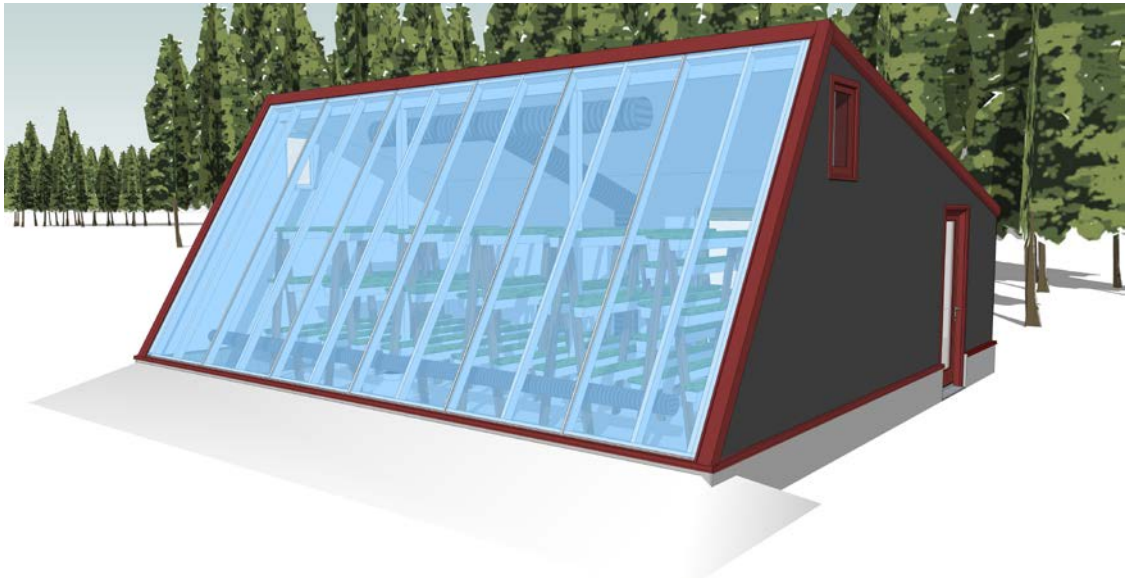
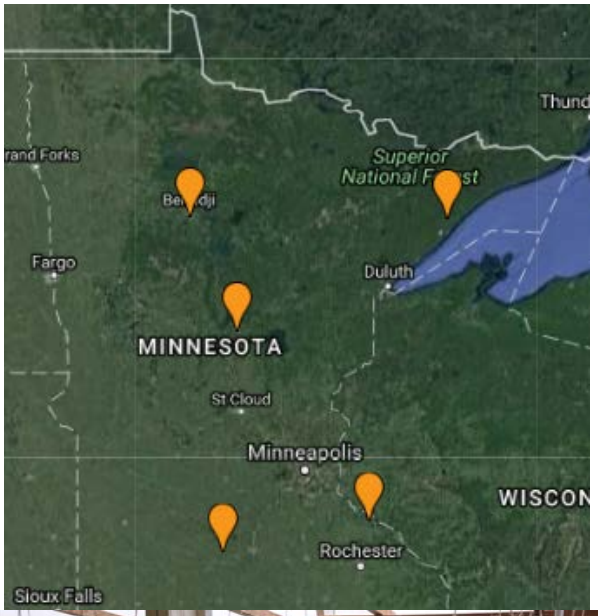
Deep Winter Greenhouse Research Convening

NOVEMBER 4, 2016

© 2011 Regents of the University of Minnesota. All rights reserved.

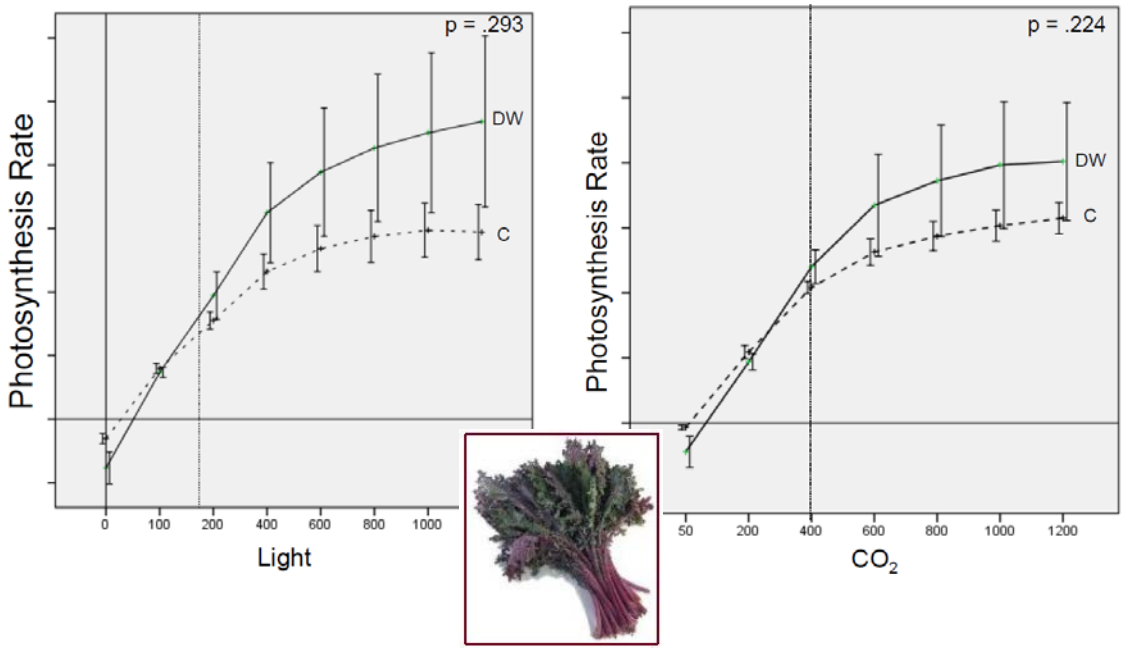
DEEP WINTER GREENHOUSE CAMPAIGN

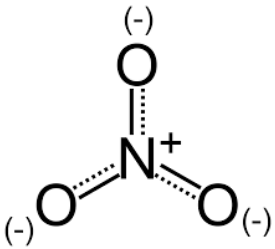




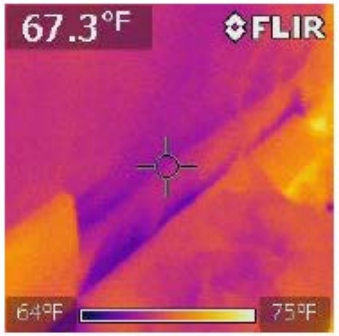
© 2011 Regents of the University of Minnesota. All rights reserved.

PREVIOUS RESEARCH





- Net earnings ranged from ($5/hr) to $20/hr (averaging 10 -13 hours/week)



© 2011 Regents of the University of Minnesota. All rights reserved.

OVERVIEW OF THE DAY

- New blood!
- Past and future research opportunities
- Discussion:
  - Shared research goals to optimize projects in the five research prototypes

