Greenhouse and High Tunnel Coverings

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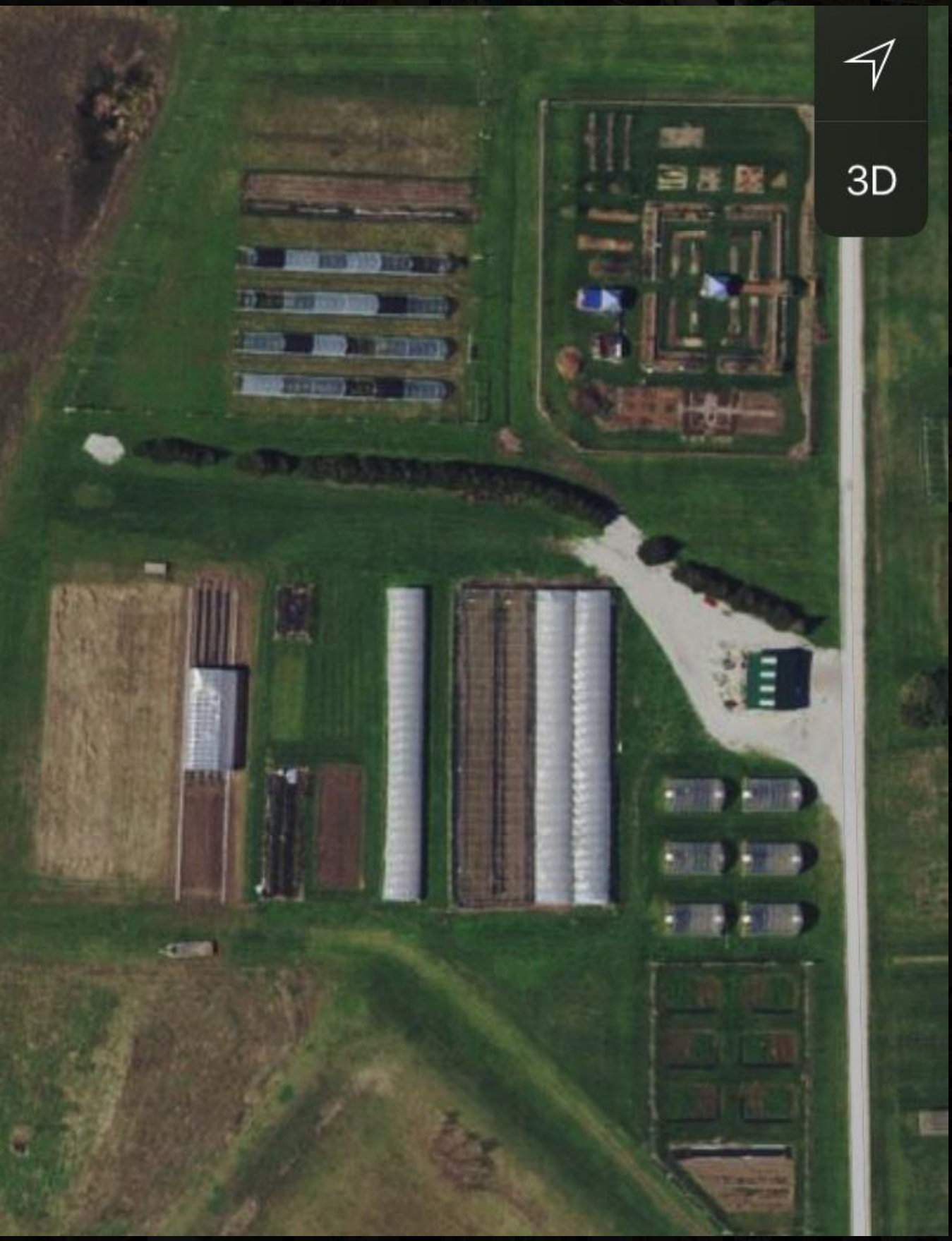
K·STATE
Research and Extension

Pre-harvest effects on postharvest quality of fresh produce

Dr. Eleni Pliakoni
Urban Food Production and Postharvest Physiology
KSU Olathe

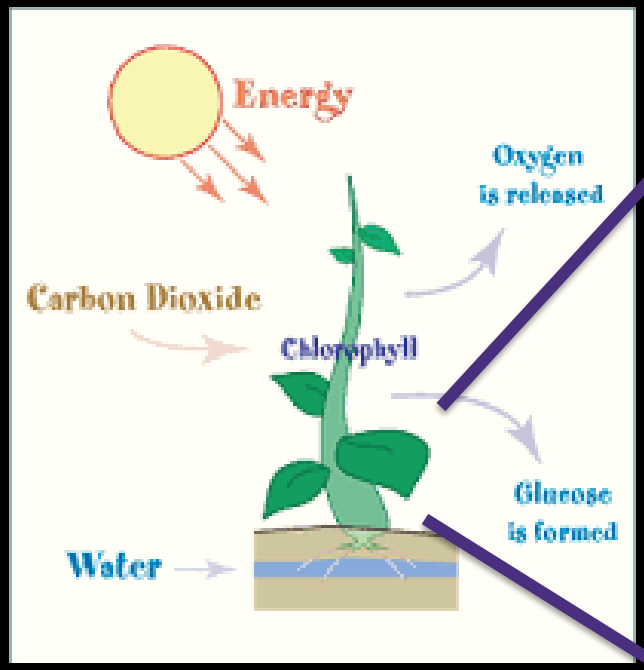
The Next Frontier in Food

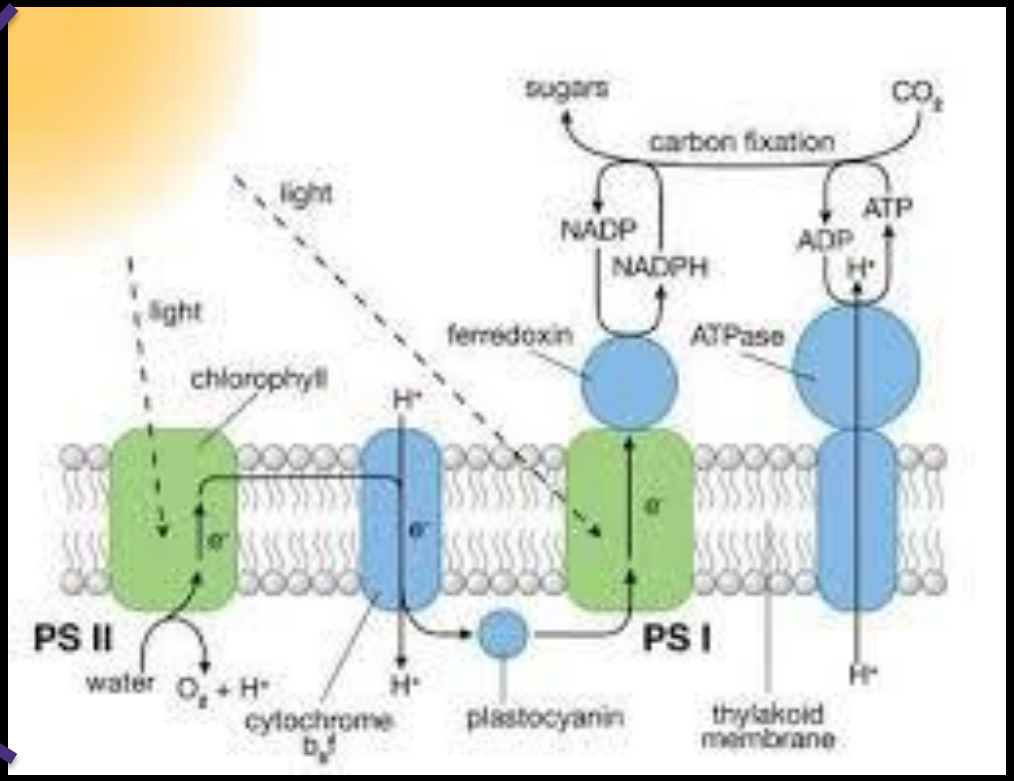
- Standard poly will reduce PAR 7-10%
- “Diffuse” poly coverings
- Ability to implement shade cloth
- Poly removal..?


3D

Why Does it Matter

Plant Physiology 101: Photosynthesis

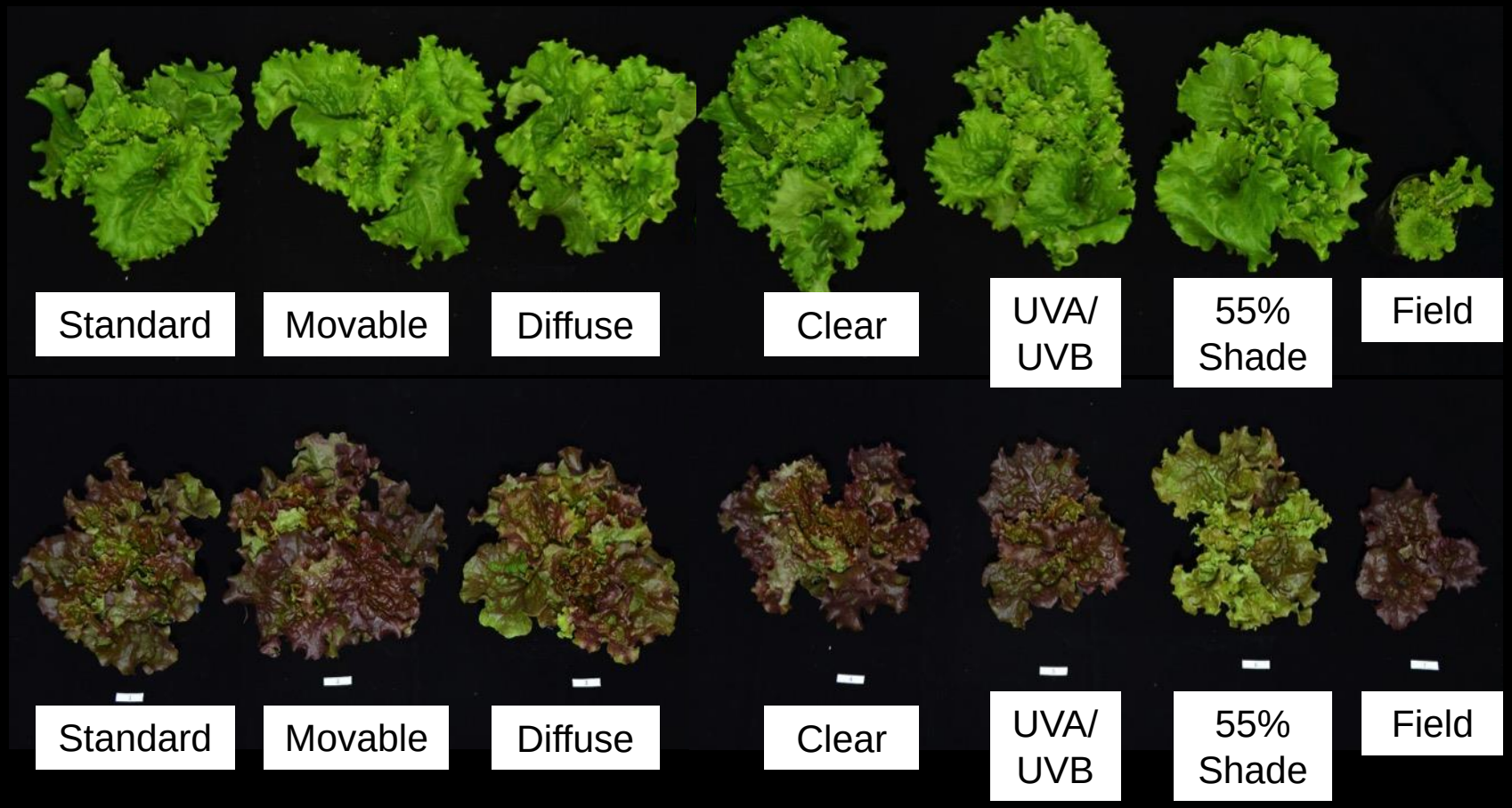




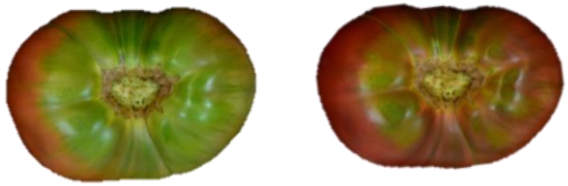
- Plants are constantly “quenching” electrons
- Carotenoids and anthocyanins

Why Does it Matter

Plant Physiology 101: Pigments



Production of Organic Tomatoes in High Tunnels is reducing Pre-Harvest and Postharvest Losses.



