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Acknowledgements:

Topics Covered:

I. Profitable high tunnel cropping systems
II. Temperature/Environmental management for high tunnel crop production.
III. Pest management considerations
IV. Mitigating salinity within high tunnels

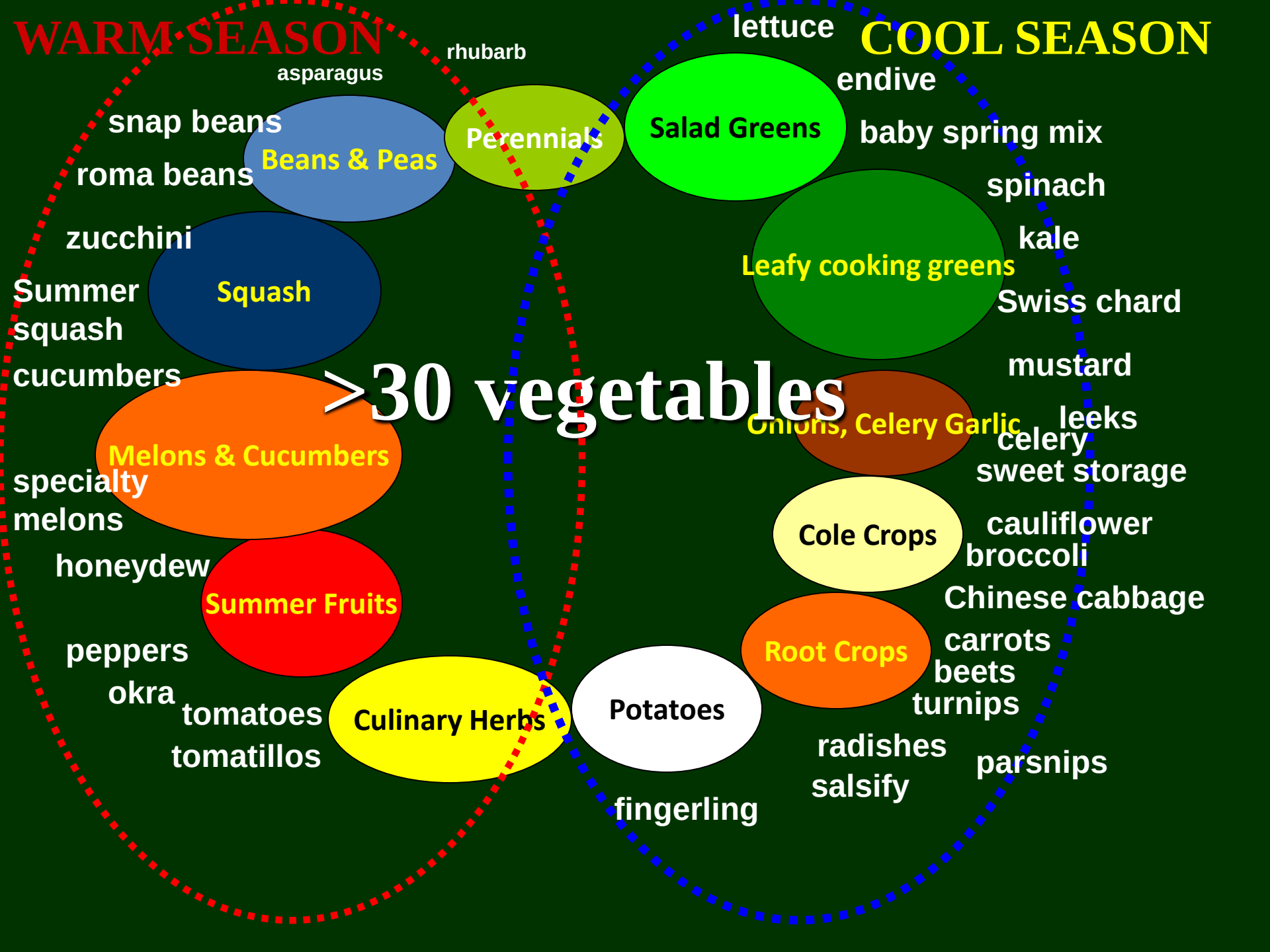
High Tunnel Cropping Systems







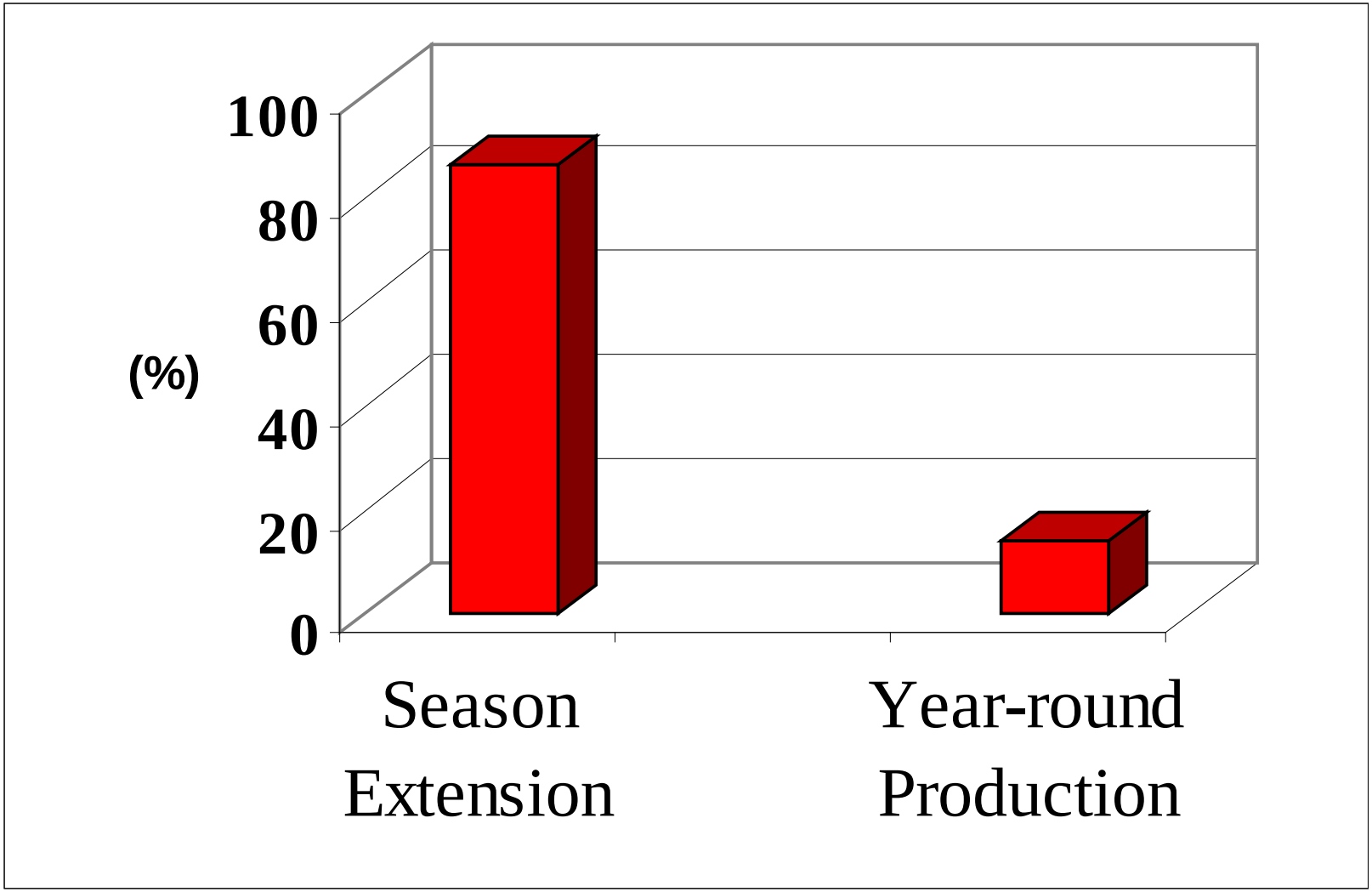

West Farms,Lewisburg, WV


WARM SEASON
COOL SEASON
>30 vegetables
rhubarb
asparagus
Perennials
snap beans
Beans & Peas
roma beans
zucchini
Summer squash
Squash
cucumbers
Melons & Cucumbers
specialty melons
honeydew
Summer Fruits
peppers
okra
tomatoes
tomatillos
Culinary Herbs
lettuce
endive
Salad Greens
baby spring mix
spinach
kale
Leafy cooking greens
Swiss chard
mustard
Onions, Celery Garlic
leeks
celery
sweet storage
Cole Crops
cauliflower
broccoli
Chinese cabbage
Root Crops
carrots
beets
turnips
radishes
parsnips
salsify
Potatoes
fingerling

Warm Season

Cool Season

Use of high tunnels in WV:




Spring


Winter


Summer


Fall


Tomatoes


Cucumbers


Leafy Greens


Peppers
(sweet)

Table 1. Summary of yield and revenue of annual high tunnel crops.

