Breaking Bad Habits: Integrating Crop Diversity into High Tunnel Production Systems

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Dept. of Horticulture and Natural Resources

K-STATE Research and Extension

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Olathe Horticulture Center

35230 W. 135th St
Olathe, KS 66061

- 342 acres (~5 organic)
- 2 faculty
- 3 full-time Center staff
- 6 GRAs and research staff
- 6-8 seasonal staff

K-STATE Research and Extension | Olathe Horticulture Center

Photo courtesy:
D. Loewen

Soilborne Disease Management

Integrated Pest Management

An integrative management system for pests and pathogens focused on increased KNOWLEDGE of production systems.

- Crop rotation
- Sanitation
- Raised beds
- Compost
- Soil solarization
- Biofumigation
- Chemical control
- Biological controls
- Plant resistance/tolerance

Crop Rotation in HTs

Benefits of Crop Rotation

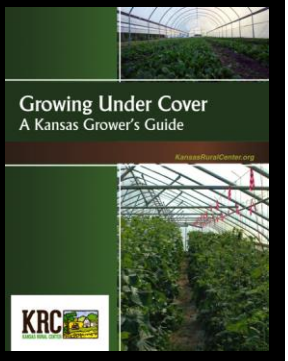
Soilborne Disease

Fertility Management

Crop Rotation in HTs

The Challenge: Generating Per SqFt Revenue

Crop Type	Production Window	Sale Price	Gross Revenue/ft^2	HT Crop
Tomato	Apr – Oct	$2.50/lb	$3.66	1
Lettuce	Sept – May	$2.00/head	$1.30	2
Spinach	Sept – May	45.50/lb	$1.09	3
Cucumber	Apr – Aug	$1.50/lb	$1.62	4
Bell Pepper	Apr – Oct	$1.50/lb	$2.30	5
Salad Mix	Sept – May	$8.00/lb	$2.40	6
Beets	Sept – May	$2.00/lb	$1.92	



- $0.44/ft^2/year fixed costs for structure (KRC, 2017)
- $0.49/ft^2/year fixed costs for structure (NCSU, 2013)
  - 2 years of tomato production ($2.60/lb) paid for structure

(Sydorovych et. al., 2013)

Crop Rotation

Rotate across plant families

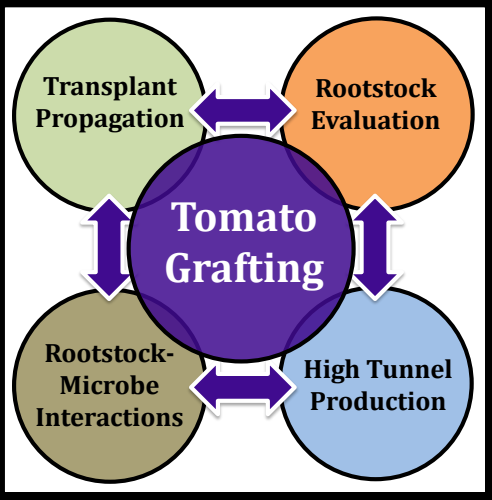
Alliaceae	Asteraceae	Brassicaceae	Cucurbitacae	Fabaceae	Solanaceae
Asparagus Chives Garlic Leeks Onions Shallots	Lettuce Endive Radicchio	Broccoli Brussels sprouts Cabbage Cauliflower Collards Mustard Radish Rutabaga Turnip	Cantaloupe Cucumbers Honeydew Pumpkins Squash Watermelon	All beans English peas Southern peas	Eggplant Peppers Potatoes Tomatoes
Apiaceae	**Polygonaceae**	**Chenopodiaceae**	**Ipomea**	**Malvaceae**	**Poaceae**
Carrot	Rhubarb	Spinach Beets	Sweet potato	Okra	Corn

Crop Rotation at Peregrine Farm (Graham, NC)

What About Cut Flowers?