Konstantinos G. Batziakas, Helena Pontes Chiebao, Cary L. Rivard and Eleni D. Pliakoni

Department of Horticulture & Natural Resources, Kansas State University, USA

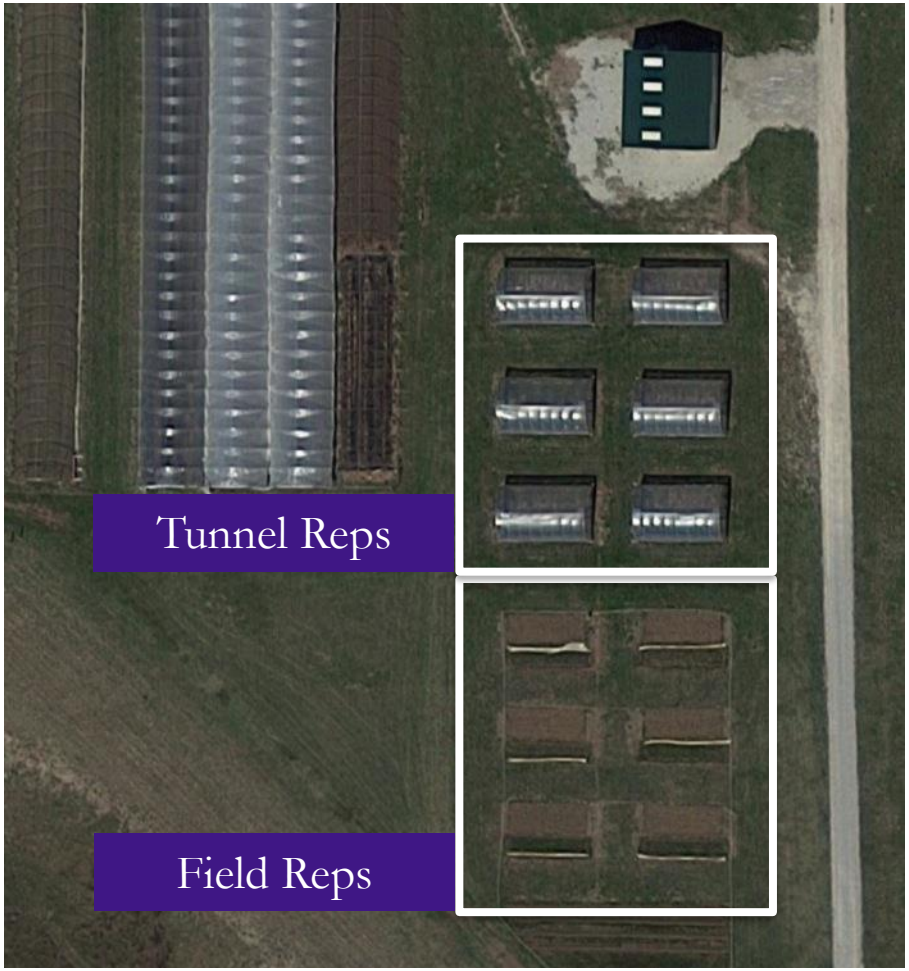
KANSAS STATE UNIVERSITY

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Materials & Methods Pre-harvest Study

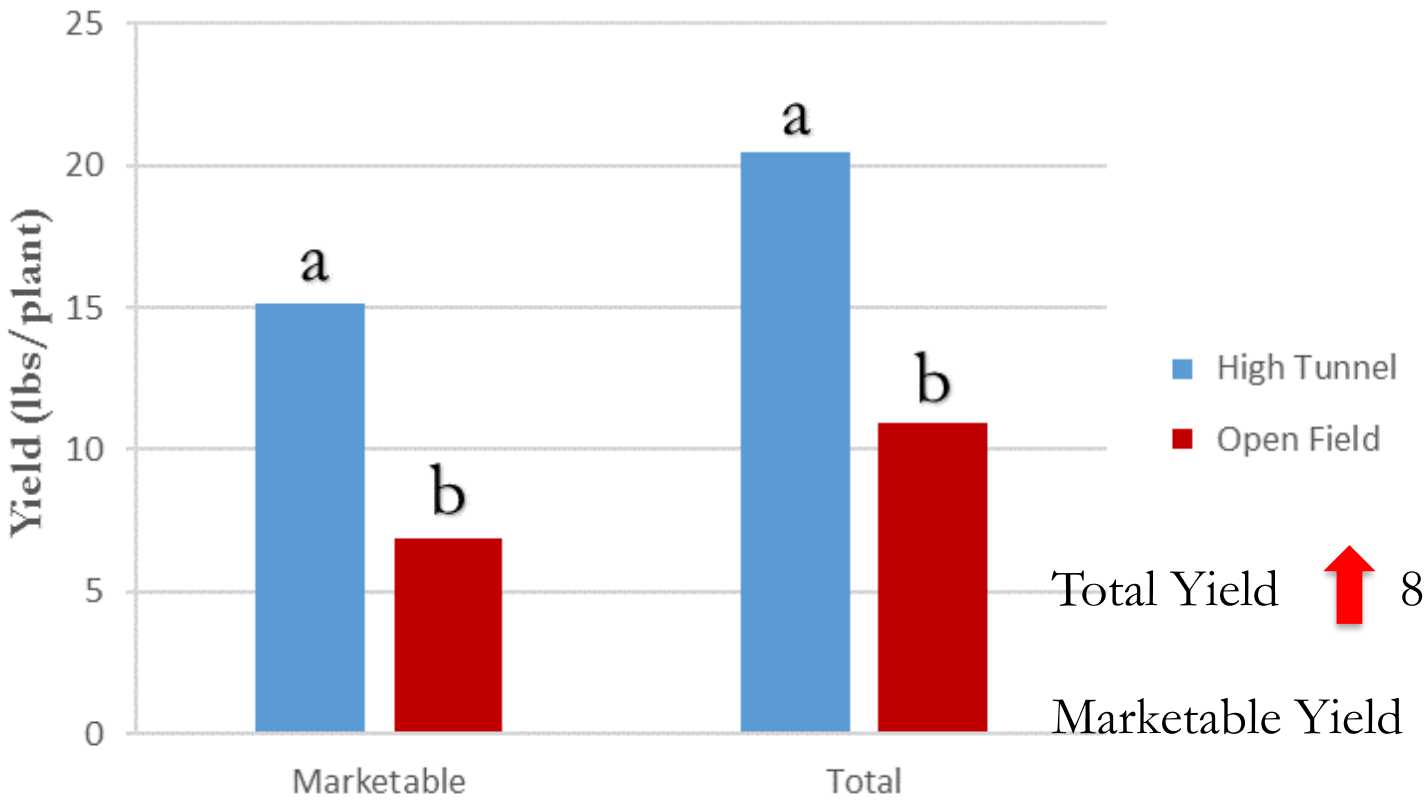
K- State Olathe Horticulture Research and Extension Center, Olathe Kansas



- 2014-2016
- 6 replicates, RCBD
- 6 plants/replicate
  - 'BHN 589'
  - 'Cherokee Purple'

Tomato Yield

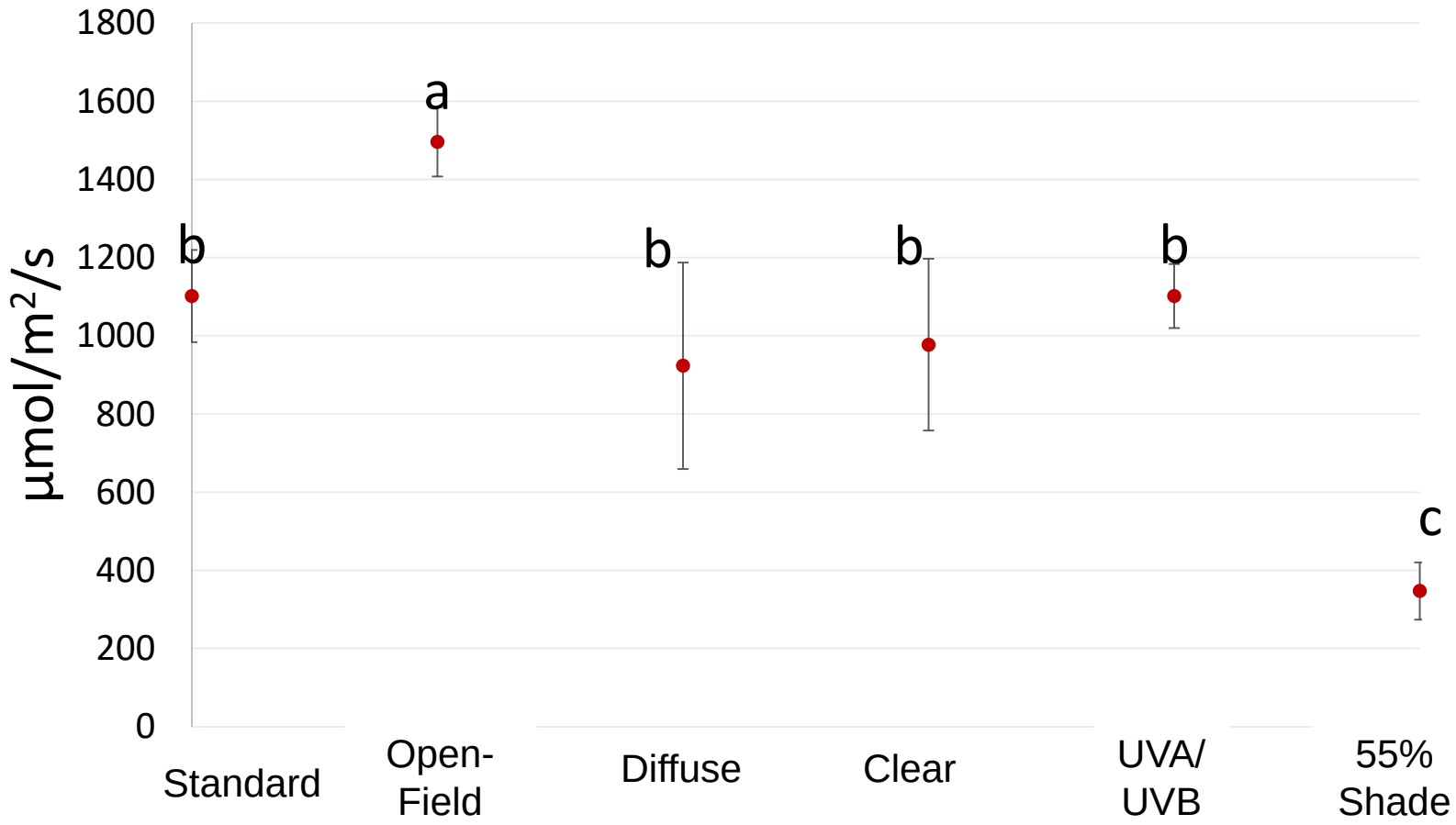
2014-2016 Yield per growing system ($p<0.01$)