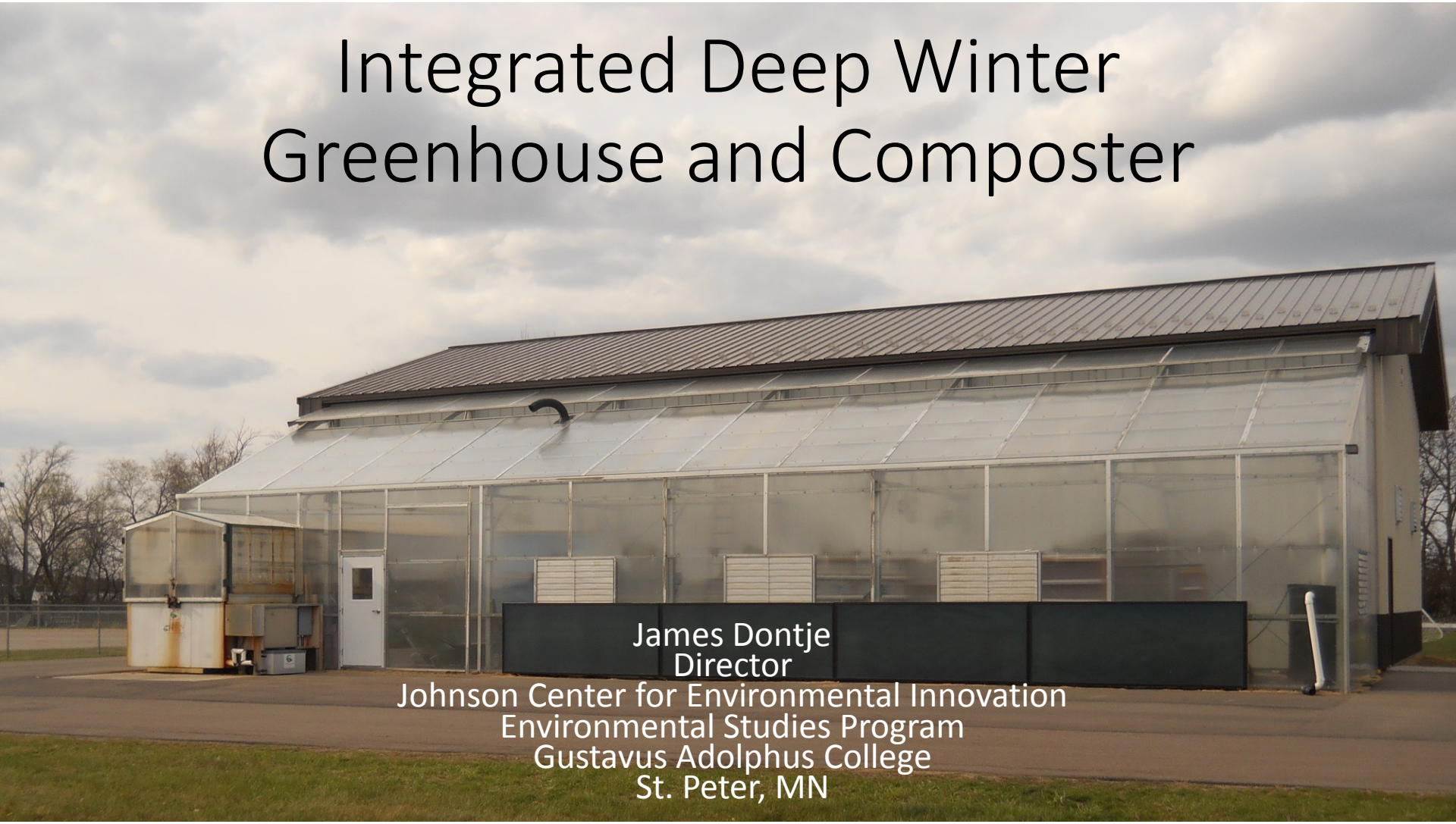
© 2011 Regents of the University of Minnesota. All rights reserved.

INTRODUCTIONS

- Name
- Where are you from?
- What is your affiliation? (UMN Dept, farm, organization, student, etc…)

© 2011 Regents of the University of Minnesota. All rights reserved.

Integrated Deep Winter Greenhouse and Composter



James Dontje
Director
Johnson Center for Environmental Innovation
Environmental Studies Program
Gustavus Adolphus College
St. Peter, MN

Project background

- Supportive Dining Services program
- Physical Plant support for composting
- Strong student interest and activism about composting
- Student garden, Big Hill Farm, beginning 2009
- Students noted mismatch between academic year and growing season
- Env. Studies senior seminar class explored the concept in Fall 2009

Project funding

- Unique grant from the Margaret A. Cargill Foundation
- Env. Studies faculty chose to allocate part of the funding composter/greenhouse concept
- Additional internal funds
- NSF grant funds for solar air heat panels

Composter and greenhouse design

- Integration of the two parts done without major architectural project (<$)
- Regulatory questions drove the inclusion of the large building
- Trying to find “off the shelf” solutions
- Flexibility for experimentation and research
- Teaching and production facility

Project timeline

- 2012-2013 Project planning and integration (shuttle diplomacy between Rimol Greenhouses and Morton Buildings)
- May 2013 Pole building construction
- July 2013 Vessel composter installed (Green Mountain Technology) and composter operation begins
- Fall 2013 Greenhouse frame construction
- 2013 to 2014 Greenhouse construction stalled
- Fall 2014 Greenhouse shell completed
- Spring and Fall 2015 hiatus (hydroponic experimentation)
- Spring 2016 Detail work: solar air heat system installed, biofilter upgrade, first growing cycle, back wall insulated

End of June 2013

End
of
August
2013

Fall 2014

Spring 2015

Winter 2016

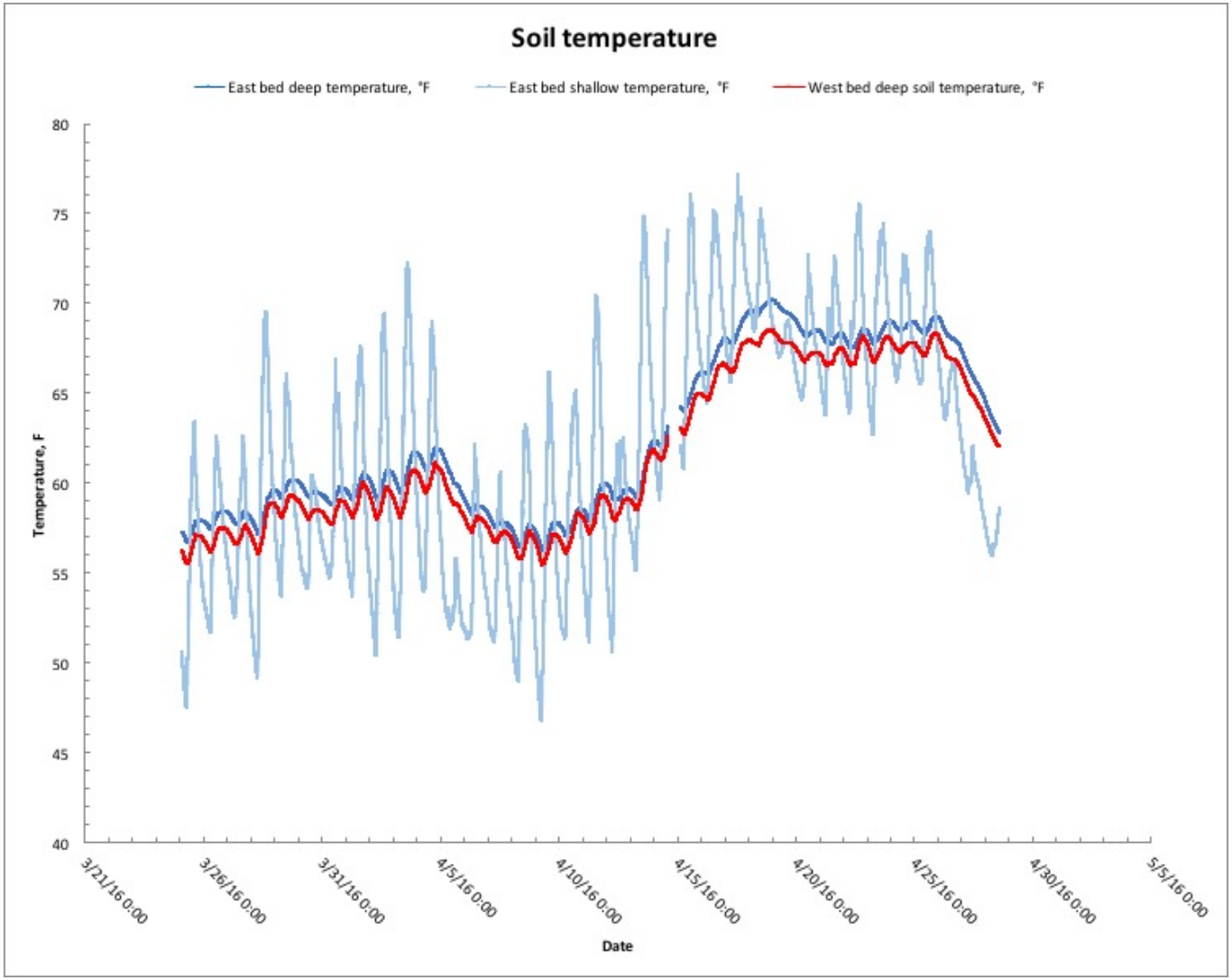
Spring
2016

Specifications

- 15’ x ~72-’ shell dimensions
- Composter vessel passes through greenhouse
- Double-wall polycarbonate
- Automated ridge vent
- Automated window vents
- Two ~10’ x ~20’ x ~2’ insulated sand beds
- 6” drain tile ducts with reverse return flow path
- Four 4’x10’ RREAL air heat panels (two per sand bed)
- Wood chip biofilter

Costs

- Main grant $250 K
- Solar panels and balance of system $10K
- Additional internal money $5-10K (insulation, wireless)
- In kind not charged to project (some labor, paving, site work)
- Some project costs driven by institutional setting (e.g. phone service, quality of doors, extra ventilation (that isn’t used))


Soil temperature
East bed deep temperature, °F
East bed shallow temperature, °F
West bed deep soil temperature, °F
Temperature, F
80
75
70
65
60
55
50
45
40
3/21/16 0:00
3/26/16 0:00
3/31/16 0:00
4/5/16 0:00
4/10/16 0:00
4/15/16 0:00
4/20/16 0:00
4/25/16 0:00
4/30/16 0:00
5/5/16 0:00
Date

Unfinished business

- Air sealing
- Rain water pressurization
- Hydroponic design
- Vertical growing surface
- Instrumentation and control

Design second thoughts, questions, and ”wish I could/would haves”

- Size of building (choices by compost operator) and greenhouse shape
- Insulation under beds or not?
- Media—sand or gravel or
- Solar panels vs. heat from within greenhouse vs. compost heat
- Loss of light from solar panel shading
- Composter design and cost
- Rainwater collection area (heavy flow onto vent)
- Agri-Lab heat exchanger

Research and development plans

- Maximize production cycle
- Temperature monitoring
- Comparison of compost vs. greenhouse space vs solar panels as heat source
- Affect of added thermal mass
- Monitor pest levels
- Compost management (CO2 production)
- Crop choice and fertility (compost sufficient?)
- Aquaponics and hydroponics

Questions?