Crop	Ft^2/plant	Yield/ft^2 (lbs.)	Price/lb.	Total Revenue ($)[z]	Time (days)	$/$ft^2$/day	Rank
Beans (bush)	0.1	0.5	2.00	1800	65	28.00	10
Beets	0.2	1.25	2.50	5625	75	75.00	7
Broccoli	1.5	0.4	2.50	1800	80	21.00	14
Carrots	0.2	1.3	3.00	7020	75	94.00	6
Ch. Cabbage	1.5	2	1.65	2700	70	39.00	9
Cucumbers	4	2.5	3.00	13500	65	208.00	**1**
Eggplants	6	0.7	2.00	2520	100	25.00	11
Kale	0.6	1.0	6.00	10800	60	180.00	**2**
Lettuce	0.2	1.0	6.00	10800	65	166.00	**3**
Melons	8	1.5	0.50	1350	120	14.00	16
Peas	0.1	0.5	2.00	1800	75	24.00	12
Spinach	0.2	1.0	4.00	7200	65	111.00	**5**
Squash (Summer)	8	0.6	1.00	1080	70	15.00	15
Strawberries	2	0.8	3.00	4320	200	22.00	13
Peppers	4	2.0	1.00	3600	100	42.00	8
Tomatoes	8	2.5	2.50	11250	100	113.00	**4**

[z]Assumes 1800 ft^2 bed space within a commercial high tunnel.


4-week-old lettuce plug


Establishing crops from transplants is the most efficient method of high tunnel crop management.


High Tunnel Tomatoes
Indeterminate tomatoes


Determinate tomatoes

High Tunnel Tomatoes

- Average high tunnel yields plant^{-1}
- Recommended varieties
- Common physiological disorders
- Common pest problems
- Best Management Practices for irrigation and fertilization