Mobile High Tunnels

Diversifying with Rootstocks



Disease Management

Pathogen Eradication with Resistant Rootstocks

Table 1.3. Root-knot nematode soil poulation[u] at Sampson County[y]

	First harvest[w]	Final harvest[x]
Non-grafted	8357 d	1964 b
Self-grafted	8751 d	1228 b
Telone II[y]	379 b	1260 b
Big Power[z]	77 a	40 a
Beaufort[z]	2680 c	2542 b
Maxifort[z]	3091 c	1251 b

= Non-, self-grafted

= Big Power

= Fumigated (Telone II)

= Beaufort, Maxifort

(Rivard et. al., 2010)

Disease Management

Rootstocks	TMV	Corky Root	Fusarium Wilt		Verticillium Wilt (r1)	Root-knot Nematode	Southern Bligh	Plant Vigor
			Race 1	Race 2				
Maxifort *	R	R	R	R	R	MR	HR	+++
Multifort *	R	S	R	R	S	R	HR	+++
Arnold **	R	S	R	R	R	R	MR	++
Estamino ***	R	S	R	R	R	R	NA	+
RST-04-106 ****	R	R	R	R	S	R	MR	+
Emperador *****	R	S	R	R	R	R	NA	+
Big Power *****	R	R	R	R	R	R	HR	++
Colosus RZ *****	R	R	R	R	R	S	NA	+++
Anchor-T ******	R	S	R	R	R	R	NA	NA

R=Resistant , **HR**=Highly Resistant, **MR**=Moderately Resisitant, **S**=Susceptible, **NA** = Not Available

*** = Seminis Seed Co. ** = Syngenta Seeds *** = Enza Zaden**

****** = DP Seeds ***** =Rijk Zwaan ****** = Takii Seed**

Diversifying with Rootstocks

- Rootstocks function as a "rotation" in very few situations.
  - Heirloom or susceptible cultivars
  - High (qualitative) resistance
- They can help with quantitative resistance
- More useful as preventative measure
- Rootstock rotations and polycultures

Diversifying with Rootstocks

Dan Kuhn, Courtland, KS

What About Cover Crops?

	Biomass (lbs/acre)		C:N	Available N (lbs/acre)
	Rye	Vetch		
High Tunnel	3749.4	329.4	9.8	83.2
Field	721.8	1589.1	8.5	54.2

(O'Connell et. al., 2012)

What About Cover Crops?

- OREI Regional Grant
  - UMN, UKY
  - Ashlee Skinner (MS)
- Comparing benefits of CC vs. spinach
  - Economic vs soil-building
- Identifying crops for HT production
  - "Short windows"
  - Summer, fall, over-winter

2017 High Tunnel Bell Pepper Variety Trials

Kansas State University
Horticulture Research and Extension Center
Olathe, Kansas
Kimberly Oxley, Research Associate
Cary Rivard, Extension Specialist

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GREEN BELL PEPPERS

530 plants per 4800 ft^2 tunnel @ $1.50/lb
= $2.17 per ft^2

- **Bayonet** (2016)
- **Declaration** (2013-2016)
- **Intruder** (2013-2016)
- **Red Knight** (2013-2016)
- **Archimedes** (2013-2016)
- **Currier** (2014-2016)
- **Galileo** (2016)
- **Karisma** (2013-2016)
- **Vanguard** (2013-2016)

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Yield and Quality of Spring-Planted, Day-Neutral Strawberries in a High Tunnel