DWG at Way Cool Farm

Owned and operated by Ryan and Kim Erickson

Specs – Constructed Sept 2015

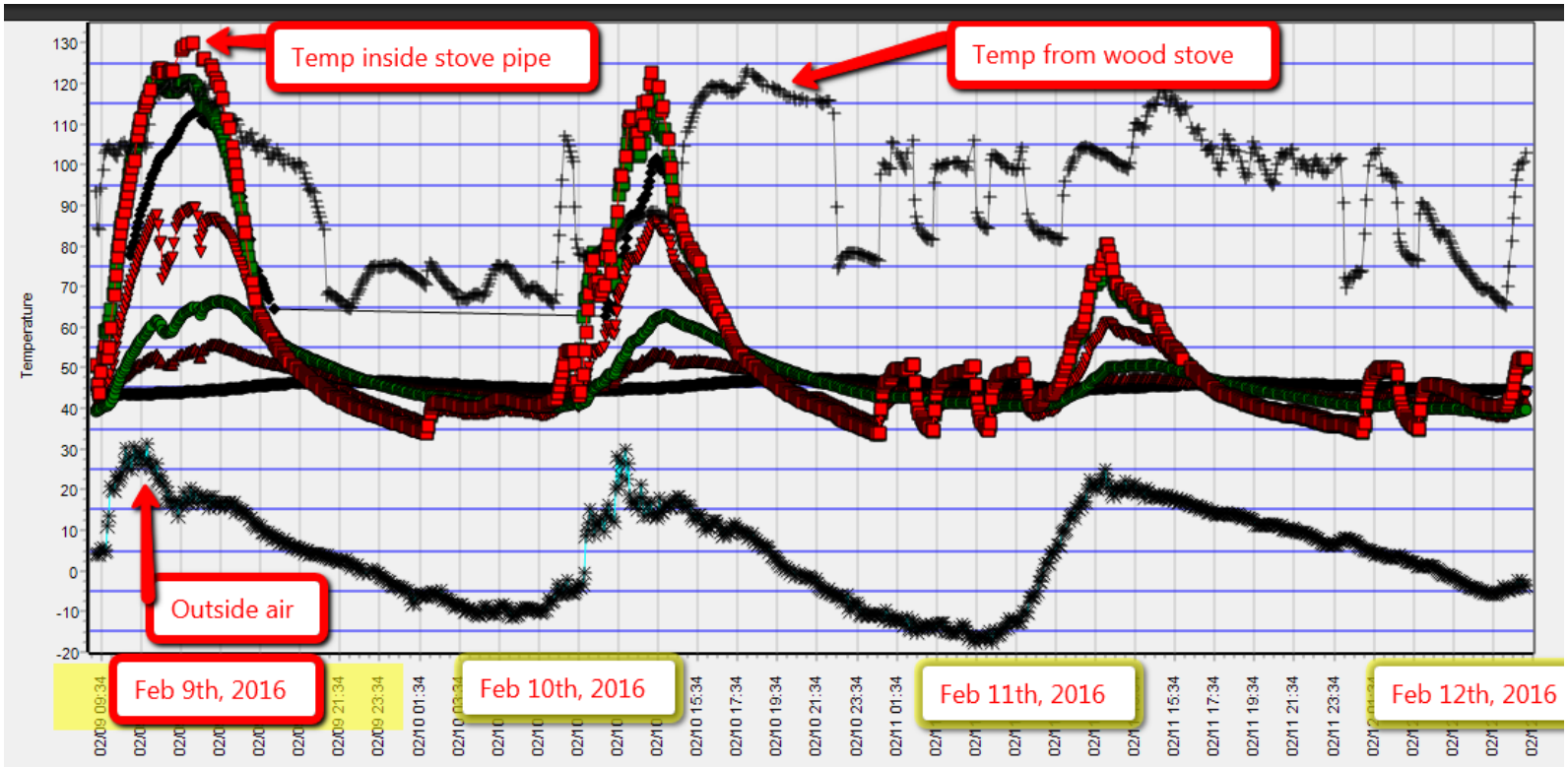
- 14X24 Pole Construction
- 10mm twin wall polycarbonate
- Attached to an existing structure – 12X18 woodshed
- Backup heat from wood boiler in the woodshed
- Peak height from ground is 14 feet
- No running water – 55 gallon drum is used for water

Construction

Passive Solar

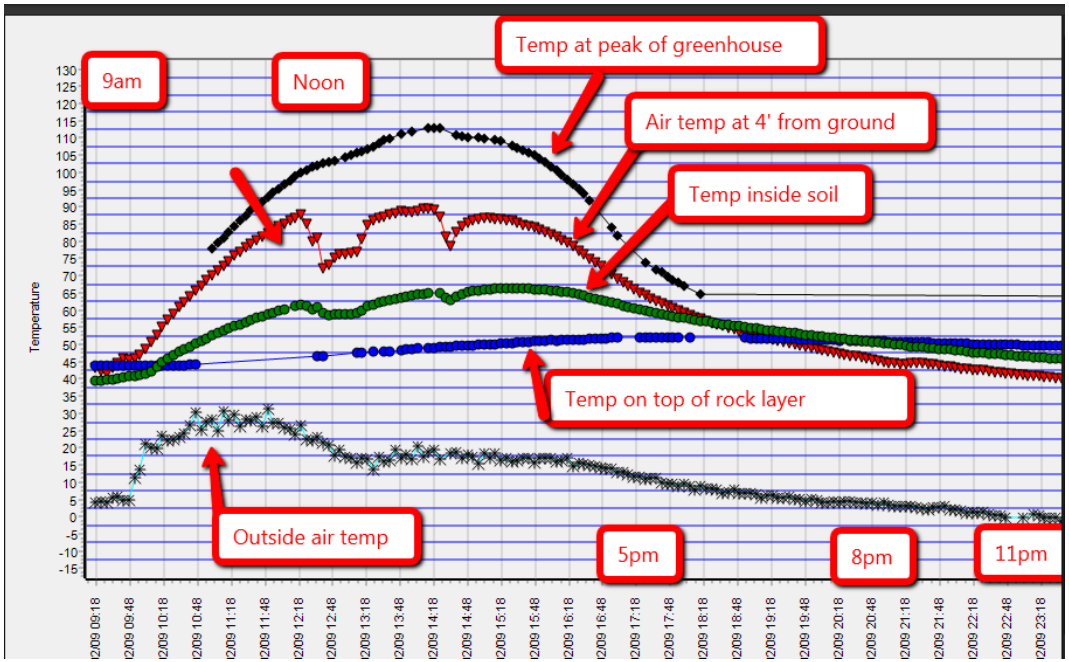
- Heat sink is a buried rock layer
- Implemented the “Northlands Winter Greenhouse Manual” method for passive solar heating
- Modified to “pull” air instead of “push” air
- 4 duct fans attached to 6 inch PVC
- 3 water filled 55 gallon drums

Temperature Monitoring



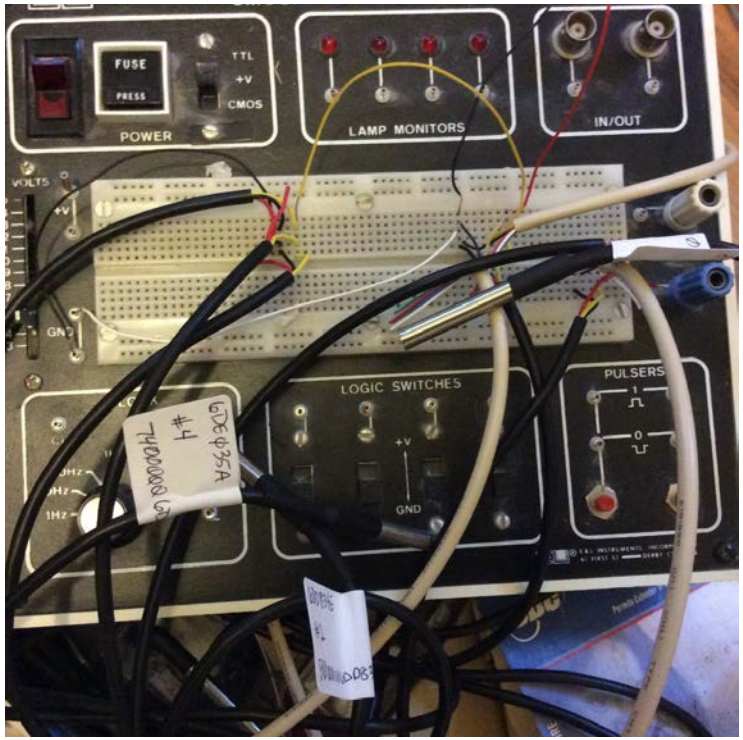
More temperature monitoring

- Temps at the rock layer don't vary much < 10 degrees
- Peak temps frequently reach well over 100 on sunny days in the middle of winter
- Need better ways to store the heat on sunny days



Temperature Measurements

- DS18B20 temperature probes encased in stainless steel
  - Probes can be connected together along 1 wire
- DS9490R 1 Wire USB Adapter – used to connect probes to the PC
- Custom application written to read the temperature probes
  - Each probe has a serial number which is used to read the current temperature at the probe



To Do List

- Add raised bed growing space, currently only gutters in use
- Experiment with LED grow light strips
- Add more sensors like humidity and light intensity
- Experiment with moving air through buried pipe to warm the air for the greenhouse
- Build another bigger DWG!