Average yields:
15-30 lbs/plant

High Tunnel Tomatoes

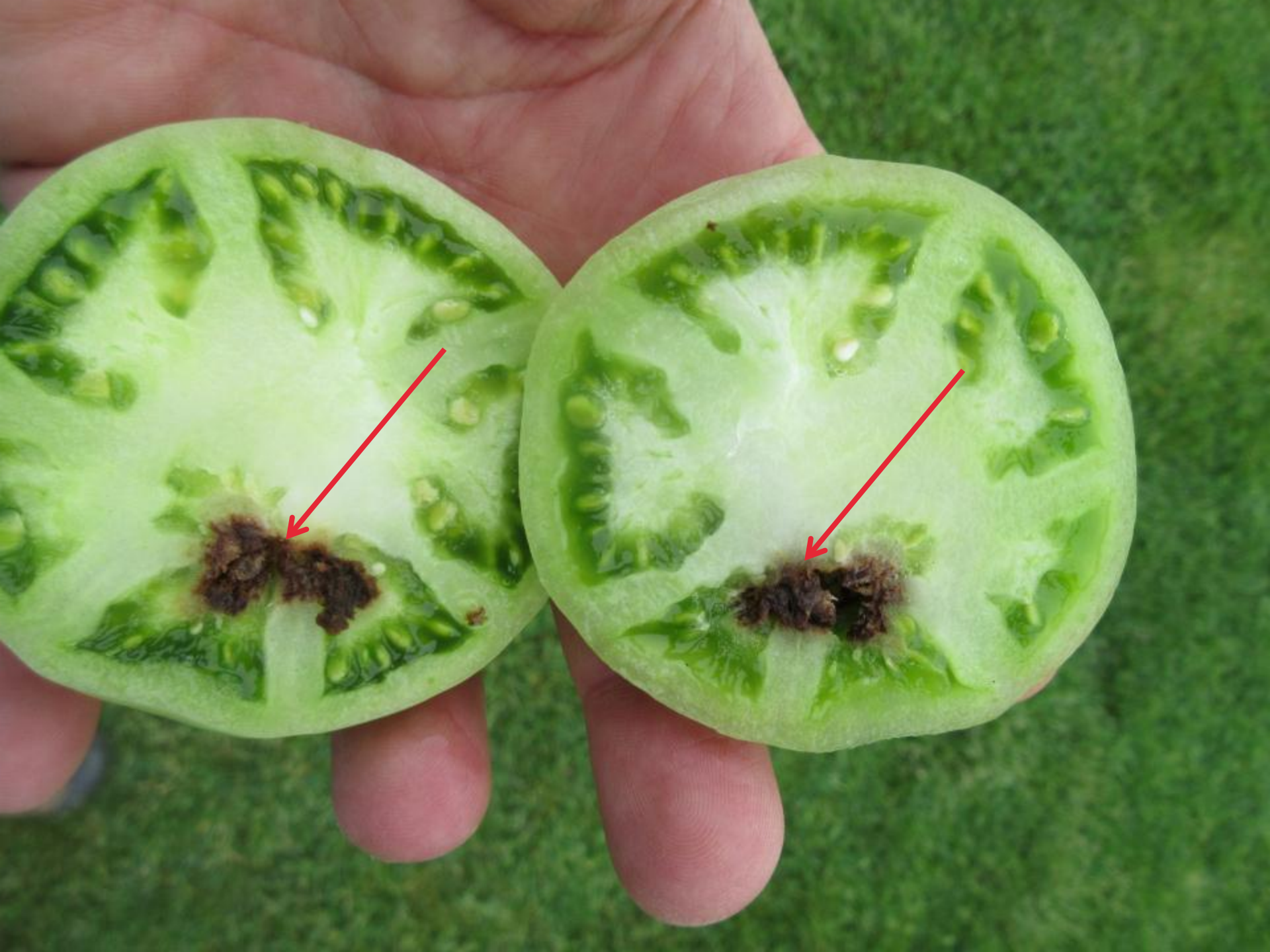
- High nutrient requirements
- High water requirement
- Temperature sensitive

Common High Tunnel Tomato Varieties:

- Celebrity
- Floralina
- Brandy Boy
- Big Beef
- Big Dena
- BHN 589
- Scarlet Red
- Red Deuce
- Rocky Top
- Trust
- Florida 91 (heat-set)
- Mt. Fresh (+)
- Skyway 687
- Cayman
- Fabulous
- Carolina Gold
- Pik Rite
- Ultra Sweet (indeterminate)
- Sweet Olive (grape)
- Sun Gold (cherry)
- Heirlooms (many!)