Kelly Gude, Sara Gragg,
Cary Rivard, Eleni Pliakoni

K-STATE Research and Extension

Kansas State University Horticulture and Natural Resources

The National Strawberry Sustainability Initiative

Fall-planted Strawberry Production

Strawberries Grown in High Tunnels

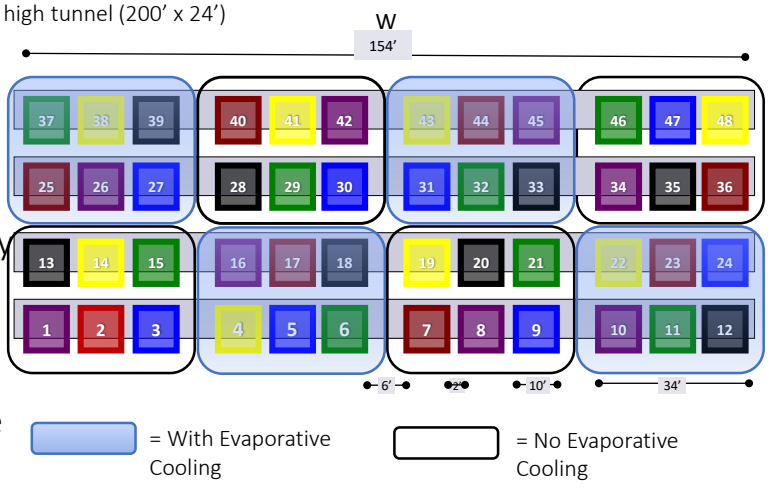
- Growing season extension & enhanced crop productivity
  - Increased yields, size, soluble solids, branch-crown development, vigor
  - Early and late season prices
- High tunnels in Kansas
- Challenges growing in high tunnels
- Solutions
  - Spring-planted day-neutral cultivars
  - Evaporative Cooling

Materials and Methods

Kansas State University Olathe Horticulture Research and Extension Center (OHREC) during 2014 and 2015

- Three-season high tunnel (200' x 24')

1. Albion
2. Evie 2
3. Monterey
4. Portola
5. San Andreas
6. Seascape



Materials and Methods

- Evaporative Cooling
  - Enabled when outside temperatures reached 85F (July)
  - 1 time/day for 5 minutes (1 pm)

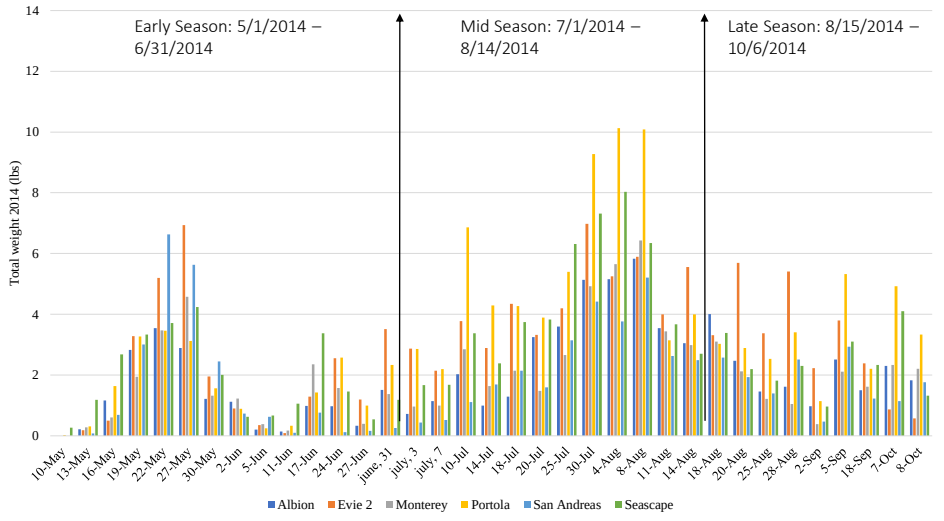
Materials and Methods

90-100% red mature fruit harvested 1-2x/week

- Separated based on marketability, counted and weighed fruit
  1. Total Yield*
     - Weight (lbs/plant)
     - Size (oz./plant)
     - Number (fruit/plan
  2. Marketable Yield
     - Weight (lbs/plant)
     - Size (oz./plant)
     - Number (fruit/plan
  3. Marketability
     - Weight (%)
     - Size (%)