Soil and Tissue Nitrate in DWG Production

Carl Rosen, Liz Perkus, Justin Carlson,
Joanne Slavin, and John Erwin

Departments of
Soil, Water, and Climate
Horticultural Science
Food Science and Nutrition

Background

- MnDrive funding: Interdisciplinary research projects that address grand challenges and include industry partnerships as a key component

- "Reinventing year-round local food production in Minnesota"
  - Optimize vegetable production using winter greenhouses
  - Identify crops, growing environments, nutritional requirements, nutritive value, economics

Approach

- Tested 6 crops with varying fertilizer amendments in the St. Paul Campus greenhouses during the winter
  - Arugula, red giant mustard, mizuna, kale, spinach, cucumber, and strawberry
  - Conventional fertilizer, fish emulsion, dried poultry compost, purple cow potting mix, leaf compost + organics
  - Sampled soil and tissue in all treatments

- Compared data with soil and tissue nutrients from DWG from participating growers

Nitrate is a Concern in Leafy Greens

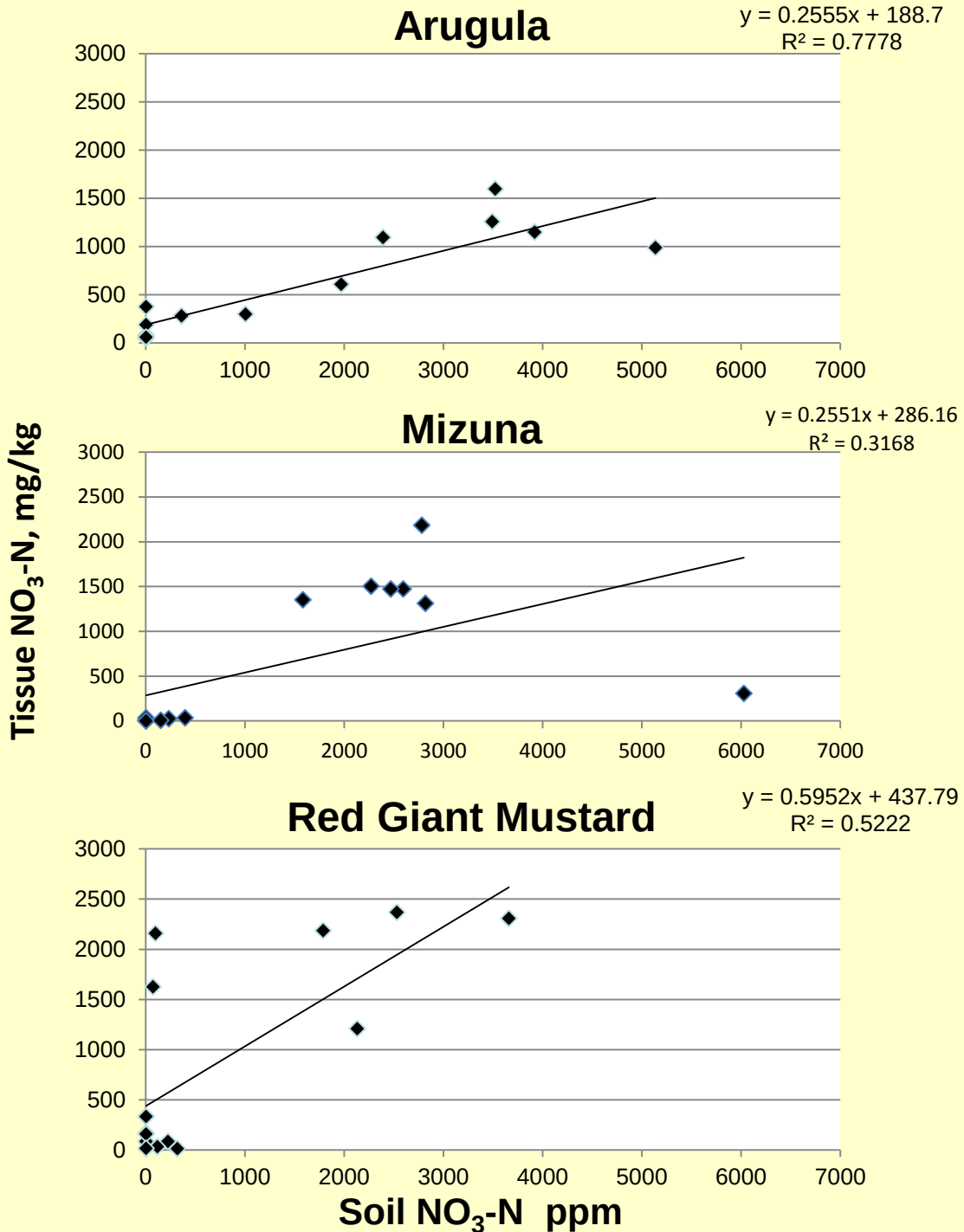
- Leafy greens accumulate nitrate in their leaves and especially do so in the winter
- Fresh and processed leafy vegetables are major sources of dietary nitrate
- Nitrate is not carcinogenic, but can form compounds that are
- Standards for dietary nitrate have not been set for the U.S., but there are European standards

Factors Affecting Nitrate in Greens

- Type and amount of fertilizer used
  - Conventional fertilizer generally (but not always) results in tissue higher nitrate than organic sources
  - The higher the rate of fertilizer applied the higher the tissue nitrate
- Low light and low soil temperatures usually increase tissue nitrate
- Plant species and variety

Soil Nitrate-N Levels

Fertilizer Amendment	Initial	Harvest
	-------- Nitrate-N, mg/kg -------	
Conventional	3733	< 5 - 205
Dried Poultry Compost	< 5	< 5 - 147
Fish Emulsion	1016	< 5 - 434
Purple Cow	1206	792 - 4194
Leaf Litter + Organics	3492	1197 - 3686



For a given level of soil nitrate, Red Giant Mustard accumulated more tissue nitrate than Arugula or Mizuna

Tissue nitrate-N expressed on a fresh weight baiss

Soil and Tissue Nitrate

Growers Survey

	Nitrate-N, mg/kg
Soil	<5 - 16,657
Tissue - Mizuna	70 - 1,878
Tissue - Red Giant Mustard	60 - 2,520

Implications

- European Standard – Allowed Daily Intake
  - 0.84 mg NO_3-N/kg body wt per day
- A 130 lb (59 kg) person could have
  - 50 mg NO_3-N per day
- A 160 lb (73 kg) person could have
  - 61 mg NO_3-N per day

Implications

- One ounce portion = 28 grams would supply:
  - 100 mg/kg NO_3-N = 2.8 mg NO_3-N
  - 500 mg/kg NO_3-N = 14 mg NO_3-N
  - 1000 mg/kg NO_3-N = 28 mg NO_3-N
  - 1500 mg/kg NO_3-N = 42 mg NO_3-N
  - 2000 mg/kg NO_3-N = 56 mg NO_3-N
  - 2500 mg/kg NO_3-N = 70 mg NO_3-N

- 1 gal of water at 10 ppm NO_3-N = 38 mg NO_3-N

Summary & Recommendations

- Avoid over fertilization
  - Both organic & conventional fertilizers can contribute to tissue nitrate in leafy greens
- Monitor soil nitrate levels in the soil and tissue
- Mix in lower nitrate accumulating greens (brassicas have higher nitrate than lettuce)

CAROL FORD

- UMN RSDP, DWG outreach specialist
- Garden Goddess, Milan, Minnesota

© 2011 Regents of the University of Minnesota. All rights reserved.

