byczynski & Dan Nagengast, Wild Onion Farm, grow vegetables & flowers in Kansas
- Built 5 hoophouses, 20' x 96' each
- Purchased Polar Cub cold frames from Stuppy Greenhouse Co.
- Cost for 2 houses \$3,250 (includes metal frames, 4-year poly covering, wiggle wire to attach to frame + shipping)
- Lumber for roll-up sides and end-walls \$1,600
- Bulldozing and laser leveling site \$300
- Grand total: \$5,150

**In the first year, the
hoophouses
produced TWICE
what they cost.**

Hoophouse Production at Wild Onion Farm

Crop	Date Planted	Dates Harvested	Revenue/ft ²
<i>Fall Planted</i>			
Delphinium	9/28/00	4/26-7/26/01	\$2.67
Dianthus	9/25/00	4/24-6/1/01	\$5.05
Larkspur	10/7/00	5/2-6/10/01	\$3.25
Arugula	9/27/00	fall, spring	\$1.31
Cilantro	9/27/00	fall, spring	\$0.95
Chinese cabbage	9/27/00	fall	\$1.11
Green onions	9/27/00	fall	\$0.61
Leeks	9/27/00	spring	\$1.10
Lettuce	9/27/00	fall, spring	\$0.40
Mizuna	9/27/00	spring	\$0.69
<i>Spring Planted</i>			
Stock	3/21/00	5/18-5/30/00	\$1.92
Campanual	4/1/01	6/3-6/30/01	\$3.62
Lisianthus	4/12/00	6/26-10/8/00	\$3.32
Cucumbers	4/12/00	summer	\$1.34
Tomatoes	4/12/00	summer, fall	\$3.55



Year-round High Tunnel Production with Cool Season Crops

Cool Season Crops Project

- Conducted fall/winter 2008-2009
- 3 varieties of 11 crops grown in high tunnels and in low tunnels, replicated 3 times
- Growth measurements and harvest data were collected
- Experiment started 28-Oct-08, ended 13-Mar-09

Cool Season Crop Varieties

- Broccoli:

- ‘DeCicco’
- ‘Waltham’
- ‘Belstar’



- Spinach:

- ‘Butterflay’
- ‘Bloomsdale’
- ‘Matador’



- Kale:

- ‘Lacinato’
- ‘Red Russian’
- ‘True Siberian’



- Lettuce:

- ‘Kweik’
- ‘Winter Density’
- ‘Brune D’Hiver’
- ‘Ruben’s Red Romaine’
- ‘Drunken Woman Frizzy Headed’
- ‘Red Oakleaf’



- Swiss chard:

- ‘Chadwick’s Choice’
- ‘Glattersilber’



Cool Season Crop Varieties

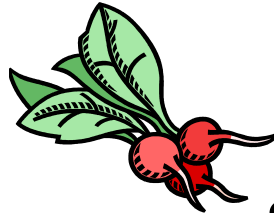
- Leeks:

- ‘Varna’
- ‘Longfall’
- ‘Blaugruner’



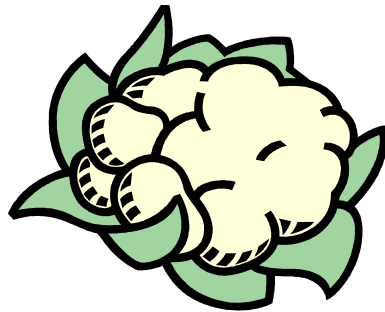
- Radish:

- ‘Round Black Spanish’
- ‘Cherry Belle’
- ‘Miyashige White Daikon’



- Cauliflower:

- ‘Graffiti’
- ‘Odysseus’
- ‘Cassius’

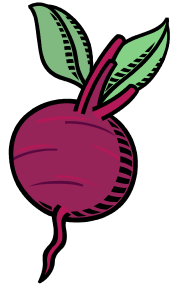


- Kohlrabi:

- ‘Dyna’
- ‘Kolibri’
- ‘Superschmelz’

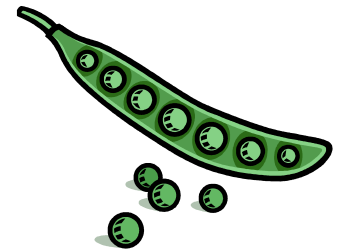
- Beets:

- ‘Moneta’
- ‘Golden Detroit’
- ‘Chioggia’



- Sweet peas:

- ‘Mammoth Melting’
- ‘Cascadia’
- ‘Sugarsnap’