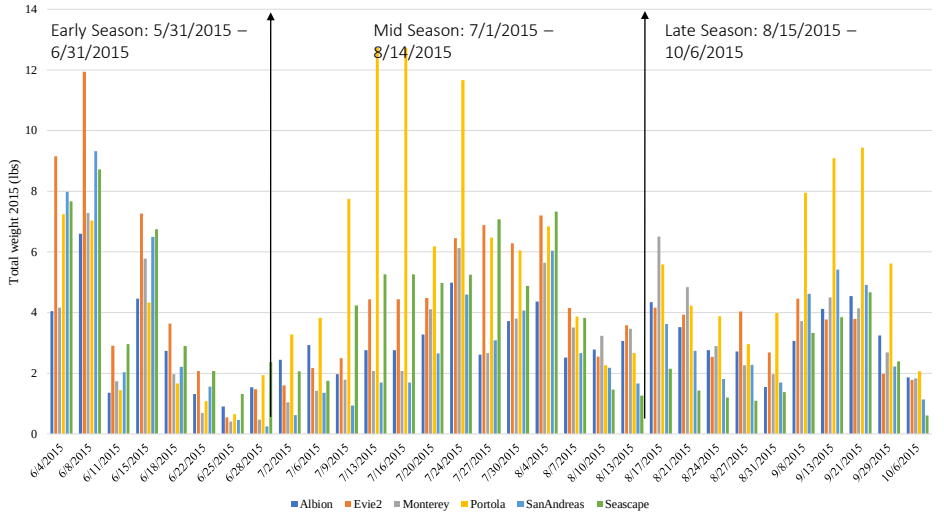
Materials and Methods

Planted April 7



Materials and Methods

Planted April 21



Cultivar	Total fruit yield[w] weight (kg/plant)	size (g/fruit)	Marketable fruit yield weight (kg/plant)	size (g/fruit)	Marketability weight (%)
			2014[xy]		
Albion	0.39 bc[z]	10.49 ab	0.34 bc	11.06 ab	88.6 a
Evie 2	0.53 ab	8.79 cd	0.42 ba	9.36 cd	79.4 b
Monterey	0.40 bc	9.64 bc	0.34 bc	9.92 bc	84.8 ab
Portola	0.60 a	11.06 a	0.51 a	11.90 a	
San Andreas	0.33 c	11.06 a	0.27 c		
Seascape	0.48 ab	8.22 d			
P value	****				
Seas					
Albion			0.24 b	7.80 bc	82.5 ab
Evie 2		7.26 bc	0.28 b	8.13 ab	76.5 b
Monterey	0.30 b	7.44 bc	0.26 b	8.04 b	83.5 a
Portola	0.51 a	8.71 a	0.42 a	9.23 a	82.0 ab
San Andreas	0.28 b	7.97 ab	0.22 b	8.34 ab	78.9 ab
Seascape	0.33 b	6.30 c	0.26 b	6.63 c	79.2 ab
P value	***	****	****	****	*
Season Mean	**0.34**	**7.51**	**0.28**	**8.03**	**80.4**

1600 plants per 4800 ft^2 tunnel @ $4/lb
= $1.76 per ft^2

Results

Parameter means of soluble solids content (SSC), Titratable Acidity (%TA)* at-harvest

Cultivar	SSC(°Brix)	Titratable Acidity (%TA)	SSC/%TA
Albion	7.77 a	0.934 ab	8.32
Evie 2	6.46 bc	0.877 bc	7.36
Monterey	7.65 a	0.831 cd	9.21
Portola	6.33 c	0.811 d	7.81
San Andreas	7.12 ab	0.842 cd	8.46
Seascape	7.19 a	0.927 a	7.76

Means marked with the same letter do not differ at P≤0.05. Student t-test procedure.