blossom end rot: Tomatoes

blossom end rot: Peppers

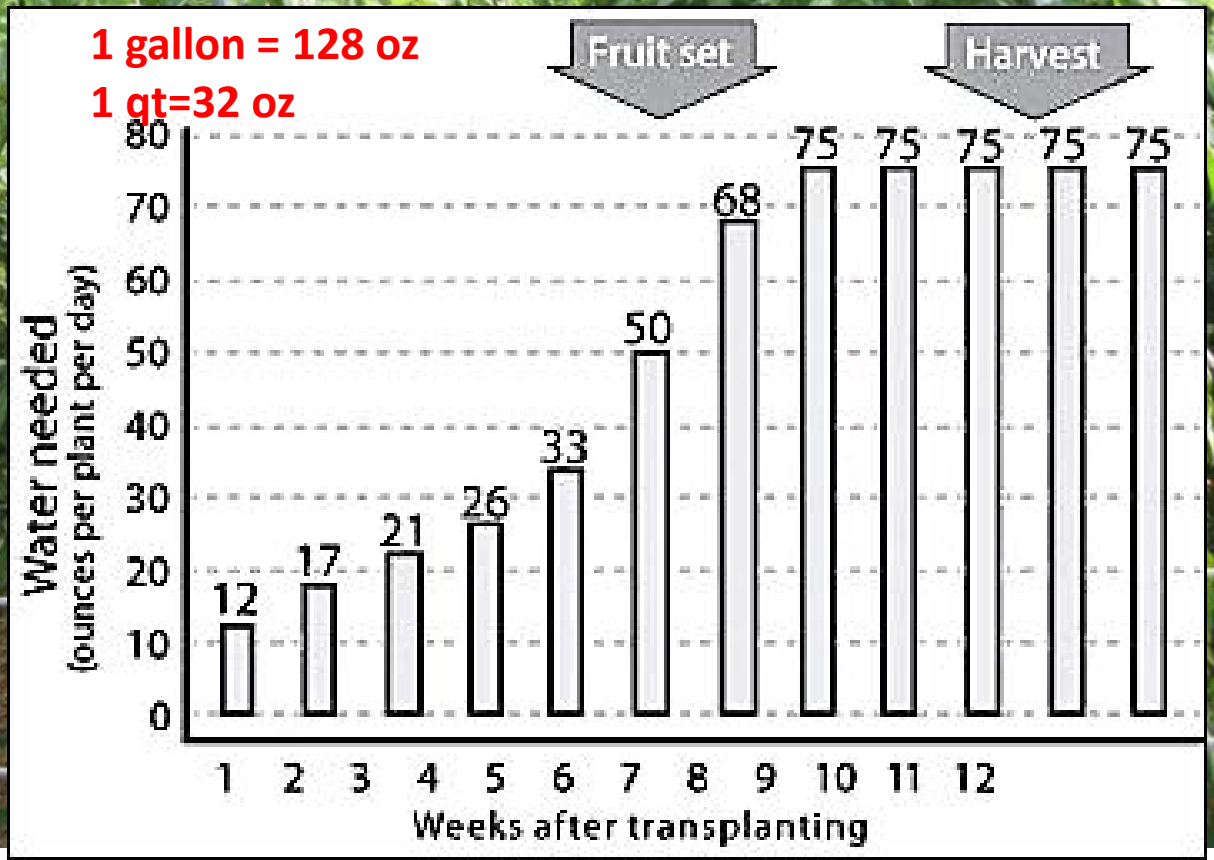



Water Stress
Low pH
Low Calcium
Imbalance in root/shoot growth
High tunnel too warm
High Nitrogen

High tunnel irrigation

1 gallon = 128 oz

1 qt=32 oz

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Thu
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PROGRAM START TIMES
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MU Guide
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Watering and Fertilizing Tomatoes in a High Tunnel

Lewis W. Jett, Division of Plant Sciences

Successful production of tomatoes within a high tunnel hinges on proper watering and fertilization. High tunnels exclude natural rainfall, so timely irrigation is important. Because tomato fruits are more than 90 percent water, yield and quality suffer when plants are under drought stress. When tomatoes are not adequately watered, there are fewer flowers per truss, less fruit will develop and blossom end rot will occur.

A high tunnel is a low-cost, solar greenhouse that can be used to extend the growing season for many horticultural crops.

Drip irrigation is the most efficient method of delivering water and nutrients to high tunnel tomatoes. Using a small, collapsible tube (¾ inch diameter), water is slowly applied to the plant without wetting the foliage. Drip tape is usually 8–10 mil thickness and is buried 1–2 inches deep. Dripper or emitter spacing is typically 4–12 inches. Tomatoes require a single drip line per row; offset about 2 inches from the plant. Flow rates of drip tapes vary; most growers choose a medium-flow tape (½ gallon per minute (gpm) per 100 feet). High-flow tape (0.8–1.0 gpm) is useful to prevent clogging and reduce irrigation time (Table 1).

Another distinct advantage of drip irrigation is the ability to inject water-soluble nutrients through the irrigation system, a technique that is called *fertigation*. Rather than applying all the nutrients at once (either at planting or before), the nutrients and water can be applied as the crop grows (Figure 1). Fertigation saves both water and fertilizer.

The critical growth periods for adequate watering of tomatoes are during flowering, fruit set and fruit development. Flowers are observed on tomatoes beginning about four weeks after transplanting. Determinate varieties have a concentrated period of flowering, whereas indeterminate tomatoes flower continuously through the growing season. Tomatoes begin developing fruit about six weeks after transplanting, and adequate watering is important for the fruit to develop and attain proper size. As the fruit continues to grow, 2–2.5 quarts of water per plant will be needed (Figure 1).

Many water-soluble fertilizers can be used in the fertilization program for tomatoes. Generally speaking, large quantities of phosphorus and potassium should not be applied through the drip irrigation system. Rather, a soil test should be taken before the crop is planted (preferably the fall) and all of the phosphorus and most of the potassium can be applied before planting or between cropping cycles within the high tunnel. Potassium should be fertigated during fruit ripening to improve color and taste of tomatoes.

Table 1. Irrigation hours per week required to apply 68 ounces of water per tomato plant per day based on varying plant populations and drip tube flow rates.

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.

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2016 - 2017 Mid-Atlantic Commercial Vegetable Production Recommendations

Delaware
University of Delaware Cooperative Extension
EB137

Maryland
University of Maryland Extension
EB-236

New Jersey
Rutgers Cooperative Extension
E001

Pennsylvania
Penn State Extension
AGRS-028

Virginia
Virginia Cooperative Extension
456-420

West Virginia
West Virginia University Extension Service

High Tunnel Tomato Fertigation Schedule (Medium to High K+)

Days after planting	WEEKLY (ounces/1000ft^2)					
	Nitrogen (N)	Potash (K_2O)	20-20-20	15.5-0-0	9-15-30	2-3-1[z]
Preplant	See Table 1		-	-		
0-14	1.3	1.3	6.4	8.3	14.4	65
15-28	1.8	3.6	8.9	11.6	20.0	90
29-42	2.6	5.2	12.9	16.6	28.9	130
53-56	3.9	7.8	19.3	24.9	43.3	195
57-77	5.7	11.4	28.3	36.5	63.3	290
78-100	6.4	12.8	32.1	41.5	71.1	320