Cool Season Crop Varieties

- Carrots:
 - ‘Red Core Chantenay’
 - ‘St. Valery’
 - ‘Oxheart’
- Onions:
 - ‘Mini Purplette’
 - ‘Evergreen’
 - ‘Parade’





Results

- Soil temperatures in high tunnels were 5-10 degrees warmer than in low tunnels
- High tunnel crops out-performed those in low tunnels—no plants in low tunnels were harvested
- Crops that performed well were kale, leeks, spinach, radish and lettuces
- Crops that did not perform well were sweet peas, broccoli, cauliflower, beets, carrots, onions



Lessons Learned

- Harvest times are lengthened in high tunnels over winter
- Timing is key: plant late-maturing crops and transplants earlier
- Keeping high tunnels air-tight is important
- Also, cover inside with row cover on below-freezing days

What's growing in January, 2008



Slide courtesy of Alison and Paul Wiediger,
Au Naturel Farm



**Outside temperature,
about 14 degrees,
January 27, 2000.**

**Slide courtesy of Alison and Paul Wiediger,
Au Naturel Farm**



Frozen front of the coldframe, January 27, 2000.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



8:00 AM, and the inside temperature is about 22. As you can see, the young lettuce transplants as well as the kale look terrible.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



This red oakleaf lettuce is also frozen.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



**The same kale
an hour later,
and the
temperature
has risen to
about 32
degrees.**

**Slide courtesy of Alison and Paul Wiediger,
Au Naturel Farm**

**The Oak Leaf
lettuce at 9:00,
well on its way
to recovery.**



**Slide courtesy of Alison and Paul Wiediger,
Au Naturel Farm**



10:00 AM, 50 degrees, and mostly recovered.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



Here's that red oakleaf lettuce at the same time.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



2:00 PM, 80 degrees and everything totally recovered.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm



But outside, it's still really cold – about 19 degrees. The heat gain from the sun, and the ability of the plants to recover always amazes us – it's always a miracle.

Slide courtesy of Alison and Paul Wiediger, Au Naturel Farm

Other Types of Tunnels

- Haygrove tunnels
- Moveable tunnels

Haygrove Multibay Tunnel System

- Growers covering whole fields
- Protect high value crops from early & late frost, heavy rain, wind, hail and disease
- Frames also provide support for shade cloth and bird netting

Haygrove Tunnels

- Company founded in England in 1988 with ~ 2 acres of strawberries in hoophouses
- By 2002, expanded to nearly 250 acres of soft fruits, including:
 - Strawberries
 - Blackberries
 - Red currants
 - Cherries

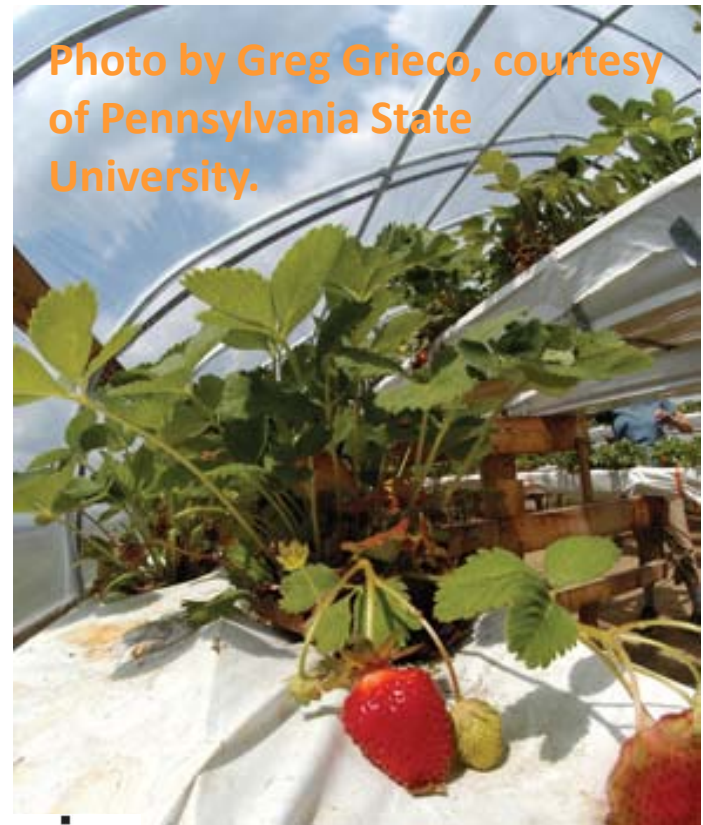


Photo by Greg Grieco, courtesy of Pennsylvania State University.