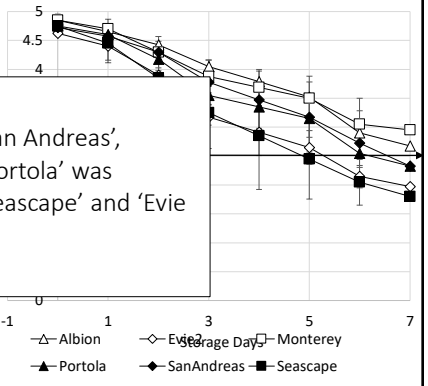
Results

Overall visual quality parameter (AUC) based on effects of cultivar, evaporative cooling treatment, and production year

Term	Scaled Estimate	Prob>|t|
Intercept	23.62	<.0001*
Cultivar[Albion]	0.86	0.1848
Cultivar[Evie 2]	-	
Cultivar[Monterey]		
Cultivar[Portola]		
Cultivar[San Andreas]		
Cultivar[Seascape]	-	
Treatment[with E.C.]	-	
Treatment[without E.C.]		
Year[2014]	0.38	0.1814
Year[2015]	-0.38	0.1814

Overall Visual Quality of 'San Andreas', 'Albion', 'Monterey', and 'Portola' was significantly higher than 'Seascape' and 'Evie 2'

Overall visual quality scores of 6 day-neutral cultivars throughout their storage life.



2017-18 High Tunnel Canteloupe and Watermelon Trials

Kansas State University
Horticulture Research and Extension Center
Olathe, Kansas
Kimberly Oxley, Extension Associate
Paul Andersen, Research Assistant
Cary Rivard, Extension Specialist

Supported by the Kansas Vegetable Growers Association

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Materials and Methods

Seedless Watermelons

- Promesa
- Extazy
- Sorbet
- Leopard
- Solitaire
- Vanessa
- Pollinator: Accomplice

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Materials and Methods

Cantaloupe

- Aphrodite
- Athena
- ME3716
- Goddess
- Grand Slam
- Home Run

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Materials and Methods

Cultural Methods

- Planted May 15 (transplants)
- 24” in-row spacing
- 5’ between rows
- Pre-plant and fertigation
- 1 pollinator per 5 plants (watermelon)
- No trellising was used

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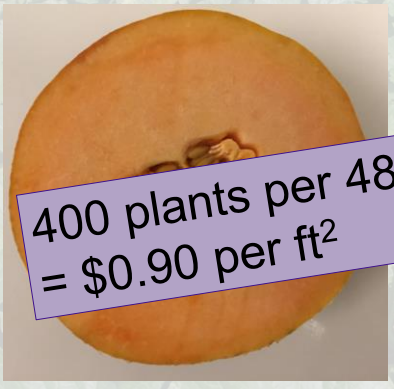
Cantaloupe



- Harvested: June 30-August 18
- Total Pounds: 3,279.02
- Total Num
- USDA (2017): $0.54 per pound
- Local Retail June/July: $0.54 per pound
- **Revenue per square feet: $0.90**

400 plants per 4800 ft^2 tunnel @ $0.54/lb = $0.90 per ft^2

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Watermelons

- Harvested: July 10-August 18
- Total Pounds: 2,964.46
- Total Number: 419
- Average lbs per fruit: 7.08
- Pound
- per pound
- $0.69 to $0.83 per square foot:
- Local Retail June/July: $0.59 per pound
  - **Revenue per square foot: $0.89**

400 plants per 4800 ft^2 tunnel @ $0.59/lb = $0.89 per ft^2

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High Tunnel Slip Production for Organic Sweetpotato in the Midwest