Crop	Soil pH	Tissue Test	Fertigated	Preplant N/1000ft^2 (ounces)	Fertigation (ounces/1000 ft^2)	
					Nitrogen (N)	Potassium (K_2O)
Beans	6.0-6.5	**YES**	NO	36.8	**-**	-
Beets	6.0-6.5	**NO**	NO	28.8	**-**	-
Carrots	6.0-6.5	**NO**	NO	28.8	**-**	-
Celery	6.0-6.5	**YES**	YES	27.2	**27.2**	37.0
Cucumbers*	6.0-6.5	**YES**	YES	27.5	**27.5**	37.0
Eggplant	6.0-6.5	**YES**	YES	23.2	**23.2**	37.0
Garlic	6.2-6.8	**NO**	NO	7.3	**-**	-
Greens	6.0-6.5	**YES**	YES	18.4	**18.4**	18.4
Leeks	6.0-6.5	**NO**	NO	37.0	**-**	-
Lettuce*	6.0-6.5	**YES**	YES	18.3	**18.3**	37.0
Muskmelon* (Cantaloupe)	6.0-6.5	**YES**	YES	18.3	**18.3**	55.0
Onions	6.0-6.5	**NO**	NO	28.8	**-**	-
Parsley	6.0-6.5	**NO**	NO	54.4	**-**	-
Parsnips	6.0-6.5	**NO**	NO	27.2	**-**	-
Peas	6.0-6.5	**YES**	NO	21.9	**-**	-
Peppers*	6.0-6.5	**YES**	YES	27.2	**27.2**	55.0
Spinach	6.5-6.8	**YES**	NO	54.4	**-**	-
Summer Squash*	6.0-6.5	**YES**	YES	18.3	**18.3**	37.0
Tomatoes*	6.0-6.8	**YES**	YES	16.0	**22.0**	74.0

Report Number: R09246-5003
Account Number: 00130

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PLANT ANALYSIS

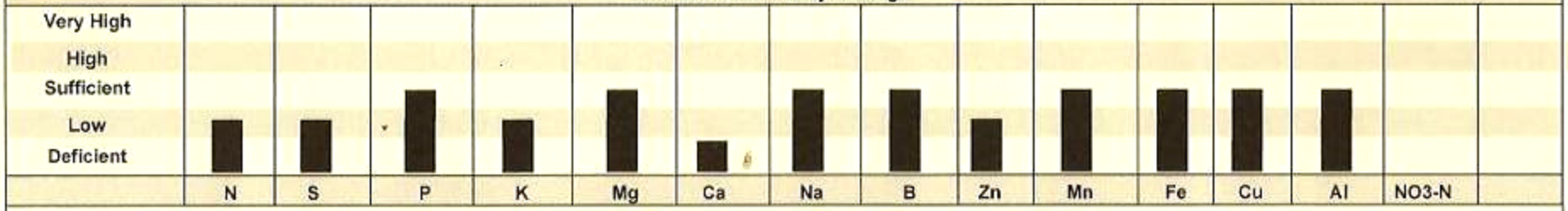
Plant tissue testing

Growth Stage: EARLY SPRING
Date Received: 09/03/2009 Date Reported: 09/04/2009

Date Sampled	Lab Number	Nitrogen (%)	Sulfur (%)	Phosphorus (%)	Potassium (%)	Magnesium (%)	Calcium (%)	Sodium (%)	Boron (ppm)	Zinc (ppm)	Manganese (ppm)	Iron (ppm)	Copper (ppm)	Aluminum (ppm)	Nitrate Nitrogen (ppm)	Molyb-denum (ppm)
	246017	2.29	0.12	0.27	1.48	0.26	0.66	0.01	24	15	66	106	8	18		
Normal Range		2.50 4.00	0.20 1.00	0.25 1.00	1.75 3.00	0.25 1.00	1.00 2.50	0.01 0.03	20 75	20 200	50 200	50 200	6 100	1 300		

	N/S	N/K	P/S	P/Zn	K/Mg	K/Mn	Fe/Mn	Ca/B
Actual Ratio	18.5	1.5	2.2	181	5.7	224	1.6	273
Expected Ratio	5.4	1.4	1.0	57	3.8	190	1.0	368