Reinventing Year-round Greenhouse Food Production in Minnesota

John Erwin

Controlled Environment Extension Specialist

Department of Horticultural Science

University of Minnesota

erwin001@umn.edu; 612-385-6863

MINNESOTA'S BUSHEL BOY™

Conventional and Deep Winter

Conventional Greenhouse

Deep Winter Greenhouse

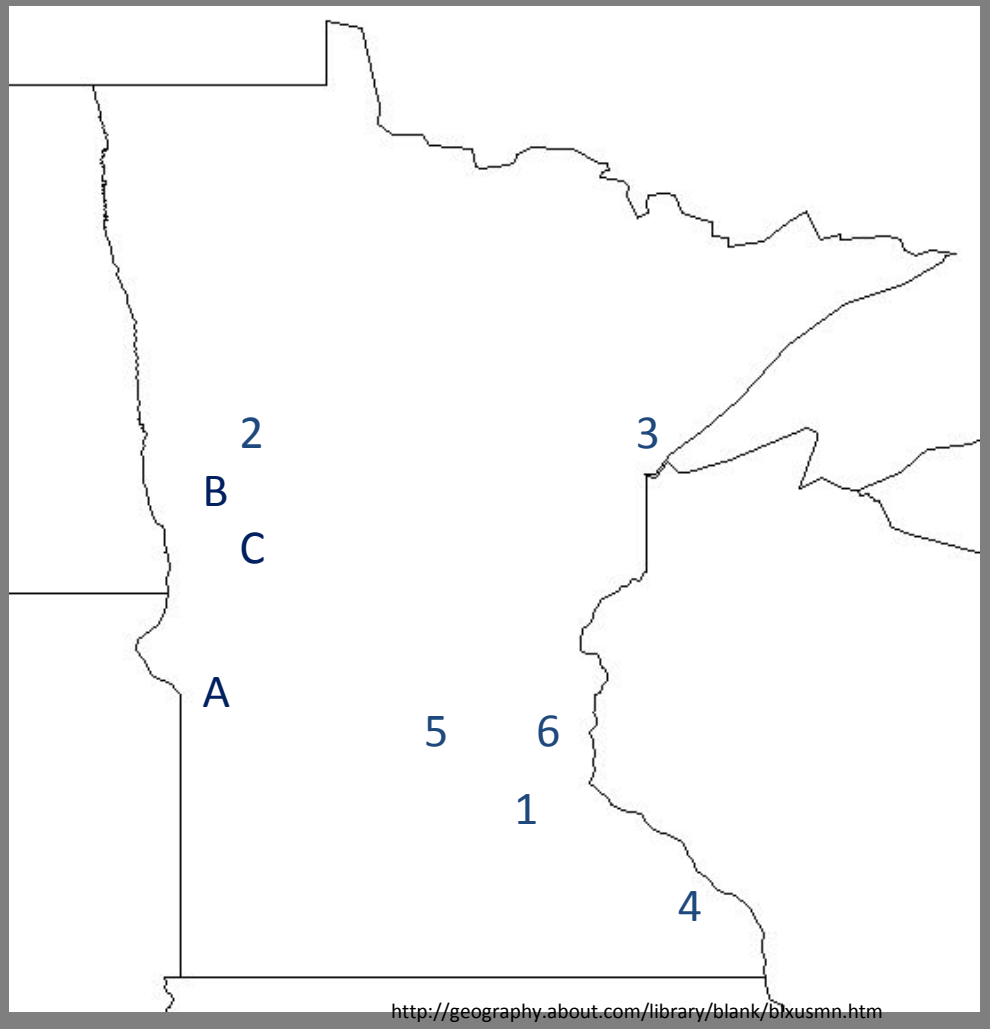
Commercial Survey Test Sites

Conventional Greenhouses:

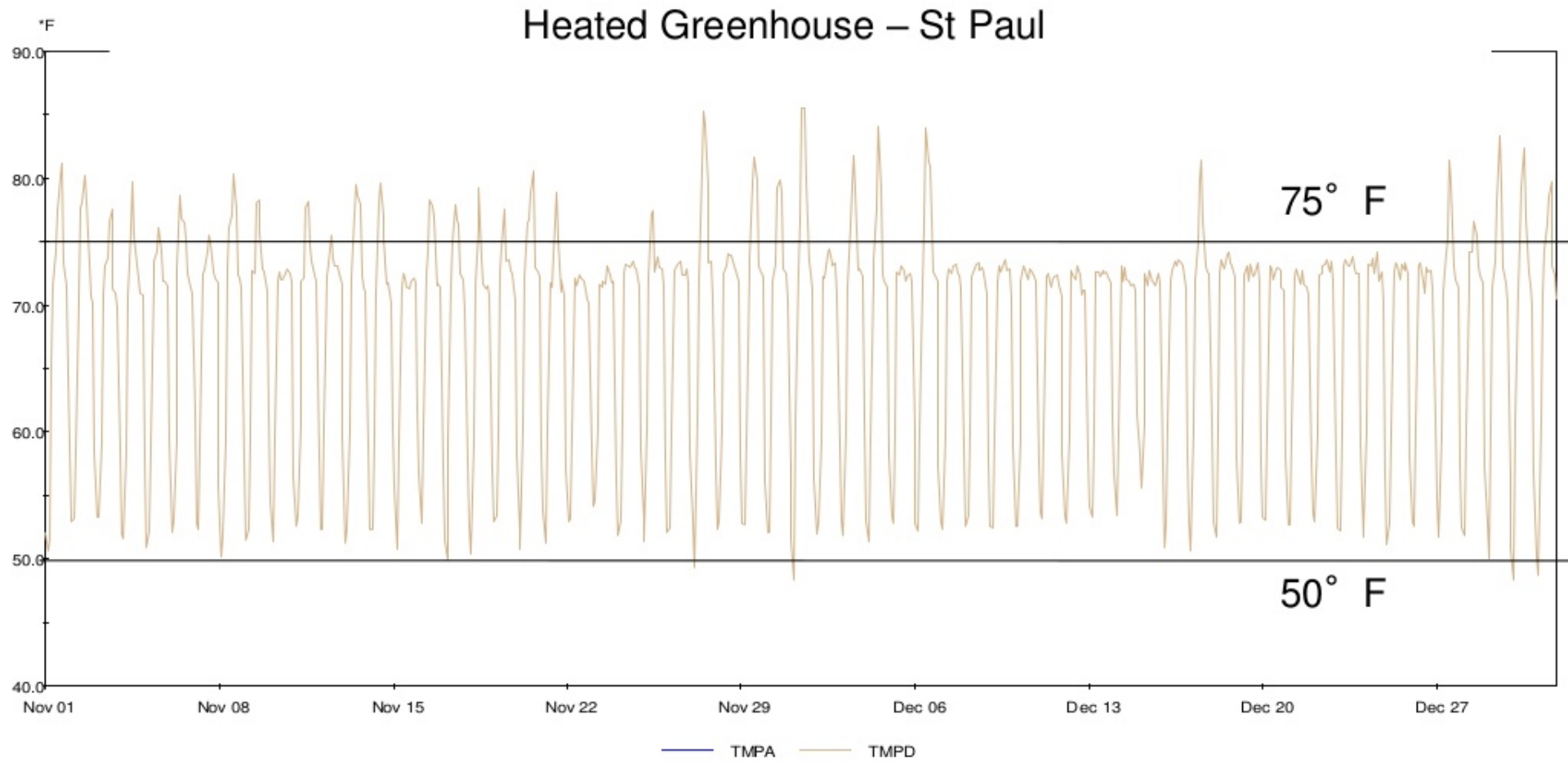
1. Bachmans
2. Bergens
3. Engwalls
4. Pork and Plants
5. Tangletown Gardens
6. UMN Twin Cities

Deep Winter Greenhouses:

A. Garden Goddess
B. Lida Farm
C. Paradox Farm

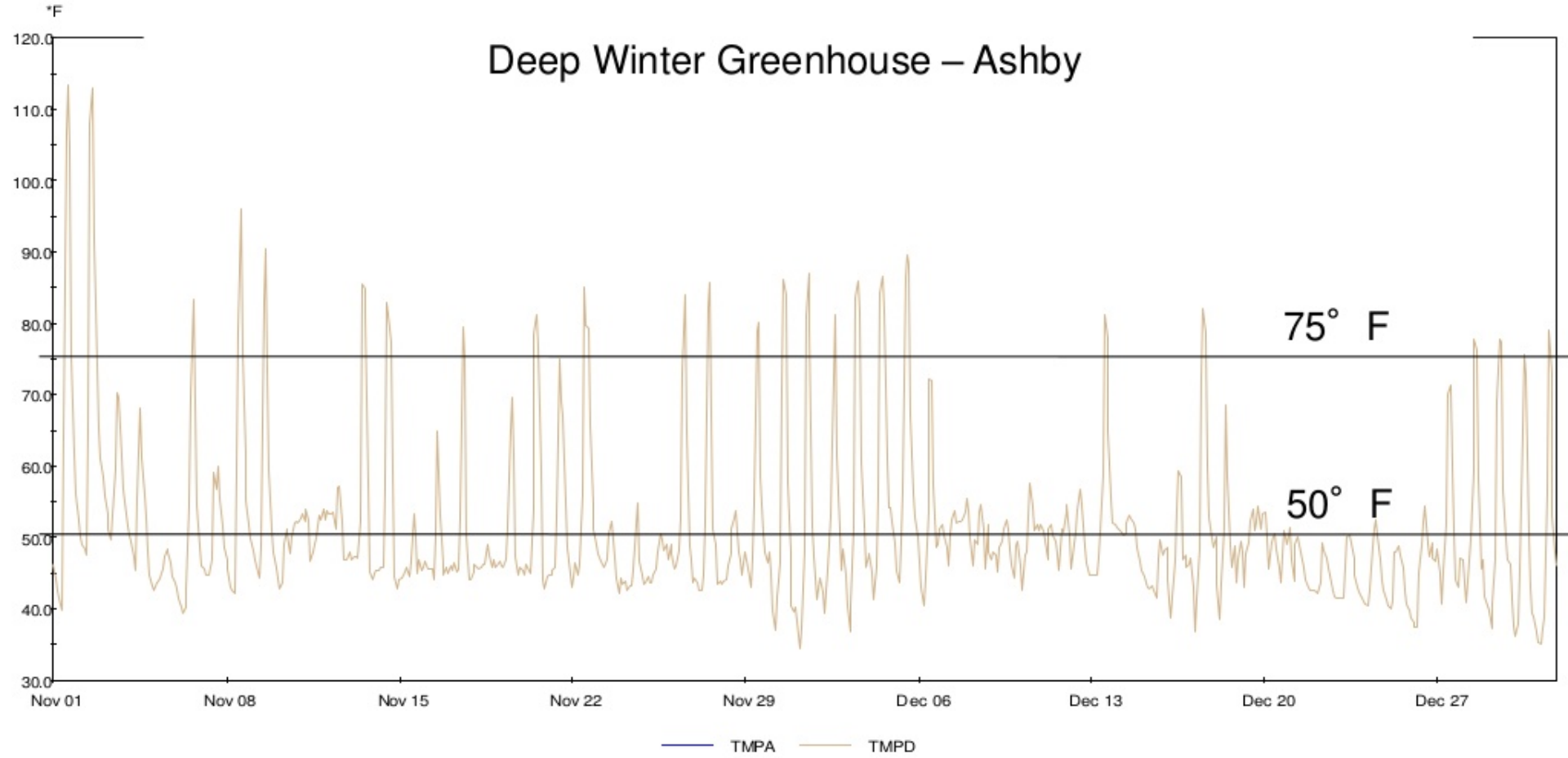


Conventional Greenhouse

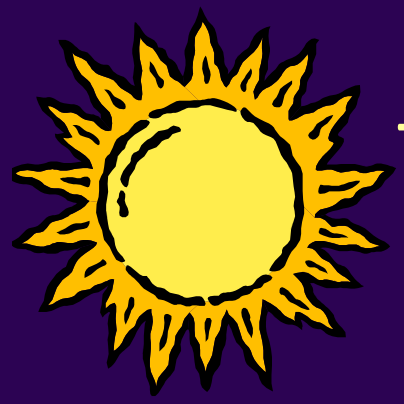


UNIVERSITY OF MINNESOTA

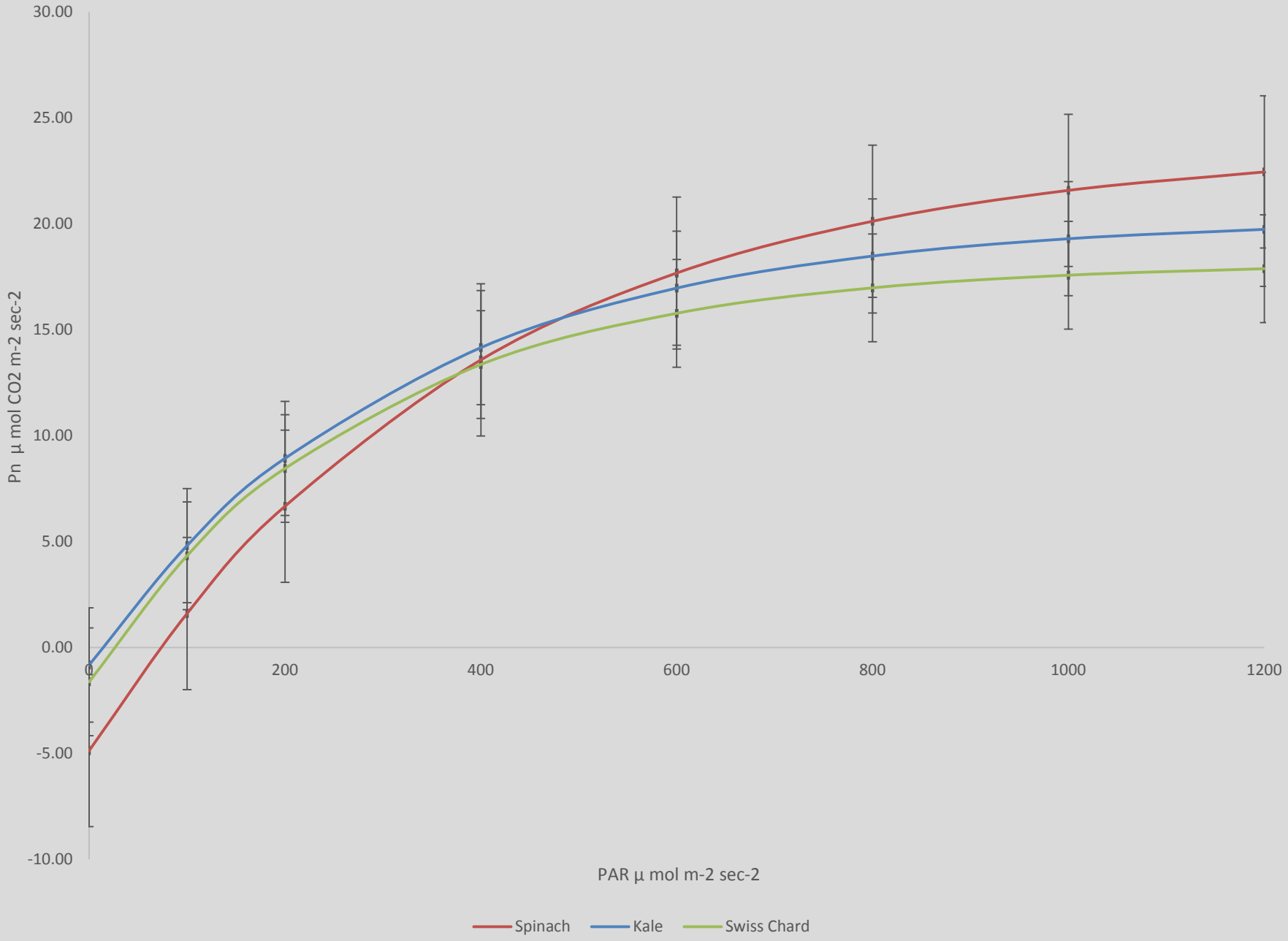
Deep Winter Greenhouse

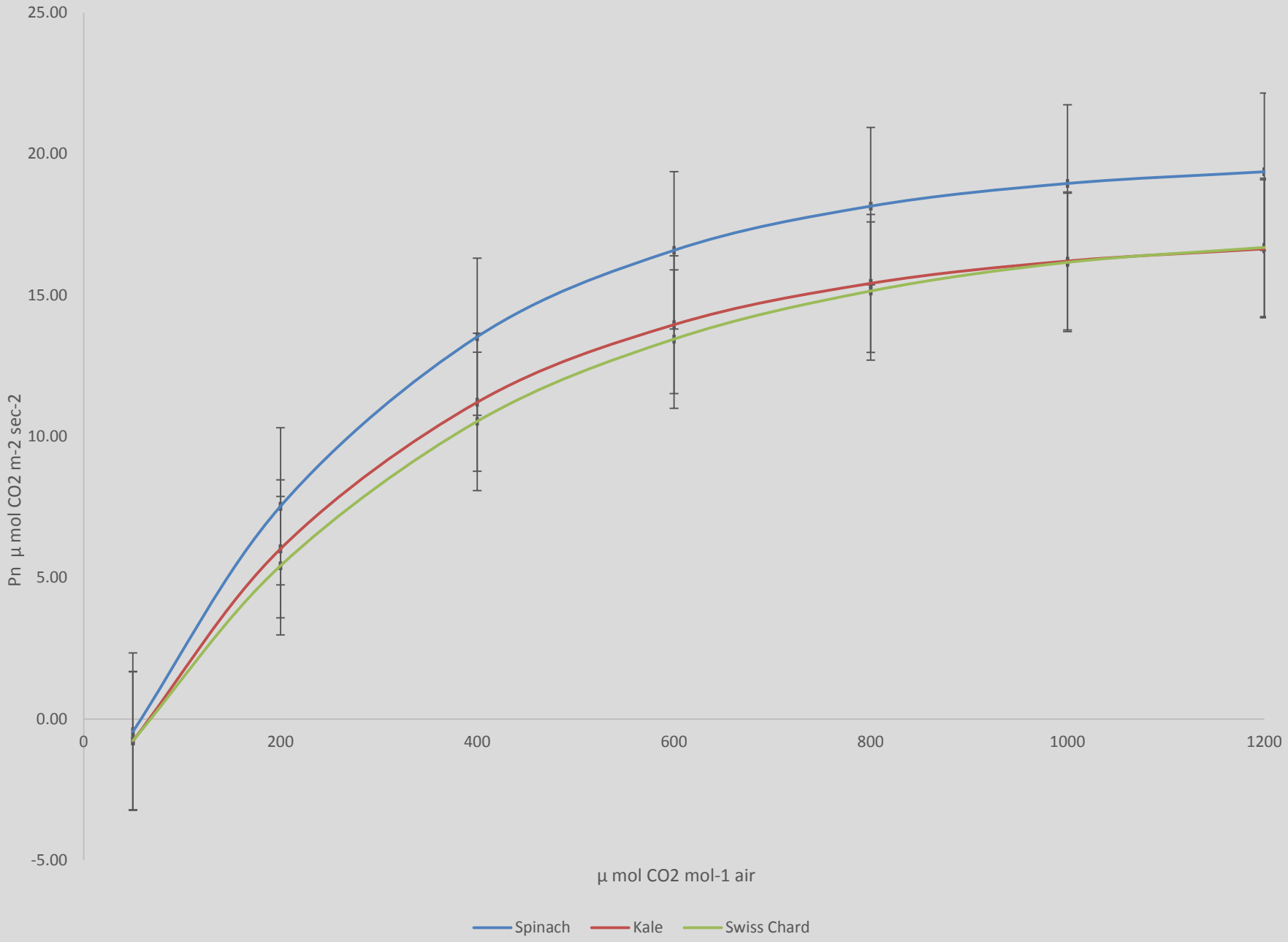


How much light can a plant use for photosynthesis?



$+ \; CO_2 + H_2O \rightarrow C_2H + O_2$


30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
Pn µ mol CO2 m-2 sec-2
0
200
400
600
800
1000
1200
PAR µ mol m-2 sec-2
Spinach
Kale
Swiss Chard


25.00
20.00