Haygrove Tunnel Dimensions

- Tunnels from 18-28' wide per bay, with 3 bay minimum
- No walls between bays
- No limit for length
- Tunnels from 65' to 1100'
- Used to cover from 1/3-100 acres of CA blueberries
- Can be built on slopes



Photo courtesy of Agri-Food Canada.

Haygrove Tunnel Costs and Returns

- One acre = $\$0.55/\text{ft}^2 = \$24,000/\text{acre}$
- NC growers, Alex and Betsy Hitt, covered two $\frac{1}{4}$ acre blocks with Haygrove Tunnels
- One block planted in heirloom tomatoes
- Traditionally field crop has severe foliar disease → Pick for 5 weeks, then dead
- In Haygroves, picked same # of plants for 10 weeks → Increased profits by 35%

Berry Returns

Strawberries	Outdoor	Tunnels
Total yield/acre	8.1 tons	9.5 tons
Class #1	73%	87%
Picking Date		20% → 2 weeks earlier

Raspberries	Outdoor	Tunnels
Total yield/acre	4.1 tons	5.1 tons
Class #1	90%	97%
Picking Date		20% → 2 weeks earlier

Source: Haygrove Tunnel Co. data

Cherries



Sugar Snaps



Plums

Caveat:

- Haygrove Tunnels not designed to carry a snow load
- Designed as temporary low-cost structures
- Can be moved with the crop

Moveable Tunnels

- Maximize space and time
- Reduces build-up of pests, diseases and excess soil nutrients
- Allow additional rotation options



Moveable Tunnels

- Many different designs
- Read more:
The Winter Harvest Handbook
- Local Resource:
Bountiful Blessings Farm
<http://bountifulblessingsfarm.com/>

This presentation was adapted from the publication ‘Season Extension Techniques for Market Gardeners’ by ATTRA (<http://attra.ncat.org/attra-pub/seasonext.html>) and the Haygrove Tunnels presentation ‘Low Cost Field Scale Protection’.

Resources

- **General References:**

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<http://aunaturelfarm.homestead.com/>

Manufacturers and Suppliers

- **American Plant Products & Supplies**
9200 N.W. 10th
Oklahoma City, OK 73127
405-787-4833
800-522-3376
www.americanplant.com
 - *Source of greenhouse frames, films and glazing, shade cloth, row covers, mulch film.*
- **Atlas Greenhouse Systems, Inc.**
P.O. Box 558
Alapaha, GA 31622
800-346-9902 (toll-free)
service@atlasgreenhouse.com
www.AtlasGreenhouse.com
 - *Structures highly recommended by growers in the South.*
- **Haygrove Tunnels**
Ralph Cramer
116 Trail Road
North Elizabethtown, PA 17022
866-HAYGROVE (toll-free)
Ralph.cramer@haygrove.com
www.haygrove.co.uk
- **Holland Transplanter Co.**
P.O. Box 1527
Holland, MI 49422-1527
800-275-4482 (toll-free)
www.transplanter.com
 - *Manufacturer of mechanical transplanters, bed shapers, mulch layers, mulch lifters, and related equipment.*

Manufacturers and Suppliers

- Jaderloon
P.O. Box 685
Irmo, SC 29063
800-258-7171 (toll-free)
jaderloon@jaderloon.com
www.jaderloon.com
 - *Offers complete line of structures & wide selection of film fastening systems, inflation blowers, poly-carbonate sheets, & poly patch.*
- Stuppy Greenhouse Mfg.
1212 Clay
North Kansas City, MO 64116
800-733-5025 (toll-free)
greenhouse@stuppy.com
www.stuppy.com
 - *Offers a variety of both coldframes and greenhouses.*
- Johnson Nursery, Inc.
1352 Big Creek Rd.
Ellijay, GA 30536
888-276-3187 (toll-free)
706-276-3187
www.johnsonnursery.com/OrchardSupplies.htm
- Mechanical Transplanter Co.
1150 Central Ave.
Holland, MI 49423
1-800-757-5268 (toll free)
mtc@mechanicaltransplanter.com
www.mechanicaltransplanter.com/mtcontact.html
 - *Plastic mulch.*
- Griffin Greenhouse
7141 Old Rutledge Pike
Knoxville, TN 37914
865- 546-9608

**Thank you for
attending this year!**

Questions or suggestions?



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