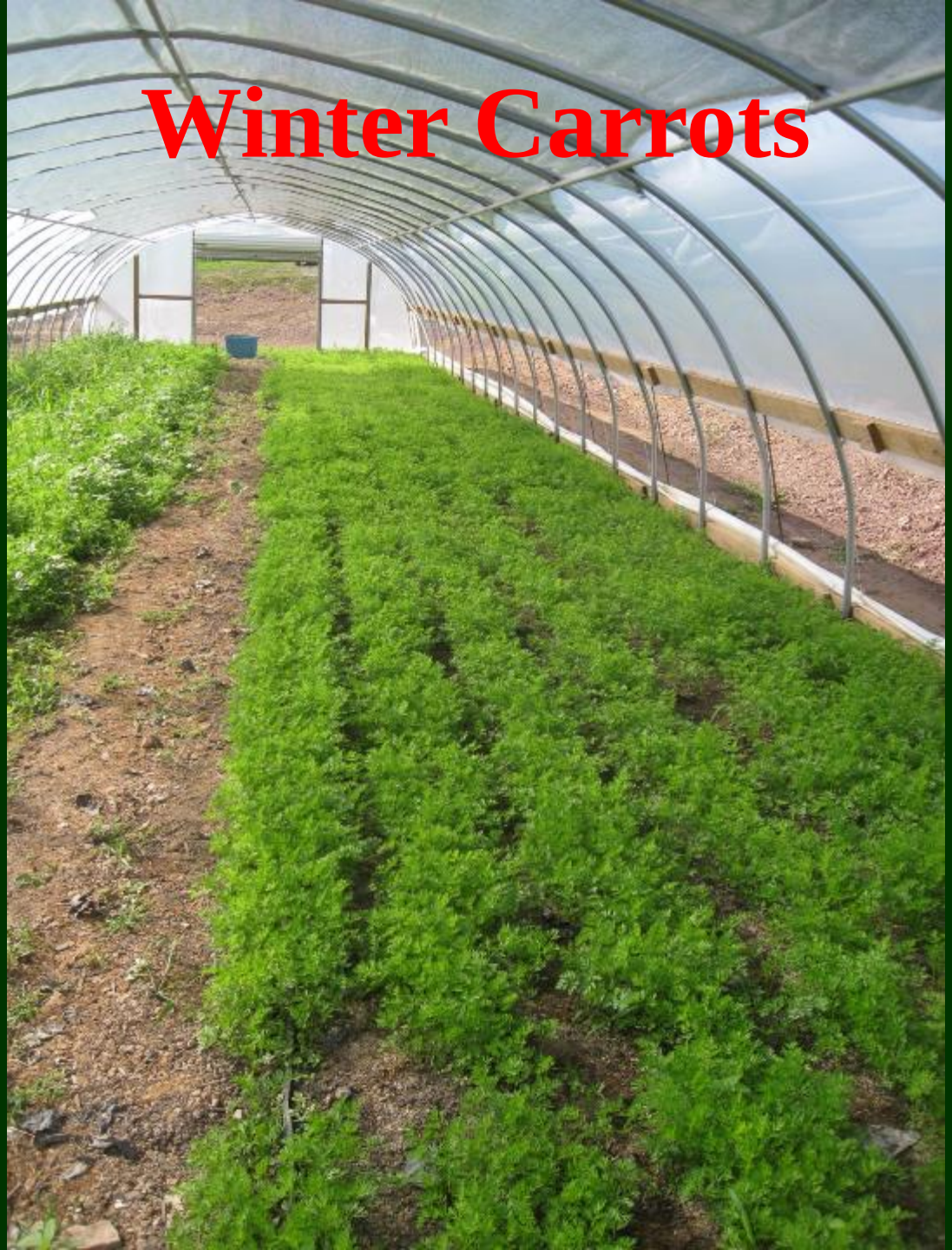
Nutrient Sufficiency Ratings



- These plants are low in NITROGEN. Additional nitrogen may be supplied to the crop with sidedress or topdress applications or in irrigation water. Apply at the rate of 20-30# of actual N per acre. Repeated applications may be necessary.
Additional nitrogen (using ammonium sulfate) may be supplied to the crop with sidedress or topdress applications or in irrigation water. Apply at the rate of 20-50# of actual N per acre. Repeated applications may be necessary.

High Tunnel Temperature Management

Winter Carrots



Leaf Mold

Keeping humidity in the high tunnel from reaching a high level (>85%) is crucial for preventing many diseases.


Leaf Mold on Tomato


Powdery Mildew


Manufactured with Gatorshield
galvanized steel tubing from
Allied Tube & Conduit


Gable Vent
HT 4


Ridge Vent

Horizontal air flow fans can improve air circulation within high tunnels.

High Tunnel Designs

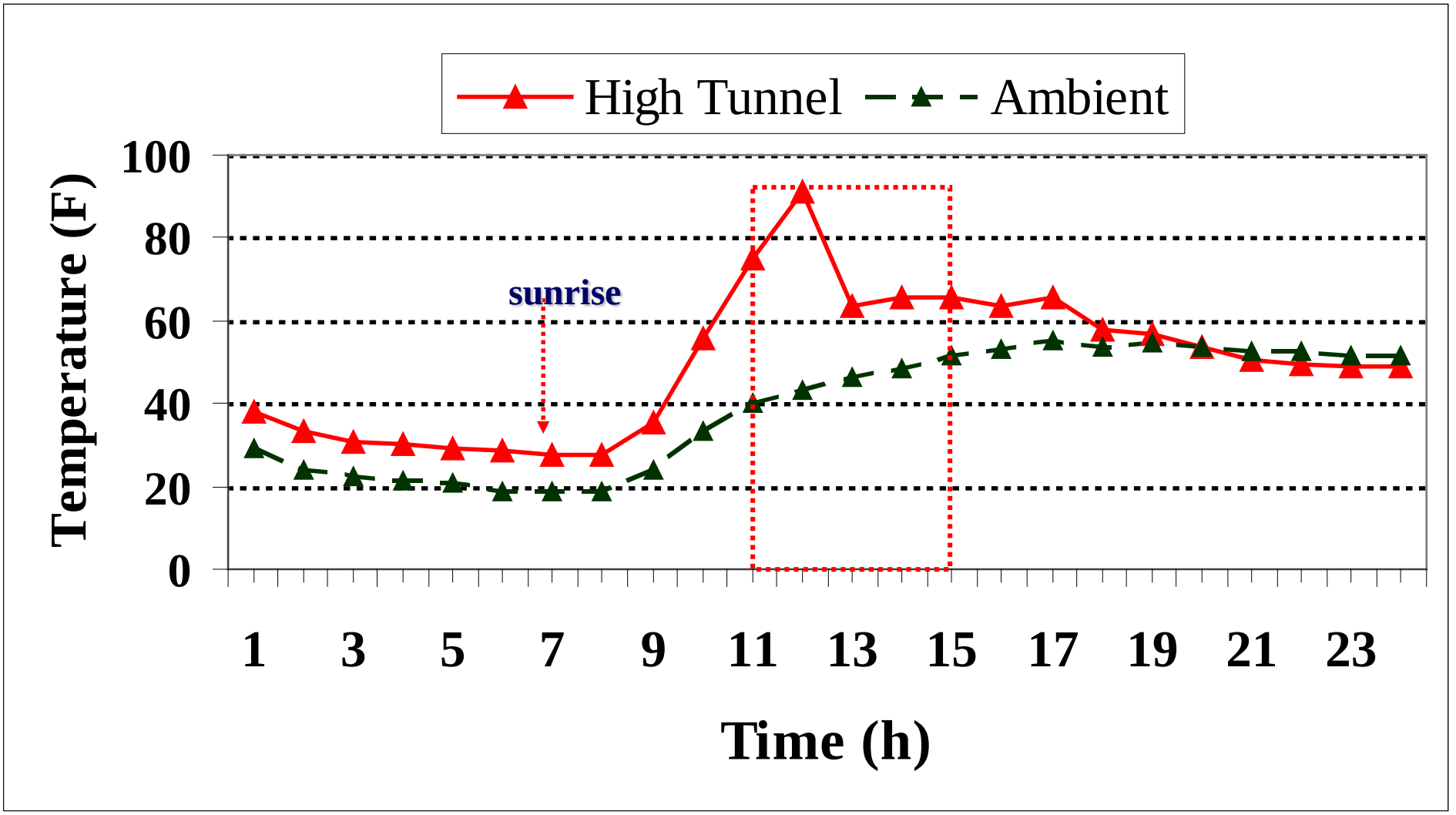

Larger air volume results in more
uniform air and soil temperature.