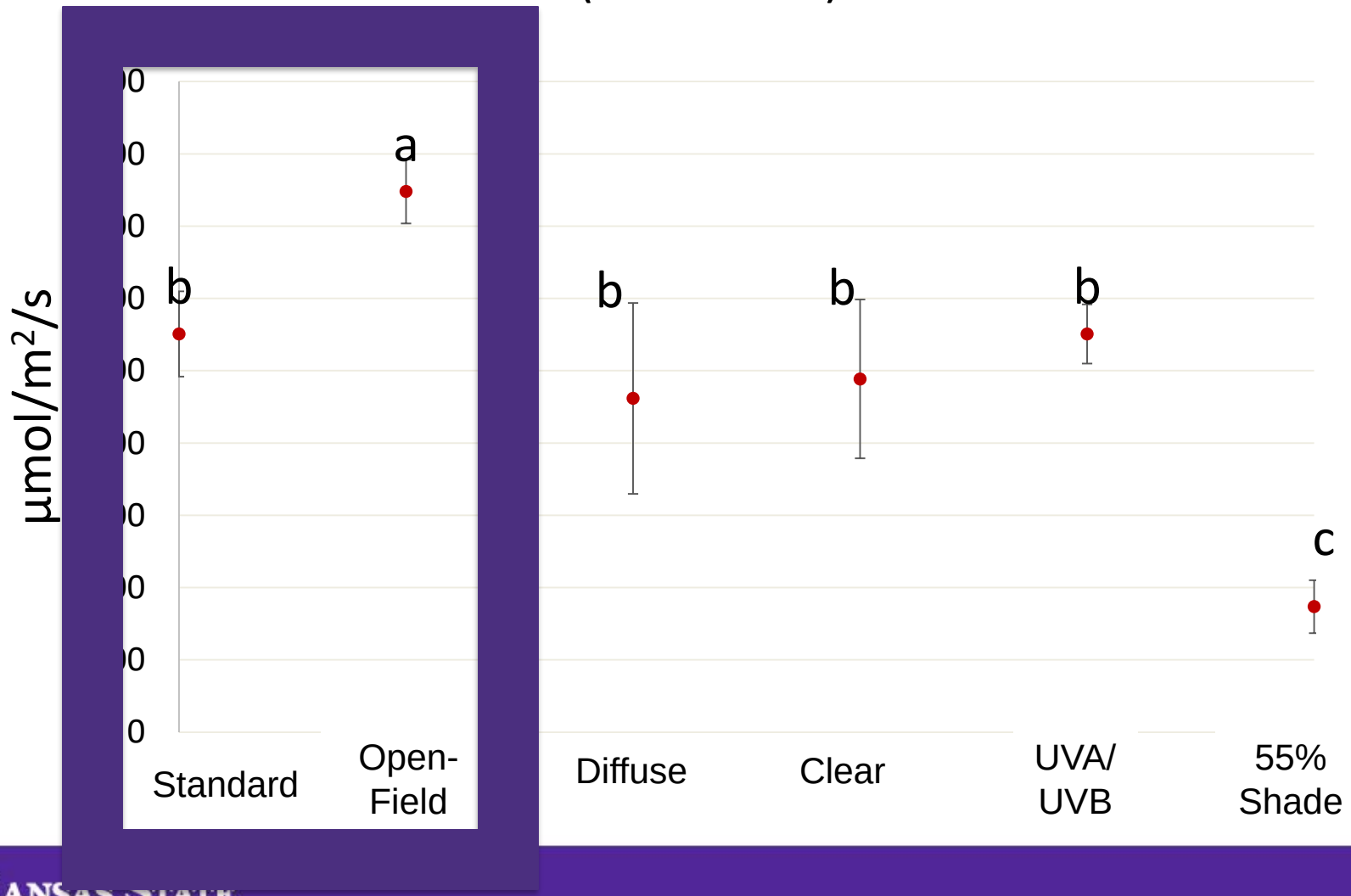
Total Yield ↑ 87%

Marketable Yield ↑ 120%

PAR (P < 0.0001)


1800
1600
1400
1200
1000
800
600
400
200
0
µmol/m²/s
a
b
b
b
b
c
Standard
Open-Field
Diffuse
Clear
UVA/ UVB
55% Shade

PAR (P < 0.0001)


µmol/m²/s
0
a
b
b
b
b
c
Standard
Open-Field
Diffuse
Clear
UVA/ UVB
55% Shade

Tomato – Nutritional Quality

Quality at day of harvest ($p<0.01$)

BHN589	**High Tunnel**	**Open Field**
ORAC	743.5 (64.1)A	723.0 (40.8)A
FRAP	295.9 (21.6)A	315.1 (25.0)A
Total Phenolics	18.6 (2.60)A	21.2 (4.28)A
Sugar/Acid	11.5 (1.27)A	9.9 (0.87)A
Lycopene	4.6 (0.48)A	4.8 (0.66)A
β-Carotene	2.8 (0.17)A	2.6 (0.11)A
Cherokee Purple	**High Tunnel**	**Open Field**
ORAC	535.4 (38.6)A	775.2 (103.9)B
FRAP	158.0 (23.6) A	300.5 (50.4) B
Total Phenolics	22.3 (0.51)A	22.1 (2.55)A
Sugar/Acid	13.3 (1.97)A	13.3 (1.18)A
Lycopene	4.1 (0.28)A	5.5 (0.90)A
β-Carotene	1.8 (0.44)A	2.5 (0.31)A

Spinach – Nutritional Quality

Growing Season	Treatment	Total Phenolic content (GA eq/100g FW)	FRAP (µMol TE/100g FW)	ORAC (µMol TE/100g FW)	Chlorophyll content (mg/100g FW)	Ascorbic Acid content (ugAA/g FW)
2 (2015/2016)	High Tunnel	65.1 **a**[z] (12.4)	145.3 **b** (30.3)	3676.9 **b** (636.6)	100.2 **a** (26.9)	672.3 **b** (115.1)
	Open Field	70.5 **a** (16.6)	225.1 **a** (52.8)	4888.9 **a** (597.9)	96.6 **a** (19.7)	759.7 **a** (135.9)
	P value	NS	***	***	NS	*
3 (2016/2017)	High Tunnel	49.7 **b** (9.4)	230.2 **b** (51.5)	3707.9 **b** (1166.1)	230.2 **b** (51.5)	786.7 **a** (160.3)
	Open Field	70.8 **a** (14.9)	301.8 **a** (102.7)	4442.1 **a** (638.3)	301.8 **a** (102.7)	838.3 **a** (205.7)
	P value	***	***	*	***	NS

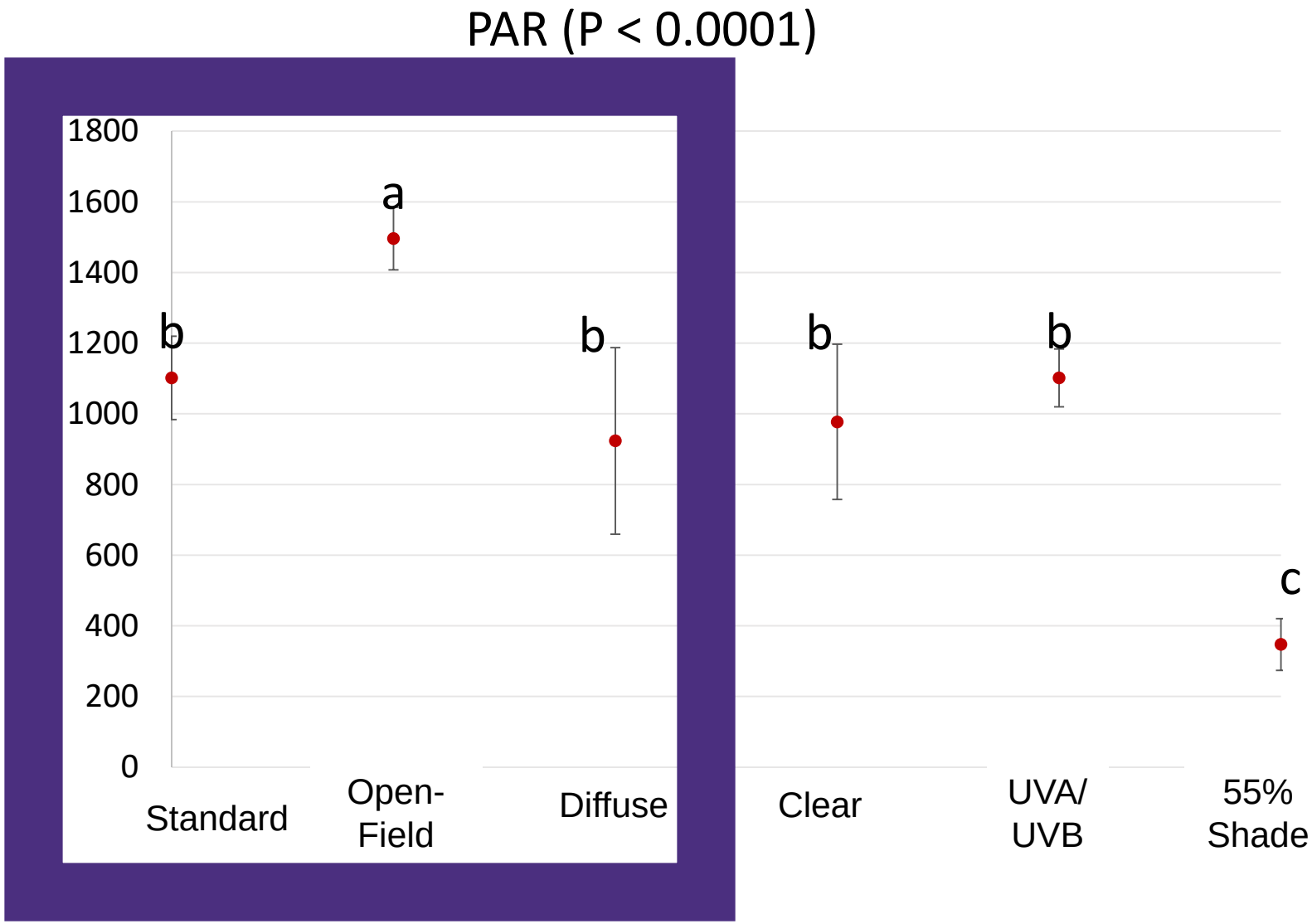
- Antioxidant capacity decreased in HT
- Vitamin C and Chlorophyll inconsistent
- Impact of environment

Diffuse Poly

Power of Refraction

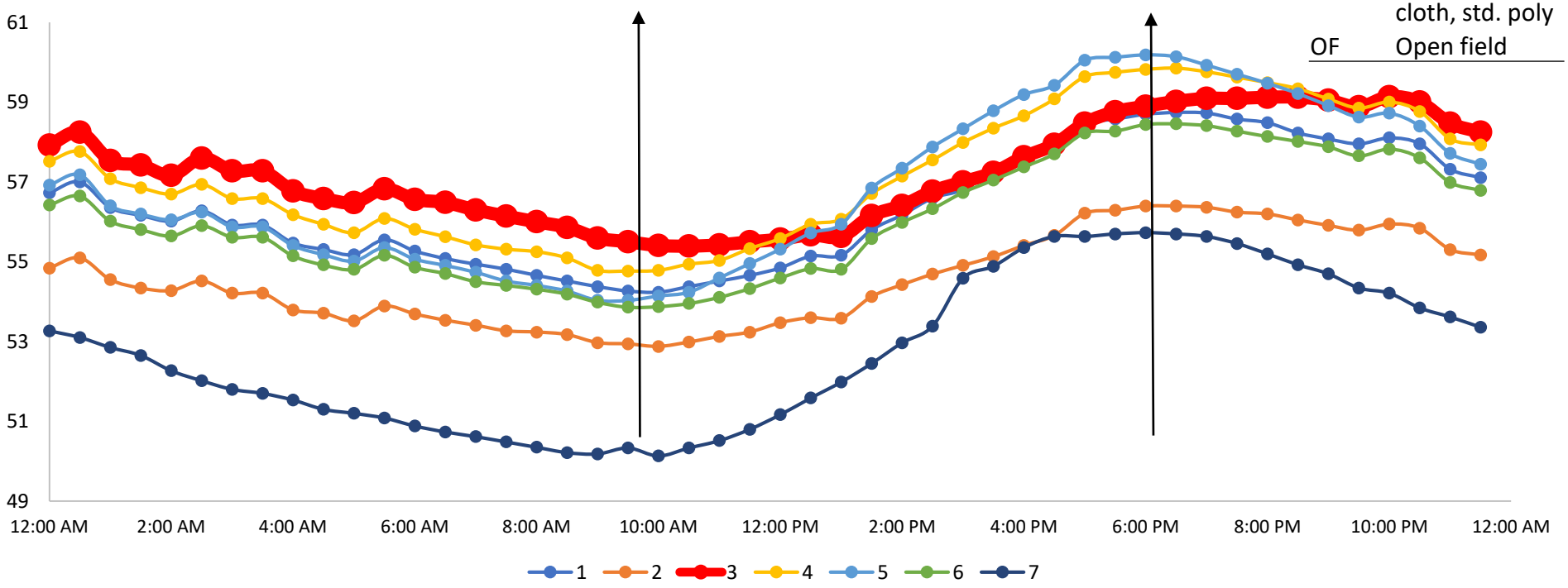
- Light is refracted as it enters the tunnel
- Trade names
  - Luminance
  - Polar Ice
- ~85% light transmission (reportedly)
- Can reduce temperatures


Diffuse
Standard


PAR (P < 0.0001)
1800
1600
1400
1200
1000
800
600
400
200
0
a
b
b
b
b
c
Standard
Open-Field
Diffuse
Clear
UVA/ UVB
55% Shade