15.00
10.00
5.00
0.00
-5.00
Pn µ mol CO2 m-2 sec-2
0
200
400
600
800
1000
1200
µ mol CO2 mol-1 air
Spinach
Kale
Swiss Chard

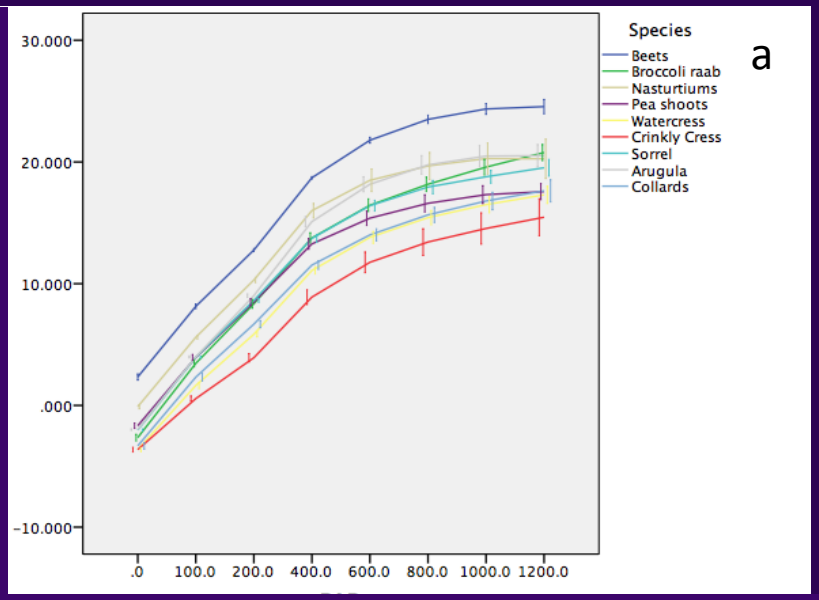
Sealing up gaps lowers CO_2

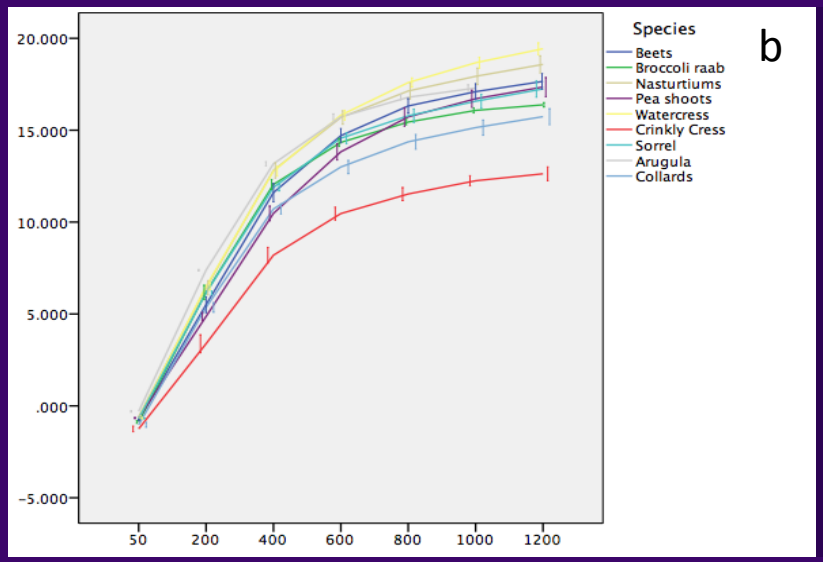
In 1 hour, CO_2 can drop to:

370 in low light
or small plants

340 in medium light
or medium plants

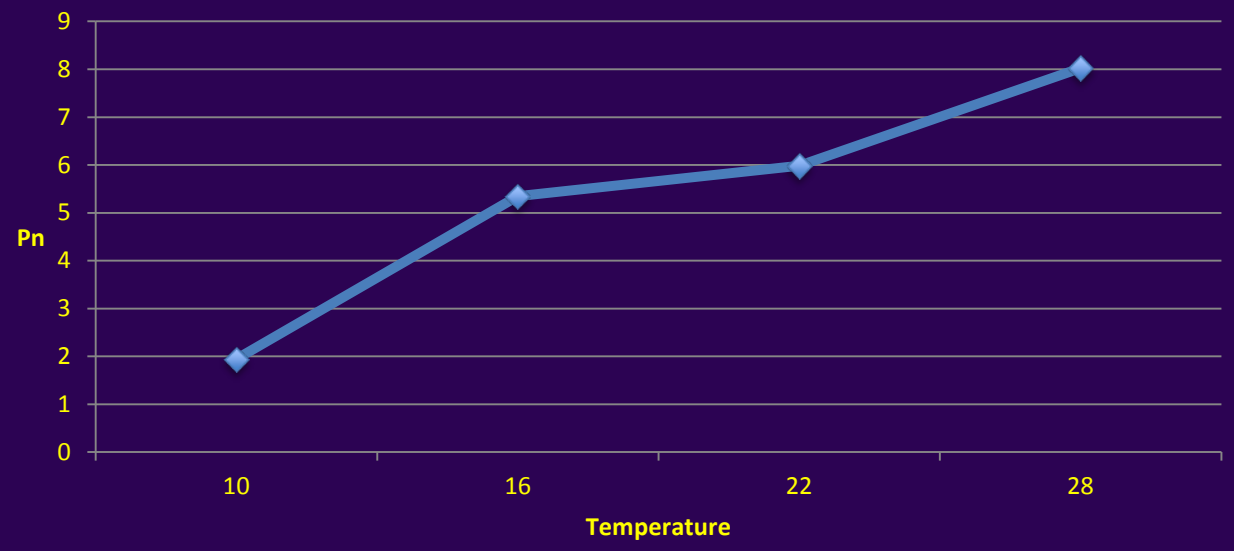
310 in high light
or large plants



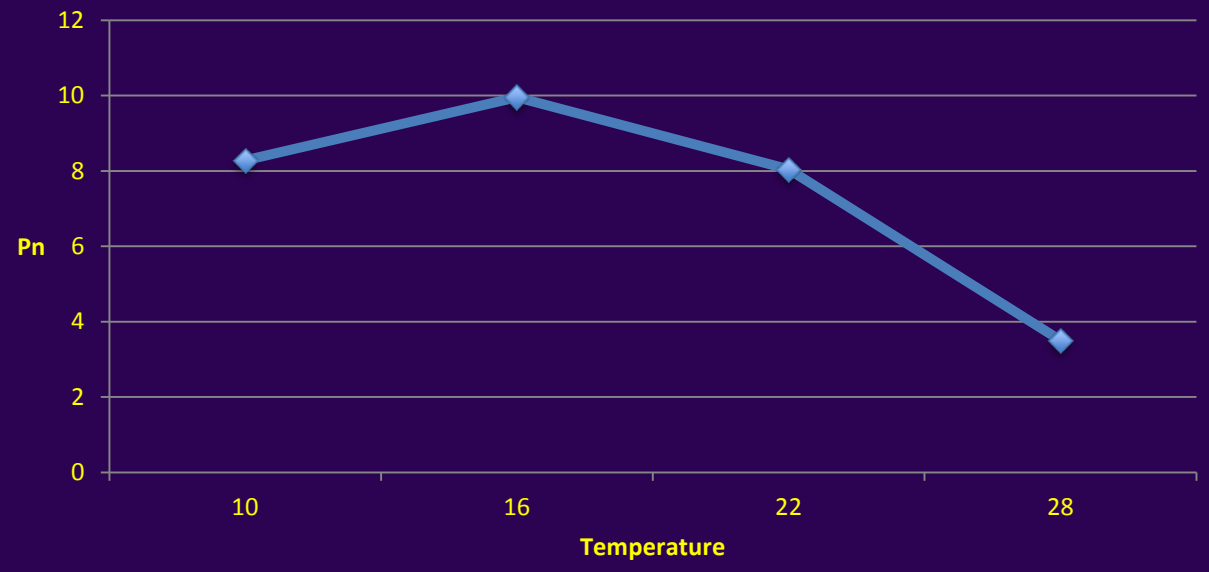


Beet, broccoli raab, nasturtium, pea shoot, watercress, crinkly cress, sorrel, arugula, and collard.