Increasing the height of the high tunnel by 3 feet will increase usable bed space for crops and provide a higher sidewall for air movement.

Marginal returns > Marginal costs


Every high tunnel crop has an optimum temperature range for growth.

Early spring high tunnel air temperatures, Morgantown, WV 39.6°N:



A. Montri

High Tunnel Pest Management


Aphids

Spider Mites

Spider mite

damage to high tunnel tomatoes.

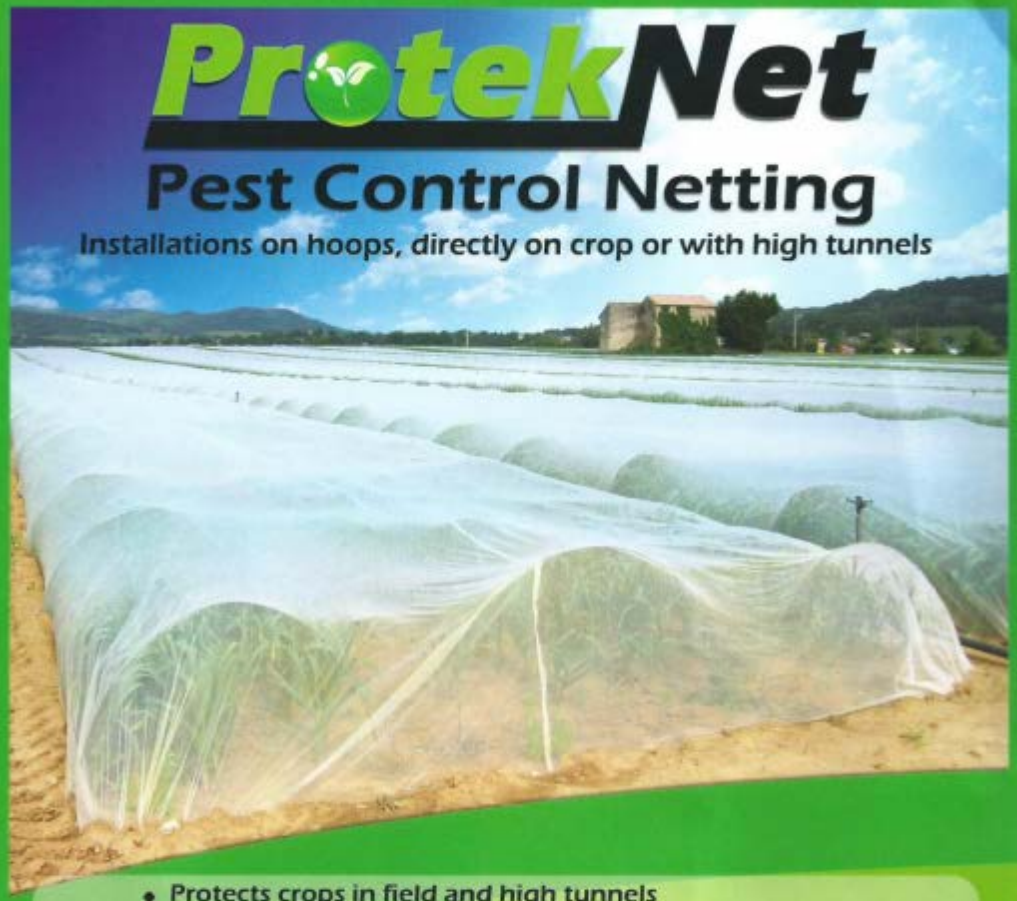
White Flies

Thrips

ProtekNet

Pest Control Netting

Installations on hoops, directly on crop or with high tunnels



- Protects crops in field and high tunnels
- No thermal effect
- Limits the usage of phytosanitary products
- Eliminates or reduces pesticide expenditures
- Protects also against birds, small animals, wind, heavy rain, and hail

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Several kinds of nets are available to fight against different insects, contact us to know the best net for your needs.

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Growers must rotate between plant families (≈2 years).
1
2
3


High tunnel cucumbers

Most growers use a single string method to train the plant up to an overhead wire.
The plant should be trained often during the growth up the string. Pinch off the lateral growth when it is young and it's easier on the crew as well as the plant.