Soil Temperature - Lettuce

Code	Treatment
SP	Std. poly
SP2W	Std. poly, removal 2 weeks prior to harvest
DP	Diffuse poly
CP	Clear poly
UVAUVB	UVA, UVB blocking
SCSP	55% shade cloth, std. poly
OF	Open field

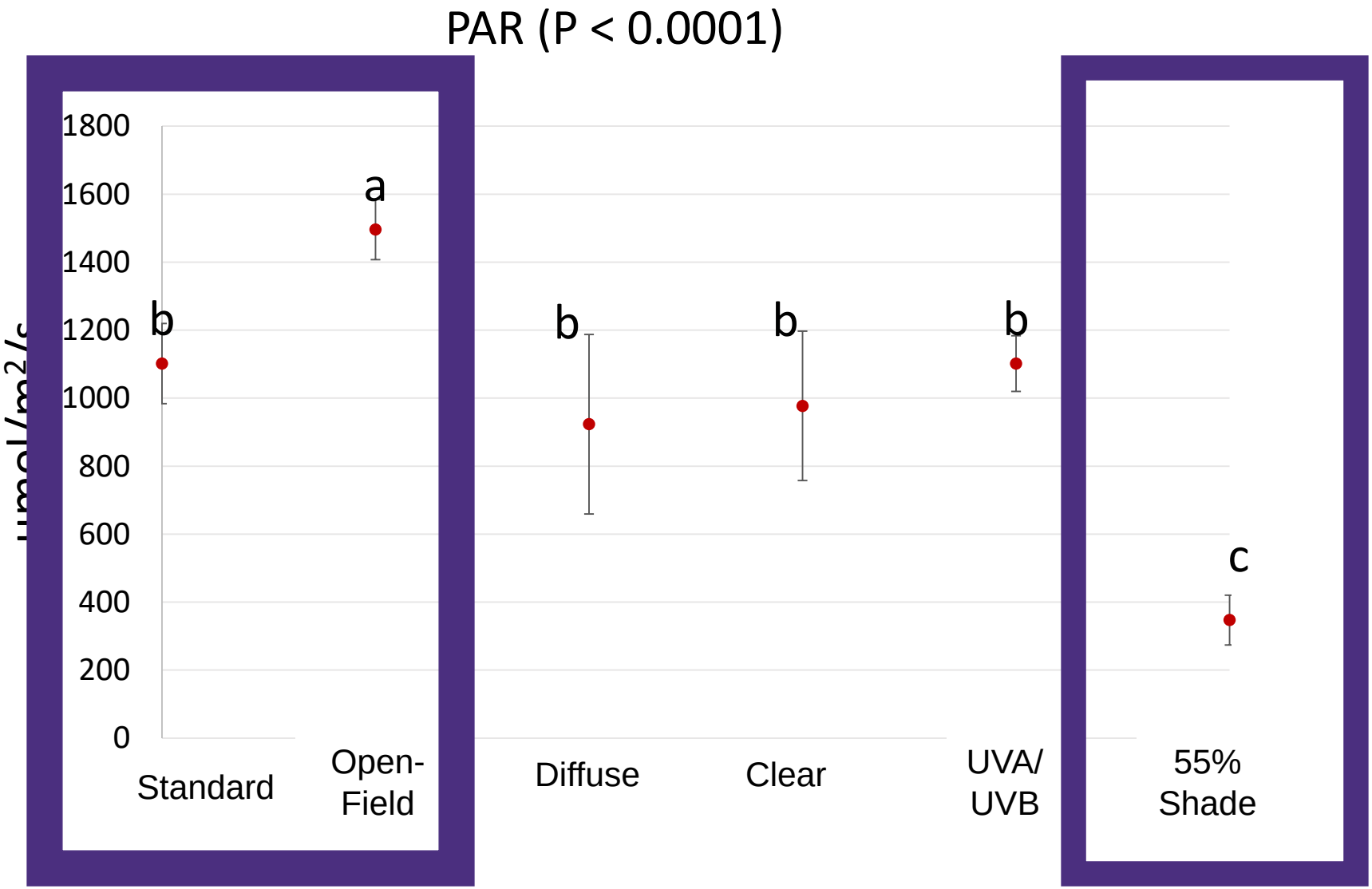


Soil temperature of lettuce in 2017 (10/7-11/17). 10:00am with the lowest recorded daily temperatures, 6:30pm with the highest recorded daily temperatures.
*******Treatment 3 with higher temperatures in comparison to 1,2,6,7 ($P < .0001$). Tukey's HSD.

Shade Cloth

So Much to Think About

- New area of research
- Few recommendations
- Timing of application
- White vs. Black vs. Metal
  - Depends on the goal
- Disadvantages:
  - Crop growth
  - Cost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1800
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c
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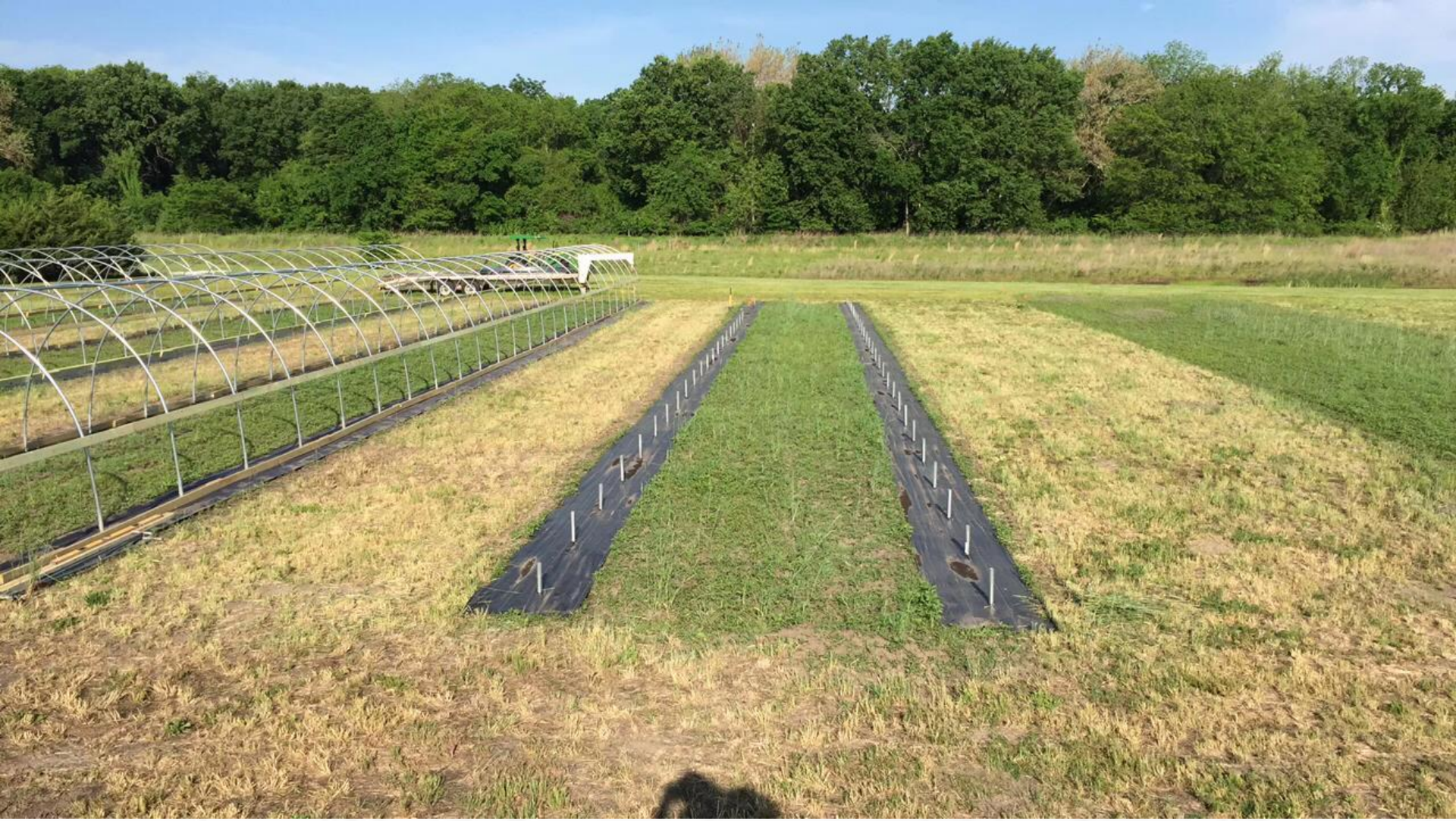
55% Shade

Light effects during pre- and postharvest stages to improve nutrition of high tunnel vegetables

Kelly Gude, Ph.D. student, Horticulture and Natural Resources

Kansas State University | Olathe

OBJECTIVE: Evaluate the impact of different poly films on spectral quality and a simulated movable tunnel on light intensity regarding photosynthesis, temperature, crop yield, storage life, and nutritional quality of tomato and lettuce.



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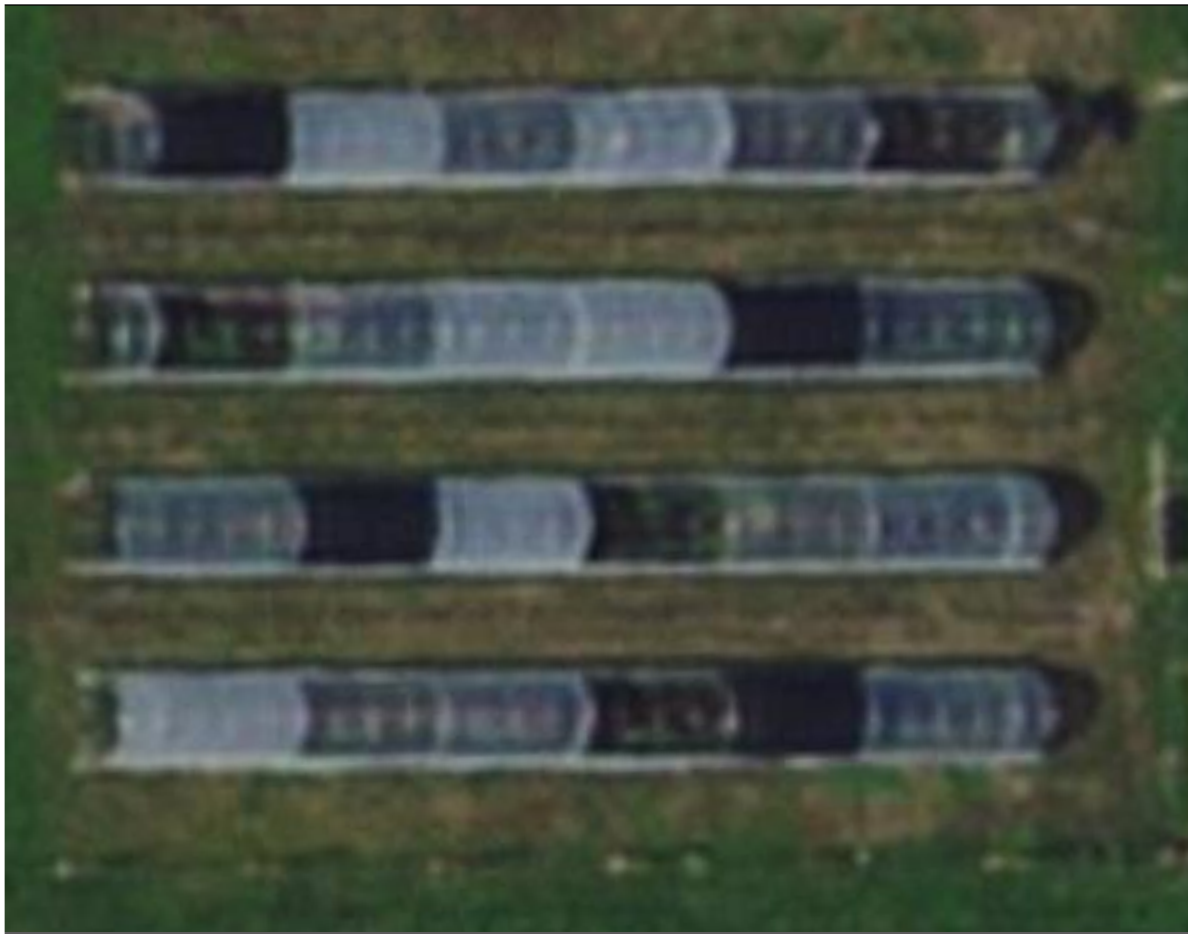
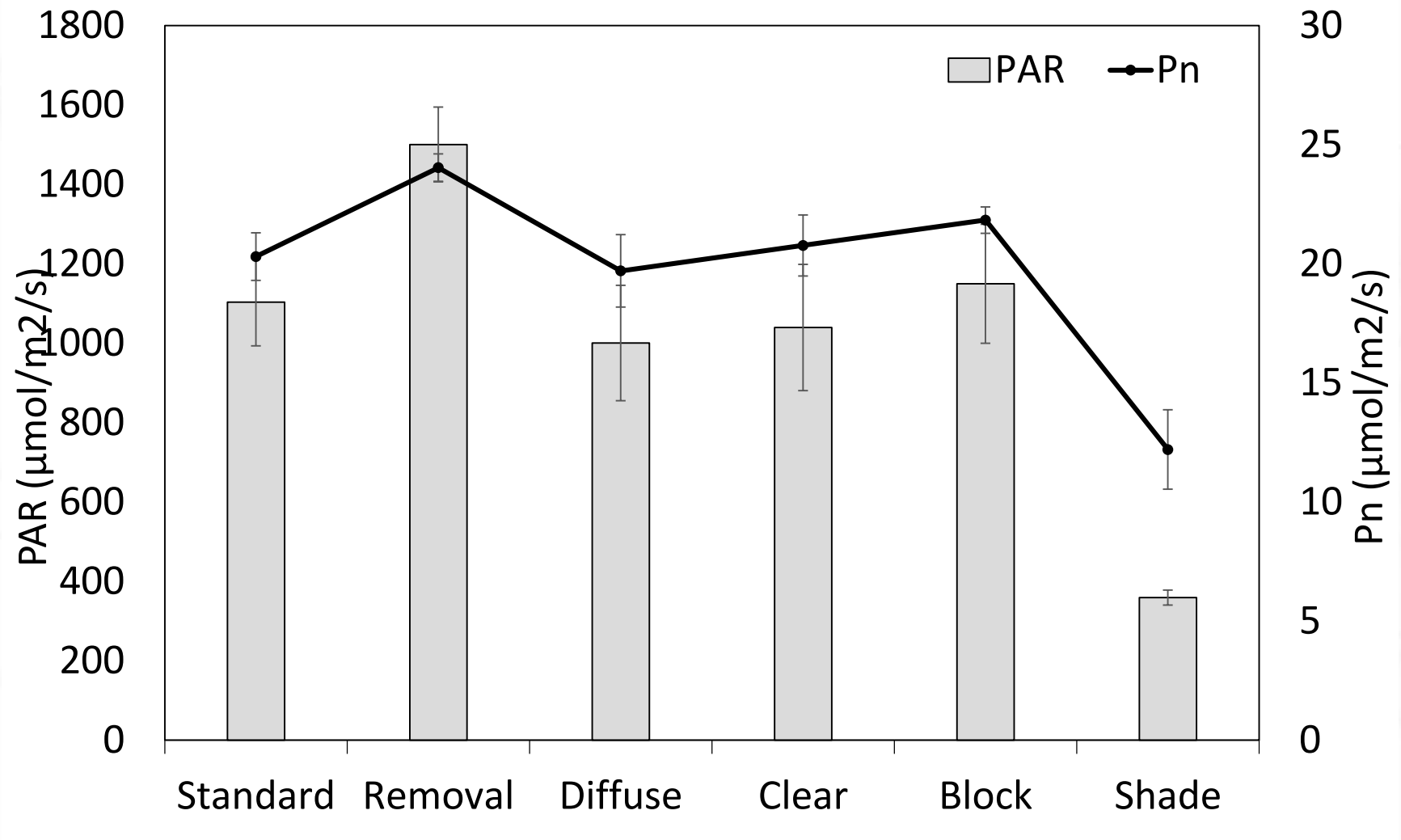