Zachary Hoppenstedt, Jason Griffin, Eleni Pliakoni, Mykel Taylor, & Cary Rivard,

Kansas Center for Sustainable Agriculture and Alternative Crops

NORTH CENTRAL SARE Sustainable Agriculture Research & Education

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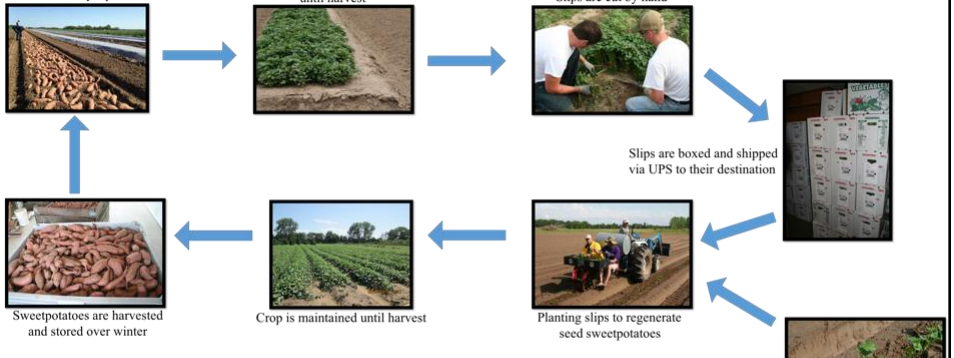
Propagation Cycle



Cultivars are propagated vegetatively.

Roots are sprouted, sprouts are cut and transplanted

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Propagation Cycle

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M.S. Thesis Research Objectives

Define best practices for high tunnel cultivation of slips

- Adapt commercial cultural practices for tunnel set-up.
- Compare open field production and planting density impact on marketable slip yield.

Evaluate high tunnel effect on quality of transplants

- Characterize physical attributes correlated with slips grown under cover.
- Conduct field trials to observe transplant vine establishment and marketable root yields.

Outline economic feasibility of high tunnel slip production

- Account for all costs and profit at different scales.
- Relate slip budget to competing cash crops and quantify value of diversified tunnel rotation.

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Materials and Methods

Sweetpotatoes are placed in ground and covered with 2-3” soil and clear plastic. Mid to late Spring.

About 4 weeks later when we see the slips breaking the surface, we remove the plastic.

Start cutting when they reach 8” – 12”

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Figure 1: Slip production system (HT v. OF) influence on marketable slip yield in Haysville (2016) and Olathe (2017)

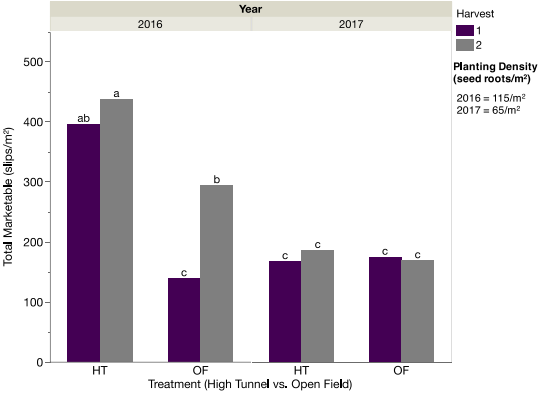

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Figure 2. Olathe HT marketable slip yield by planting density, harvest and year

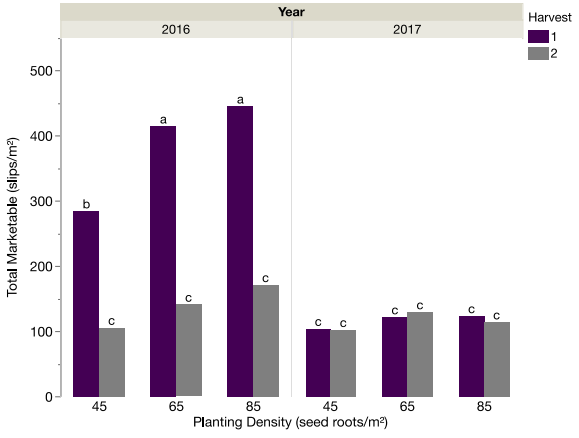

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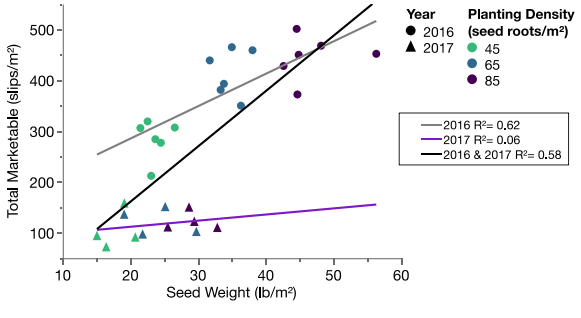
Figure 3. Correlation of HT plot weight and marketable slip yield