Syngenta


Not Trellised
Trellised


12 spotted cucumber beetle

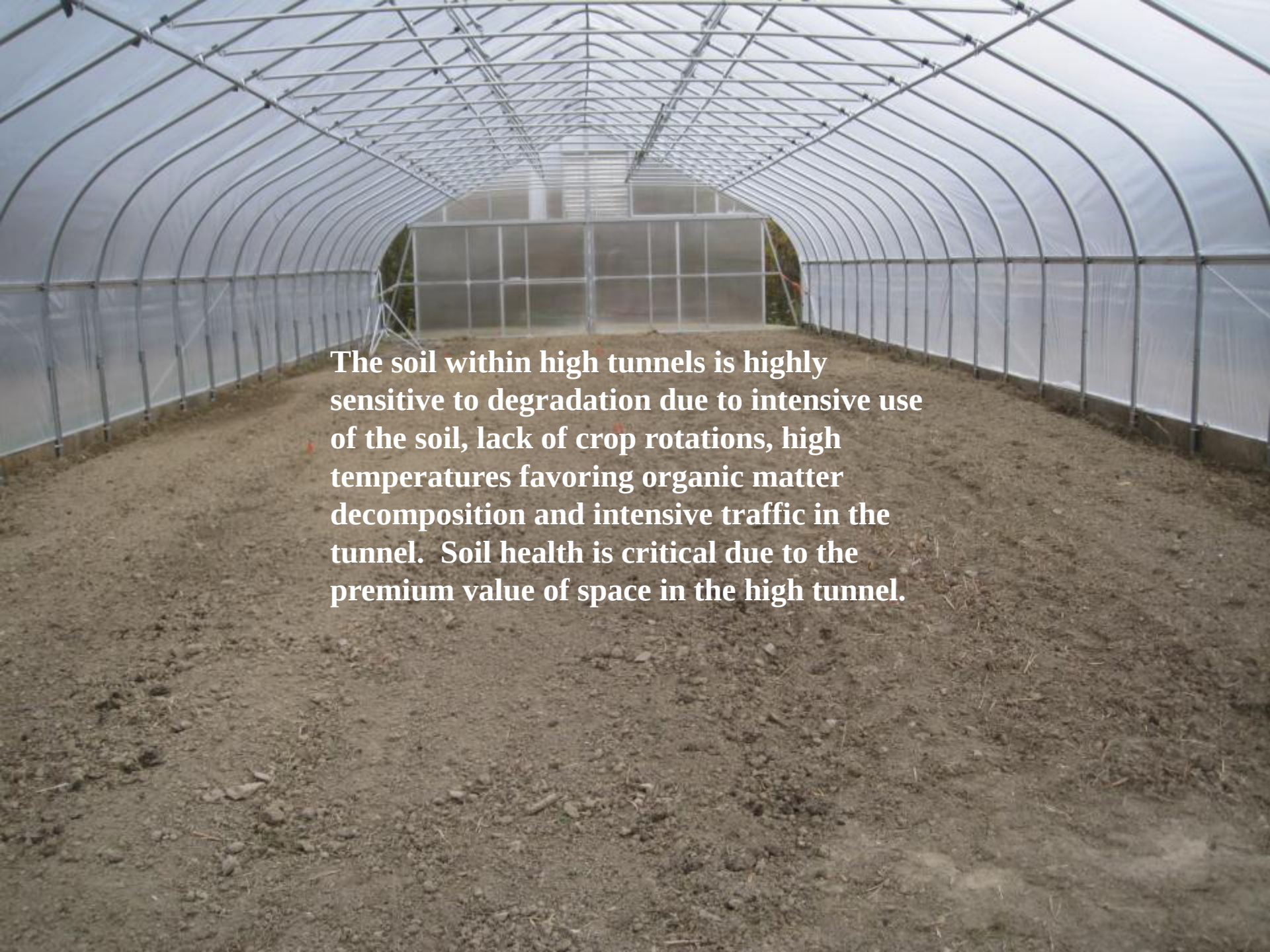

Striped cucumber beetle


Leaf feeding injury


Bacterial wilt


Bacterial wilt is spread by cucumber beetles.


Powdery and Downey Mildew Resistance is very important!



The soil within high tunnels is highly sensitive to degradation due to intensive use of the soil, lack of crop rotations, high temperatures favoring organic matter decomposition and intensive traffic in the tunnel. Soil health is critical due to the premium value of space in the high tunnel.


Broadfork

Forking of carrots and green shoulder can be reduced by subsoiling.


Synthetic fertilizer


Compost:
High NO_3 Nitrogen
High P (Phosphorus)
High K (Potassium)
High Soluble Salts


Lime (Ca Mg CO_3)

Crop Response to Salinity

Salinity (dS/m)	Crop Response
0-2	Salinity effects negligible
2-4	Yields of very sensitive crops restricted
4-8	Yields of many crops restricted
8-16	Only tolerant crops yield satisfactorily
>16	Only a few very tolerant crops yield satisfactorily

Source: *Knott's Handbook for Vegetable Growers, 4th ed.*)

Salt Sensitive Crops

salt measured by Electrical Conductivity (EC)

sensitive	*moderately sensitive*	*moderately tolerant*
bean		broccoli
carrot	cauliflower	kale
onion	cucumber	
potato	lettuce	zucchini
strawberry	pea	beets
	squash	asparagus
raspberry	tomato	

Soluble Salt

Year 1

Soluble Salts Data

Sample ID	mmho/cm	texture
k1515	0.19	silt loam
k1516	0.29	silt loam

Typical crop response to soil soluble salts Electrical Conductivity (EC)

EC (mmho/cm)	Crop Response	Degree of Salinity
0-2	Almost negligible effects	Non-saline
2-4	Yield of the most sensitive crops reduced	Slightly saline
4-8	Yield of most crops reduced	Moderately saline
8-16	Only tolerant crops yield well	Strongly saline
> 16	Only very tolerant crops yield well	Very strongly saline

Interpretation of 1 : 1 (volume soil : volume extract) Soluble Salts test

(taken from Dahnke and Whitney, 1988)

	Degree of Salinity				
Soil texture	Non-saline	Slightly Saline	Moderately Saline	Strongly Saline	very Strongly Saline
	EC (mmhos cm^{-1})				
Coarse sand to loamy sand	0-1.1	1.2-2.4	2.5-4.4	4.5-8.9	9.0+
Loamy fine sand to loam	0-1.2	1.3-2.4	2.5-4.7	4.8-9.4	9.5+
Silt loam to clay loam	0-1.3	1.4-2.5	2.6-5.0	5.1-10.1	10.1+
Silty clay loam to clay	0-1.4	1.5-2.8	2.9-5.7	5.8-11.4	11.5+


Leaching salts from the soil profile with flood irrigation.


Removing the plastic covering can allow the salts to be leached from the soil.

Irrigation

Mulch or no mulch?


Questions?