Temperature – Tomato

TRT - TOMATO	MAX - Canopy		MIN - Canopy		MAX - Soil		MIN -Soil	
STANDARD	29.8	bcd	19.5	b	25.3	bc	23.8	
REMOVAL	29.2	cd	21.2	a	25.5	b	23.8	
DIFFUSE	28.8	d	19.8	b	24.8	c	23.7	
CLEAR	30.3	abc	19.5	b	26.4	a	24.3	
BLOCK	30.9	a	19.4	b	26.2	a	23.8	
SHADE	30.3	ab	20.3	ab	25.8	ab	23.9	
OPEN	31.5	a	20.0	b	26.4	a	24.1	
	<.0001		<.0001		<.0001		NS	

Photosynthesis and PAR – Tomato



Combined Yield – Tomato

	Total Yield (kg/plant)	Marketable Yield (kg/plant)	Total Fruit Weight (kg/fruit)	Marketable Fruit Weight (kg/fruit)	Marketability (% by weight)	Plant Biomass (g)
Standard	6.53 A[2]	5.21 A	0.18 A	0.19 ab	76.5 ab	310
Removal	6.17 A	4.53 AB	0.18 A	0.18 ab	69.5 b	248
Diffuse	7.17 A	5.67 A	0.18 A	0.18 ab	73.3 ab	246
Clear	7.39 A	5.62 A	0.19 A	0.19 a	70.6 ab	278
Block	6.62 A	5.13 A	0.18 A	0.19 a	73.9 ab	311
Shade	4.40 B	3.72 B	0.15 B	0.15 b	77.7 a	209
P-value	<.001	<.001	<.001	< 0.05	< 0.05	NS[3]

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Vitamin C – Tomato

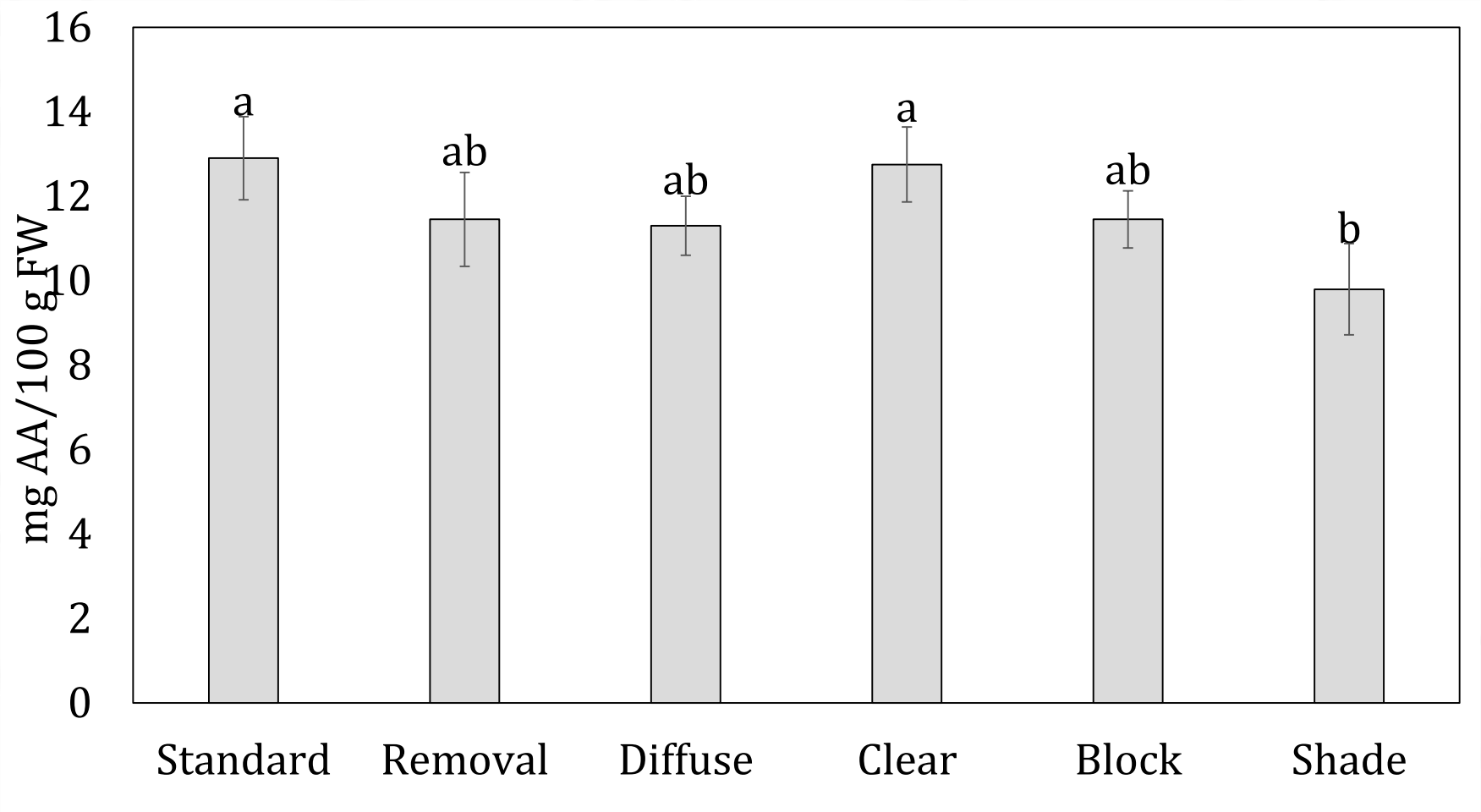
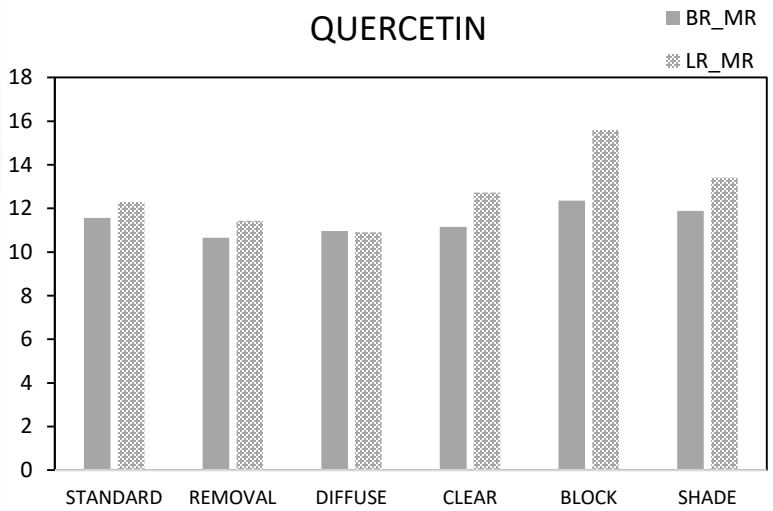
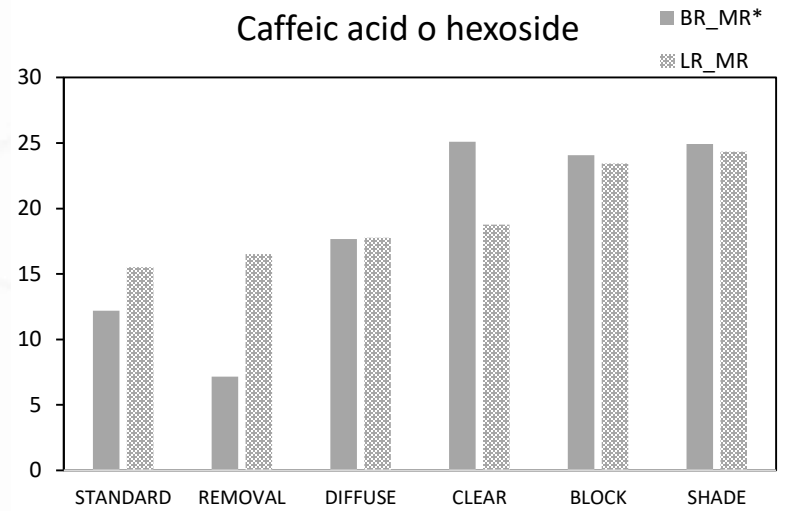
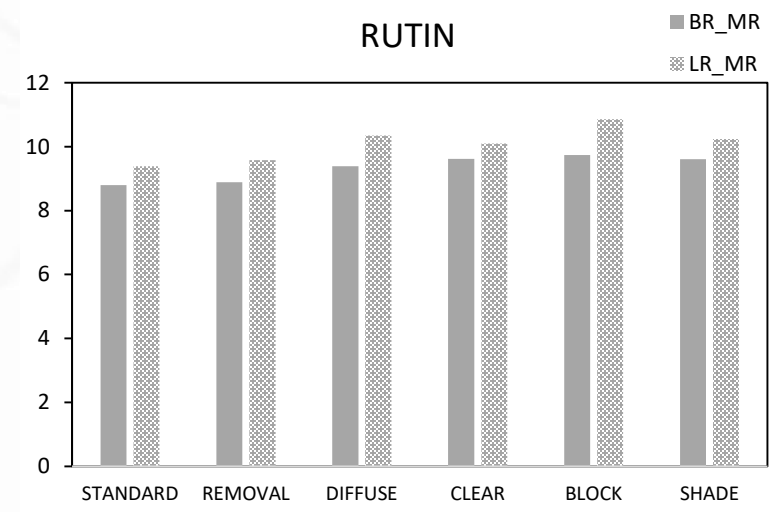