2016 & 2017 Total Marketable = -56.48755 + 10.879733*Seed Weight

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Table 1: Slip quality parameters as influenced by slip production system (2016): Combined Sites and Harvests

Treatment	Fresh Weight (g)	Length (cm)	Stem Diameter (mm)	Compactness (mg)	Nodes/Length	Leaf Area/Length (cm^2)
HT	11.71	25.87	3.94	37.07	0.33	5.75
OF	12.78	23.37	3.94	52.38	0.45	7.17
***P* value**	**0.2751**	**0.0619**	**0.9666**	**<.0001**	**<.0001**	**<.0001**



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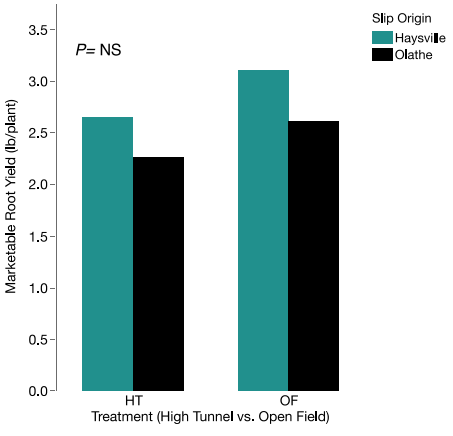
Figure 4. Marketable root yields by slip production system and trial location (2016)



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Sweet Potato Slip Research Results

- Data from these trials are being used to [illegible] nd determine the [illegible]
- [illegible] gh t[illegible]
- M[illegible] be done looking at G0 vs. G1 vs. G2 planting stock.

65 roots/m^2 and @ $130/1000 slips = $4.30 per ft^2

Crop Type	Production Window	Sale Price	Gross Revenue/ft^2
Organic Slips	Apr – Jul	$130/1000 slips	$4.30
Tomato	Apr – Oct	$2.50/lb	$3.66
Cucumber	Apr – Aug	$1.50/lb	$1.62
Bell Pepper	Apr – Oct	$1.50/lb	$2.30

Revenue based on average trial yields for two harvests and regional price for foundation seed. All other crop values are based on enterprise budgets from Kansas Rural Center's Growing Under Cover v2 Dec. 2016.

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Putting the Pieces Together

A few scenarios for planning your high tunnel

	January			December
Yr 1	Greens	Tomatoes		Greens
Yr 2	Greens	Tomatoes		Greens
Yr 3	Greens	Tomatoes		Greens

Putting the Pieces Together

A few scenarios for planning your high tunnel

	January			December
Yr 1	Greens	Tomatoes		Cover
Yr 2	Cover	Grafted Tomatoes		Greens
Yr 3	Greens	Tomatoes		Cover

Soil health = $

Putting the Pieces Together

A few scenarios for planning your high tunnel

	January			December
Yr 1	Greens	Tomatoes		Cover
Yr 2	Cover	Strawberries		Greens
Yr 3	Greens	Tomatoes		Cover

$1.76 per ft^2

Putting the Pieces Together

A few scenarios for planning your high tunnel

Yr 1	Greens	Tomatoes		Cover
Yr 2	Cover	Melons	Cover	Greens
Yr 3	Greens	Tomatoes		Greens

January December

$0.89 – $0.90 per ft^2

Putting the Pieces Together

Cucurbits Offer a "Short Season" Alternative

Zucchini

Cucumber with gourd rootstock

English Cucumber

Putting the Pieces Together

A few scenarios for planning your high tunnel

Yr 1	Greens	Tomatoes		Cover
Yr 2	Cover	Brassicas	Cover	Greens
Yr 3	Greens	Tomatoes		Greens