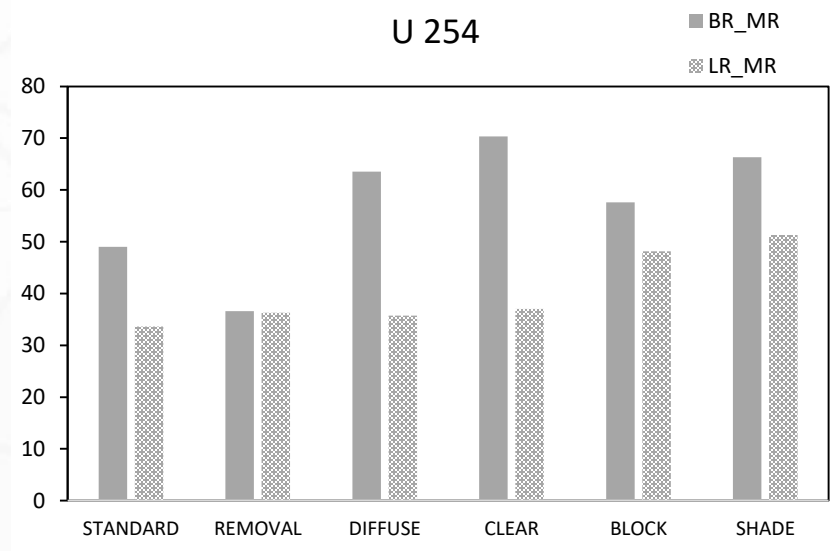
Figure 3. Ascorbic acid content (SE) in tomatoes harvested at 'breaker' and 'light red' maturity once reaching 'mature red' maturity (BR_MR and LR_MR, respectively). Significance: *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

Individual Phenolics – Tomato









PAR – Lettuce

Trts	PAR						
	Fall, Two Star	Spring, Two Star		Fall, Red Fire		Spring, Red Fire	
Standard	347.831	1340.78	a	503.105	a	1465.37	a
Removal	380.15	1498.06	a	614.634	a	1685.3	a
Diffuse	361.391	947.11	ab	373.17	ab	1139.28	ab
Clear	317.033	1278.78	a	496.098	a	1189.26	ab
Block	334.297	1050.73	ab	505.566	a	1416.71	a
Shade	171.547	474.42	b	218.683	b	562.29	b
P-value	ns	0.0076		0.0013		0.017	

Photosynthesis – Lettuce

Trts	Photosynthesis Rate (Pn)			
	Fall, Two Star	Spring, Two Star	Fall, Red Fire	Spring, Red Fire
Standard	5.20	26.66	4.74	18.28
Removal	4.08	23.22	5.18	12.11
Diffuse	4.13	12.41	3.88	13.86
Clear	3.00	21.17	4.49	18.59
Block	3.17	21.58	4.94	18.32
Shade	5.03	14.84	2.81	14.37
P-value	ns	ns	ns	ns

Yield – Green Leaf Lettuce

Yield analysis from fall harvests in 2017 (11/3-11/17) & 2018 (12/7-12/13) and spring harvests in 2018 (5/3-5/10).
*OF not statistically analyzed

Code	Treatment
SP	Std. poly
SP2W	Std. poly, removal 2 weeks prior to harvest
DP	Diffuse poly
CP	Clear poly
UVAUVB	UVA, UVB blocking
SCSP	55% shade cloth, std. poly
OF	Open field

	Green Leaf				
Trt	Fresh Wt. (g/plant)	Core length (cm)	Leaf Area (cm^2)	Moisture Loss (%)	DM
SP	68.67 A	18.43	127.22	18.23 AB	8.92
SP2W	79.67 A	18.13	139.27	15.97 B	8.82
DP	68.69 A	18.31	142.4	19.39 AB	8.60
CP	62.44 AB	17.48	136.07	18.78 AB	8.64
UVAUVB	56.65 AB	16.67	124.92	19.49 AB	8.68
SCSP	40.68 B	17.52	120.06	25.5 A	8.14
*OF	17.51				
P	< .01	**ns**	**ns**	< .1	**ns**

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*OF not statistically analyzed

Code	Treatment
SP	Std. poly
SP2W	Std. poly, removal 2 weeks prior to harvest
DP	Diffuse poly
CP	Clear poly
UVAUVB	UVA, UVB blocking
SCSP	55% shade cloth, std. poly
OF	Open field

Red Leaf					
Trt	Fresh Wt. (g/plant)	Core length (cm)	Leaf Area (cm^2)	Moisture Loss (%)	DM
SP	51.93 A	17.26 A	141.5 A	11.48	7.71
SP2W	51 A	16.06 ABC	120.28 AB	11.53	7.56
DP	52.13 A	16.71 ABC	120.59 AB	11.17	7.27
CP	45.57 AB	15.58 BC	105.32 AB	11.21	7.22
UVAUVB	39.58 AB	15.16 C	96.04 B	15.04	7.77
SCSP	29.61 B	16.18 ABC	99.1 B	16.56	7.91
*OF	14.1				
P		< .01	< .05	**ns**	**ns**

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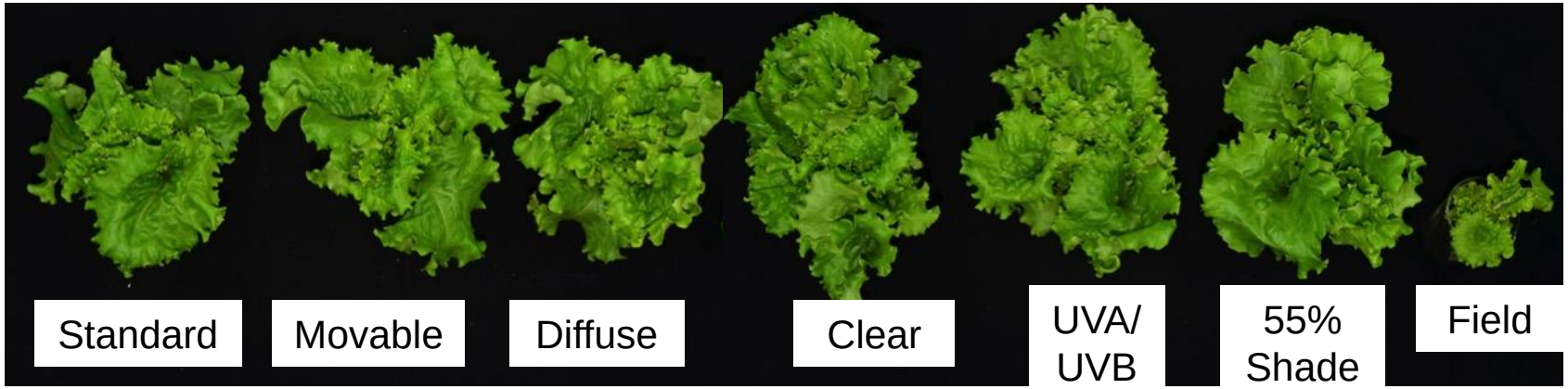
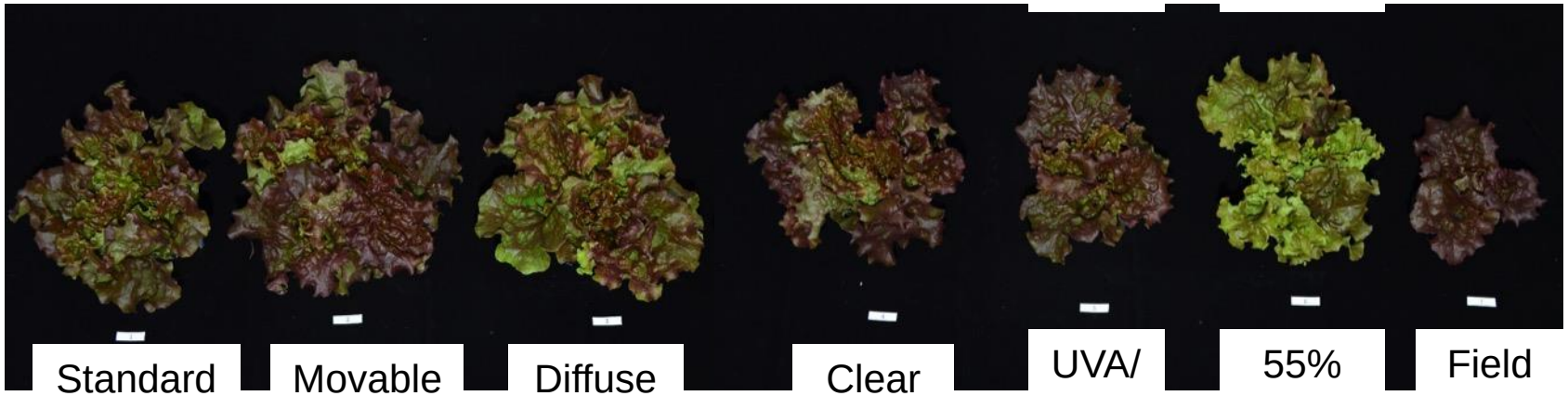
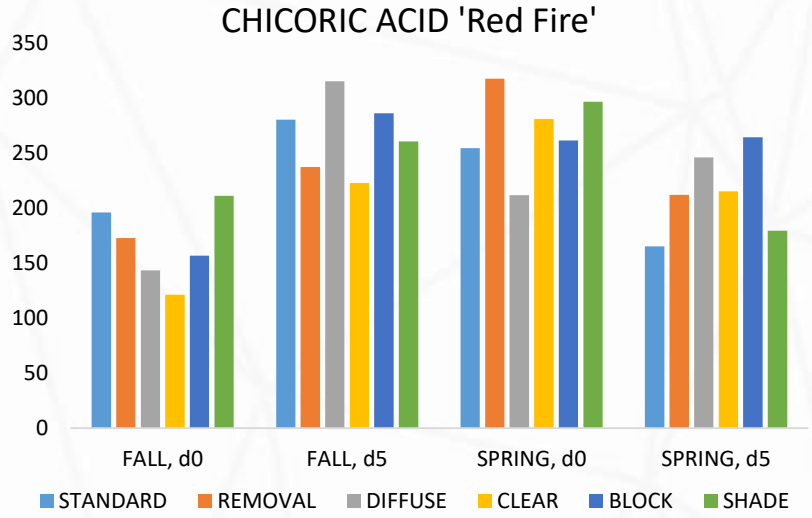
Color - Lettuce

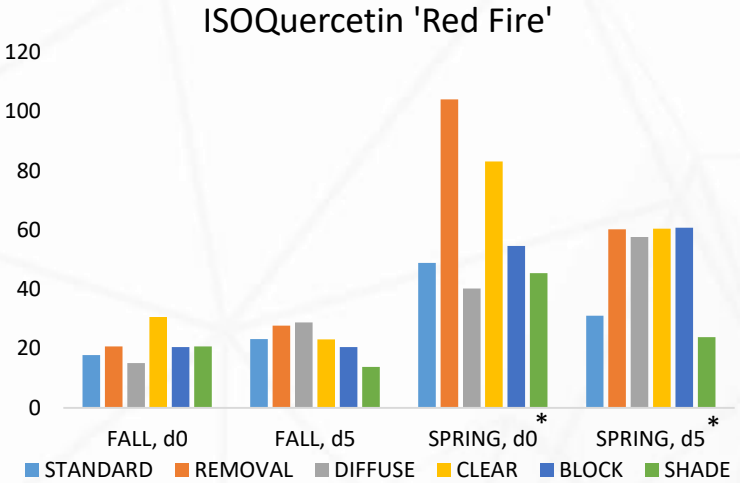
Effects Table	'Two Star'		'Red Fire'	
	Hue	Chroma	Hue	Chroma
SEASON	<.0001	0.0393	<.0001	<.0001
TRT	0.0002	0.0003	<.0001	<.0001
SEASON*TRT	0.0011	0.0003	0.5687	0.5918
DAY	0.1224	0.0088	0.1901	0.0129
SEASON*DAY	0.0035	<.0001	0.7033	0.0758
TRT*DAY	0.0367	0.2126	0.9225	0.9957
SEASON*TRT*DAY	0.0655	0.0299	0.853	0.9032

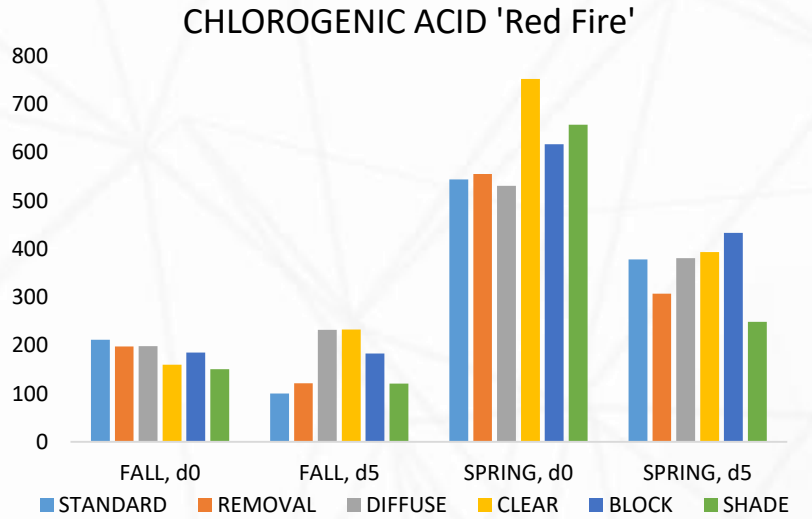


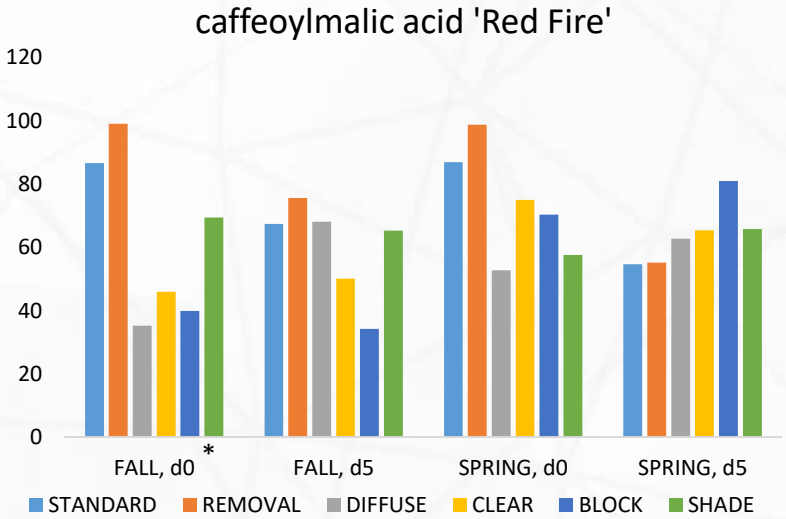


Phenols – Red Leaf Lettuce

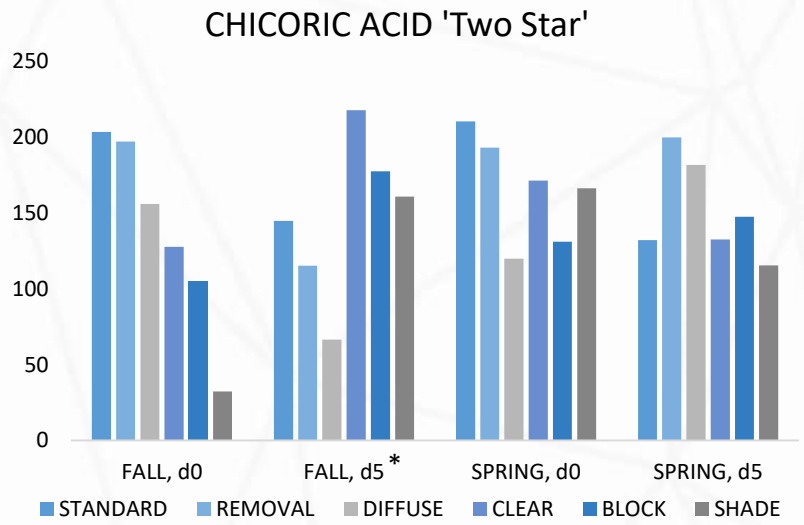


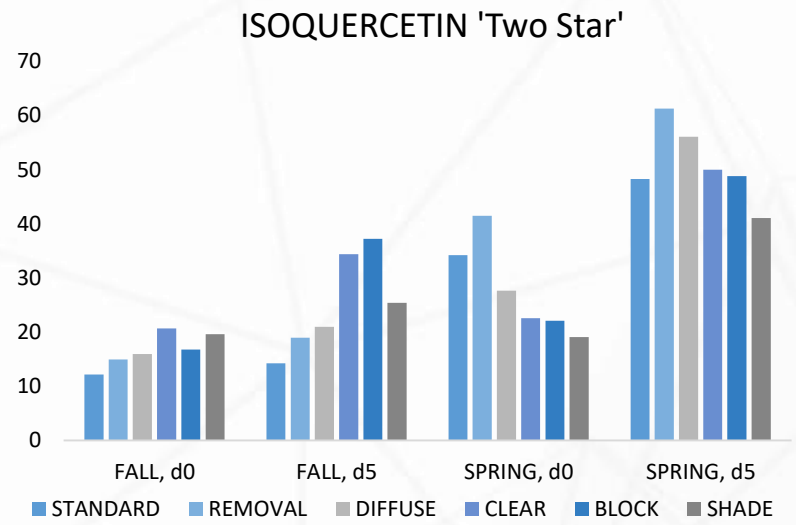


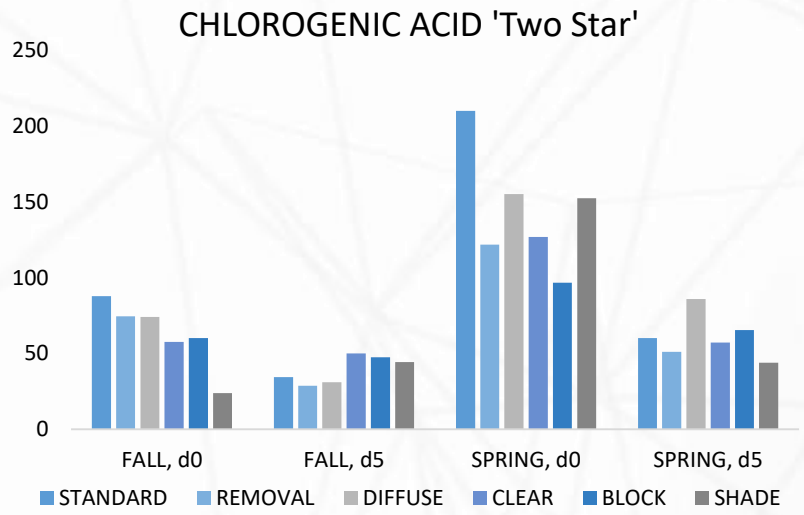


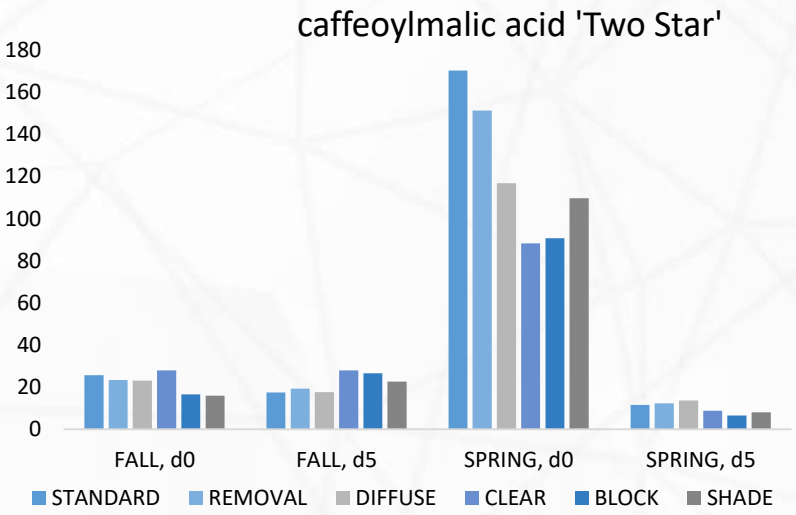


Phenols – Green Leaf Lettuce

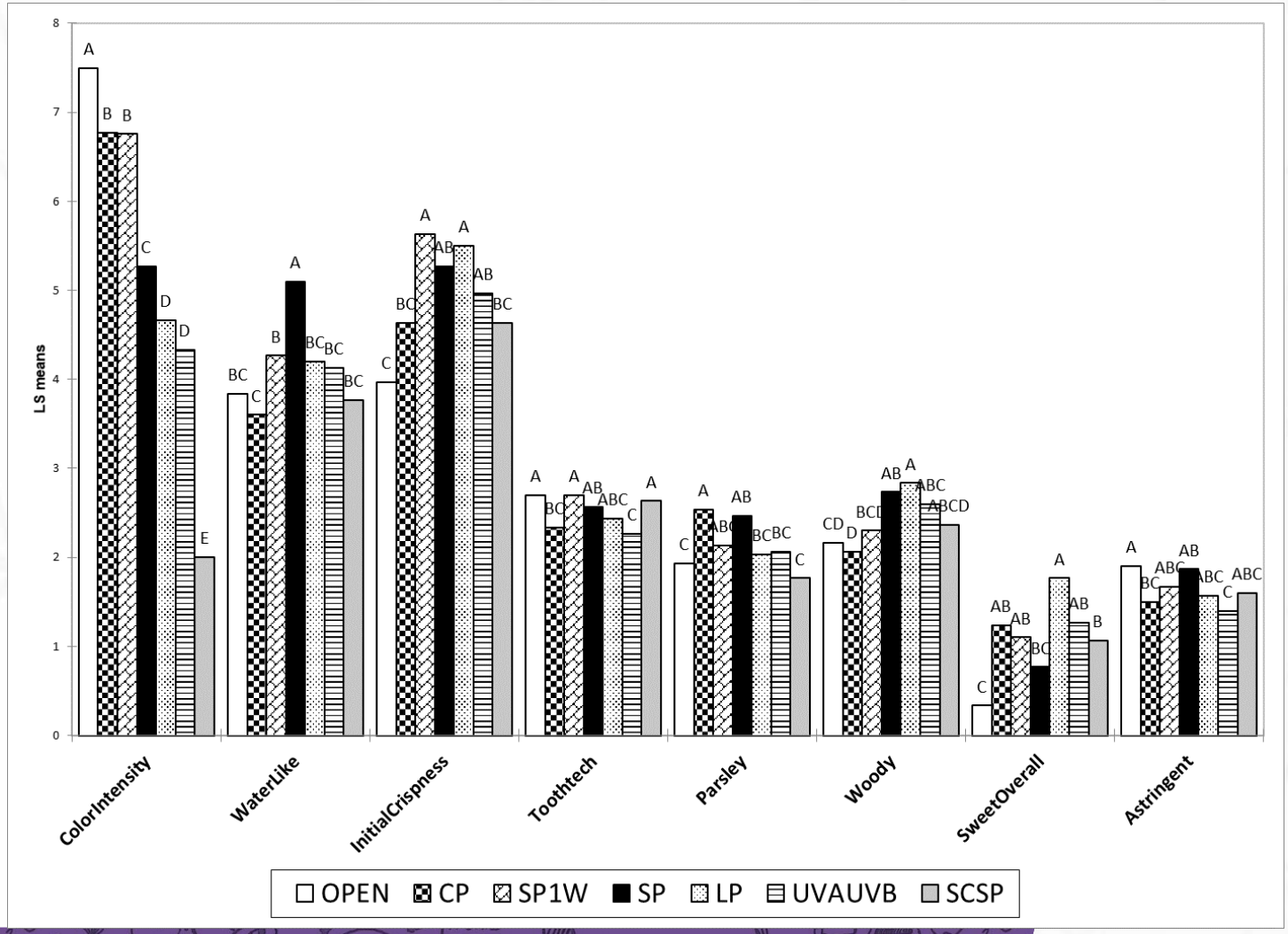




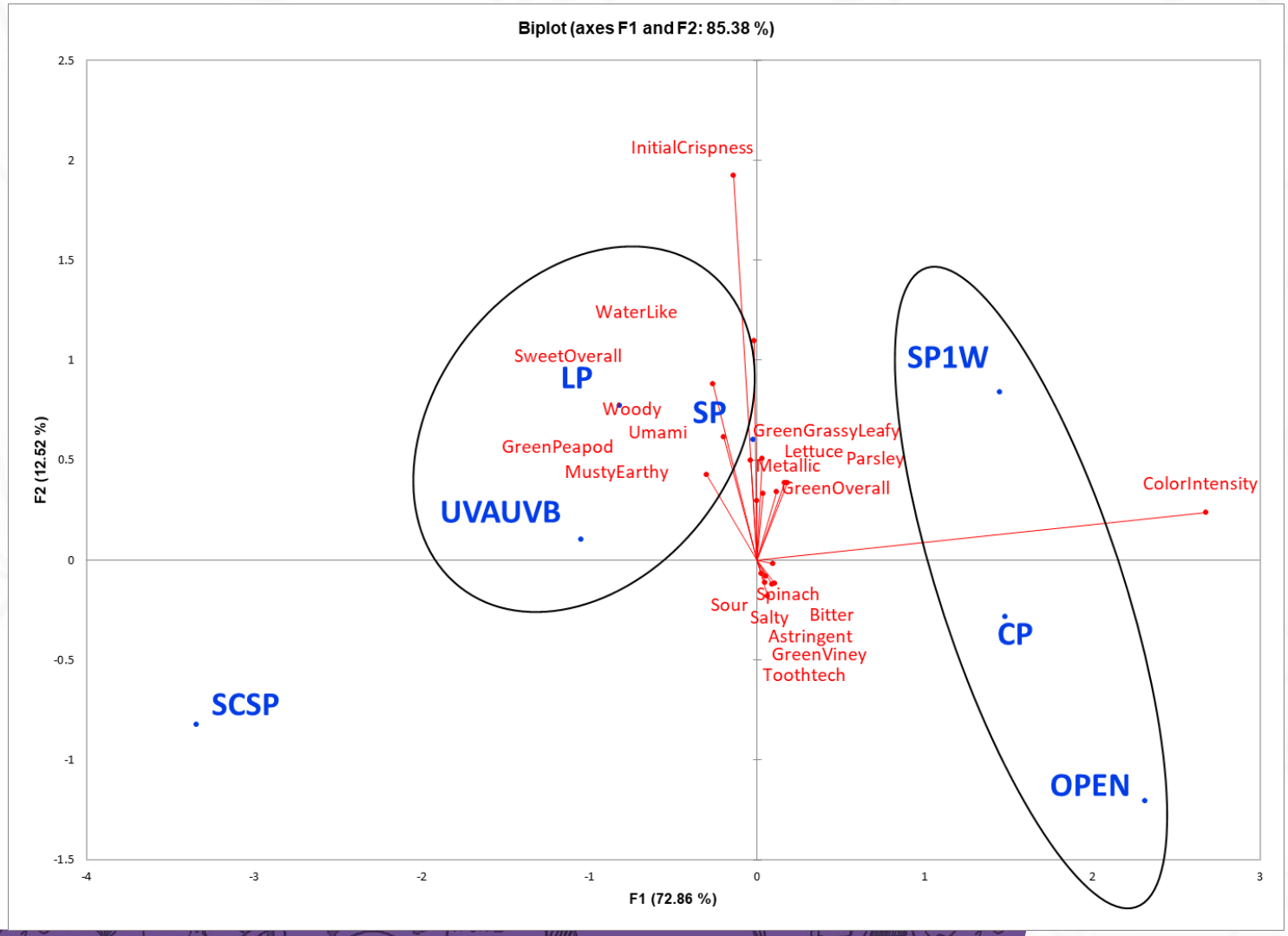




Consumer Sensory Analysis - Lettuce



Consumer Sensory Analysis - Lettuce



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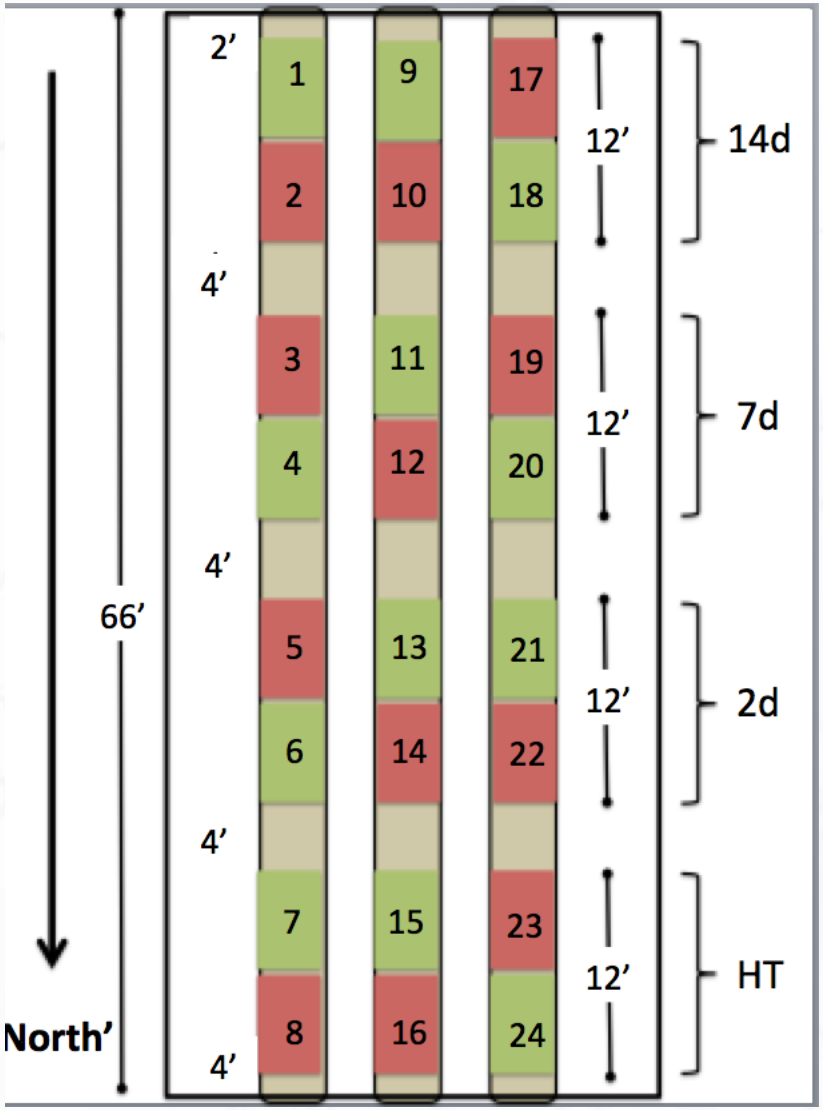
Movable Tunnel Project



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Movable Tunnel – Lettuce Yield

Red Leaf					
TRTs	Fresh Wt. (g/head)	Core length (cm)	Leaf Area (cm^2)	Moisture Loss (%)	Dry Matter (%)
SP	76.69	15.90 a	140.20 A	14.65	7.34 A
SP48h	88.11	14.98 ab	107.14 C	25.90	5.82 B
SP1W	97.36	15.19 ab	127.63 AB	29.56	5.72 B
SP2W	67.71	14.41 b	111.75 BC	29.39	6.27 AB
P		< .1	< .01		< .01

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Movable Tunnel – Lettuce Yield