January December

$1.25 per ft^2

Putting the Pieces Together

A few scenarios for planning your high tunnel

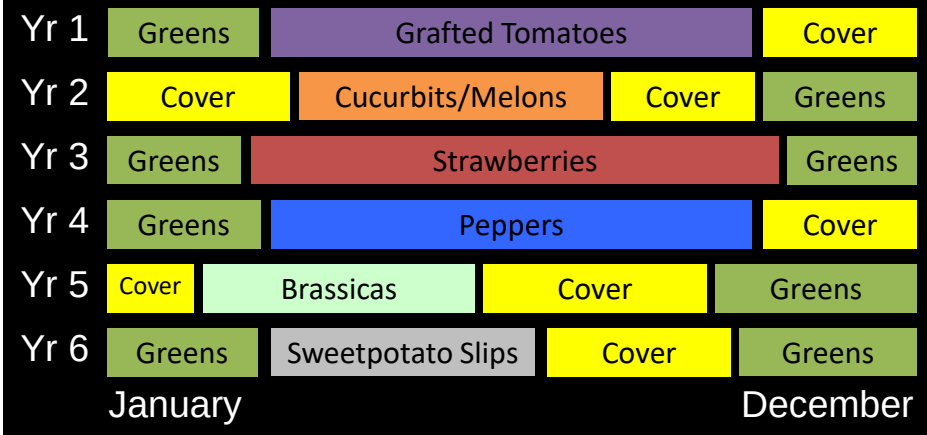
Yr 1	Greens	Tomatoes		Cover
Yr 2	Cover	Sweetpotato Slips	Cover	Greens
Yr 3	Greens	Tomatoes		Greens

January December

$4.30 per ft^2

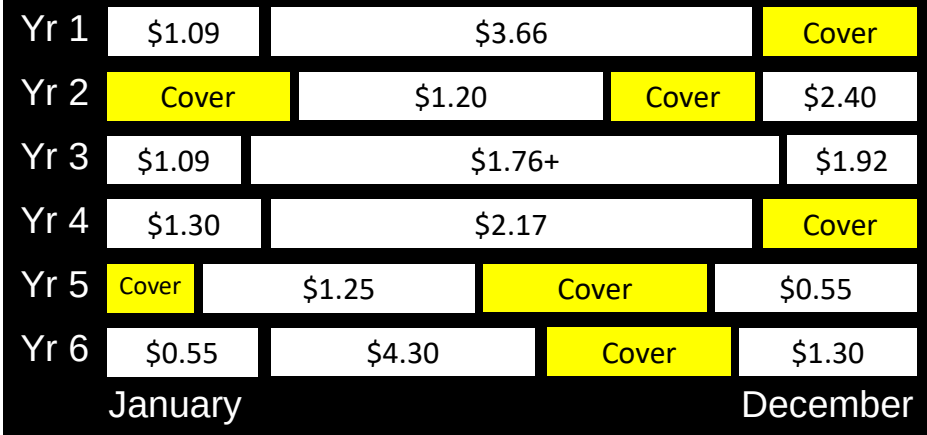
Putting the Pieces Together

A few scenarios for planning your high tunnel



Putting the Pieces Together

Think About Revenue in the Long Term



Average Annual GROSS Rev = $4.09 per ft^2
Overhead (structure) Costs = 11%

Putting the Pieces Together

Think About the Timing – Pest Cycles, Labor, etc.

	January						December
Yr 1	Cover	Grafted Tomatoes					Greens
Yr 2	Greens	Cover	Cucurbits/Melons				Greens
Yr 3	Greens	Strawberries					Cover
Yr 4	Cover	Peppers					Cover
Yr 5	Greens	Cover	Brassicas				
Yr 6	Greens	Sweetpotato Slips		Cover			Greens

Summary

- Don't grow tomatoes every year
  - Peppers not a rotation crop
  - Consider inter-specific rootstocks
- Develop new systems
  - Day-neutral strawberries
  - Sweetpotato slips
  - Melons
- Recognize the value of crop rotation and soil building
- Find a niche and have fun!

www.hightunnels.org