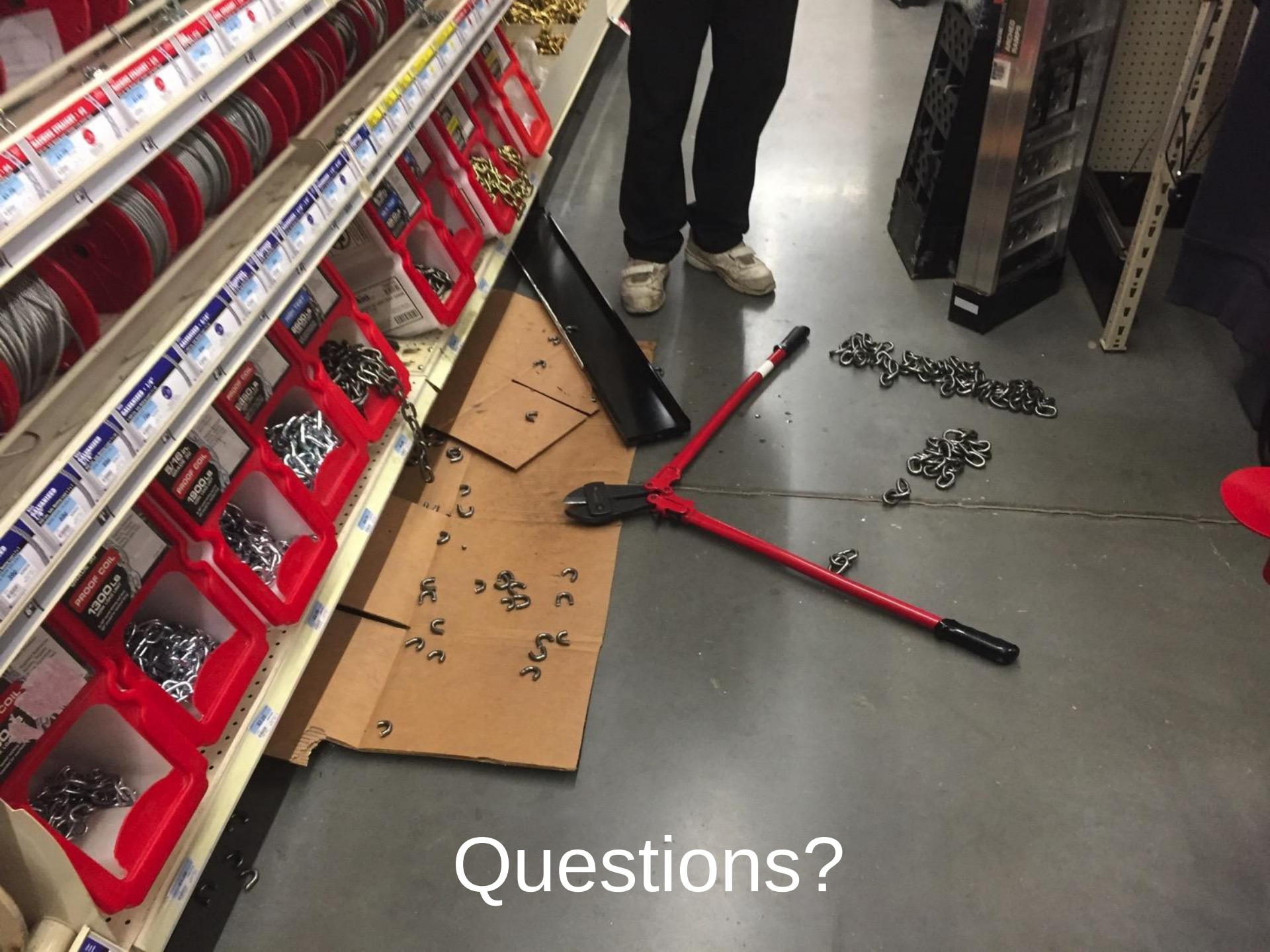
Green Leaf					
TRTs	Fresh Wt. (g/head)	Core Length (cm)	Leaf Area (cm^2)	Moisture Loss (%)	Dry Matter (%)
SP	105.97A	17.31A	120.30	18.23	7.60AB
SP48h	122.96A	17.98A	114.88	19.52	6.26B
SP1W	103.05AB	16.83A	103.55	19.31	7.31AB
SP2W	69.60B	13.96B	82.87	17.16	8.47A
P	< .05				< .05

Summary

- Manipulating light and microclimate is the next frontier in food production technology
  - Role of HTs
- Research is thin right now, but a few findings from our work:
  - UV light probably important, but not for everything
  - Phytochemicals can behave differently
  - ENVIRONMENT trumps HT covering
  - Light is likely impacting: microclimate, Pn, quality, and yield

Summary

- Grower Recommendations:
  - Standard poly performing well compared to other plastics (including clear)
    - Antioxidants
  - Diffuse plastics comparable with standard
  - Be careful with shade cloth
    - Yield, color (lettuce), phytochemicals
  - Industry recommendations may be suspect (transmission)
  - Movable tunnels provide a NEW option
  - More research is needed (and otw)



Questions?