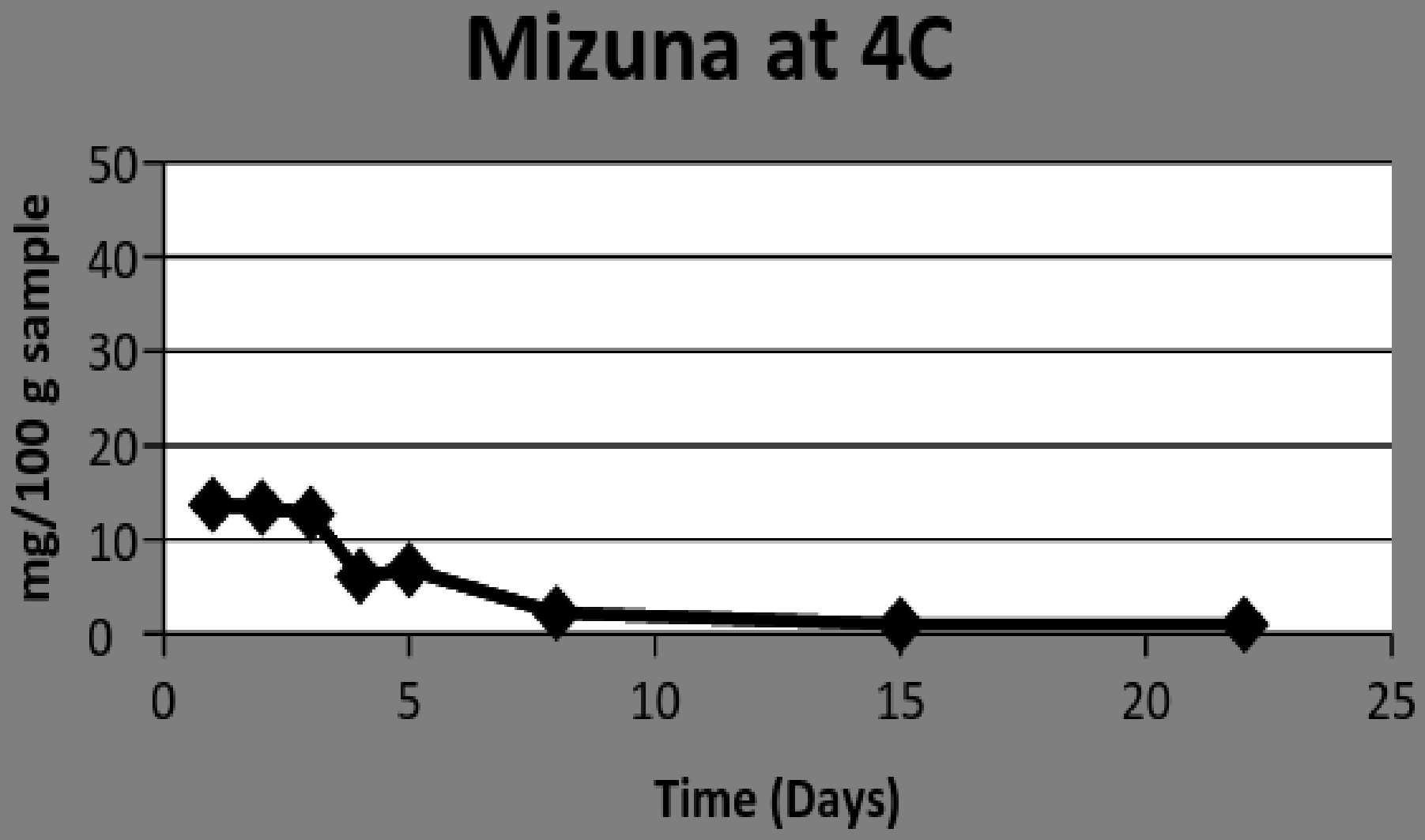
Chard FH Giant Temperature Response

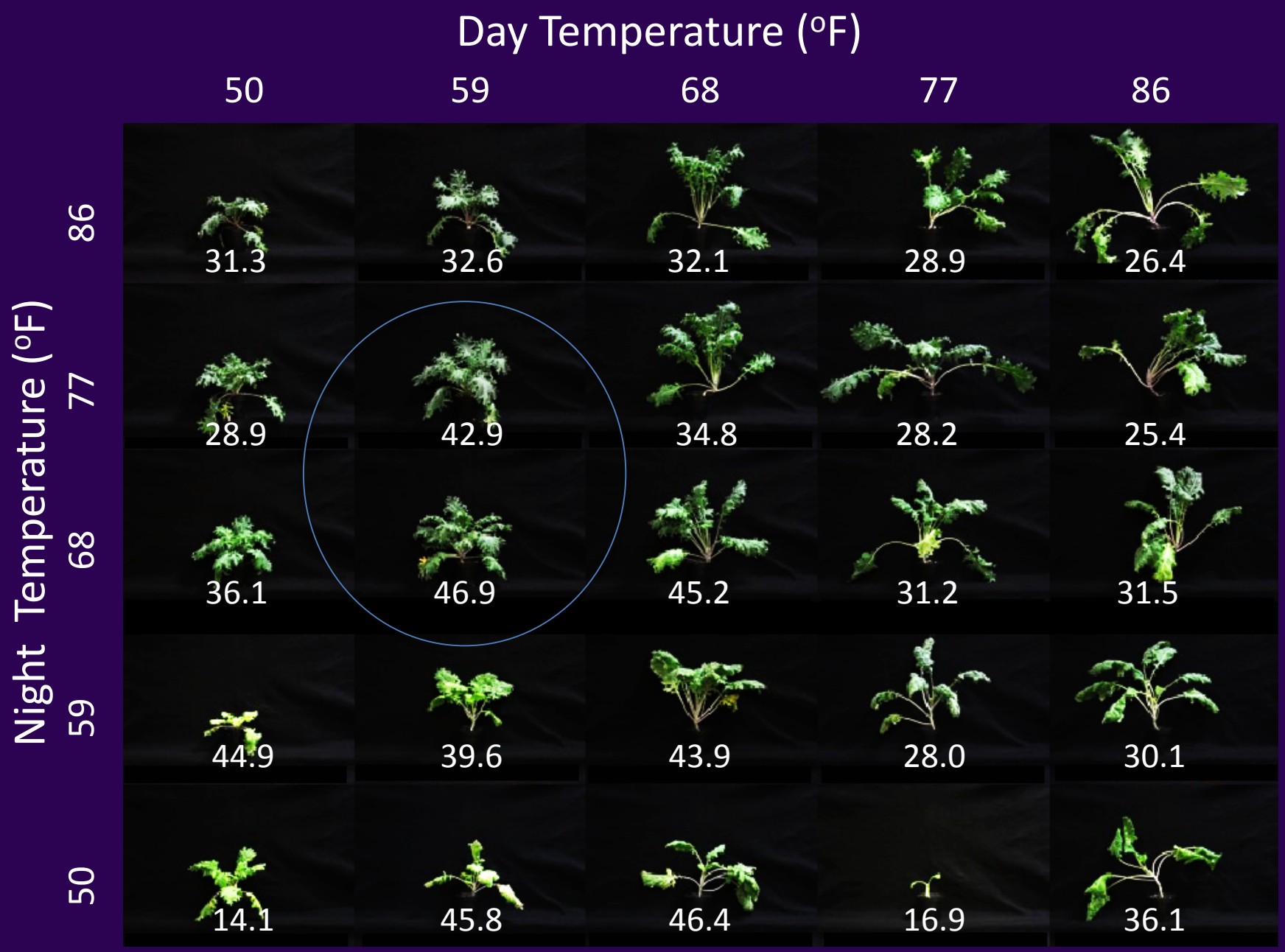


Kale Red Russian Temperature Response

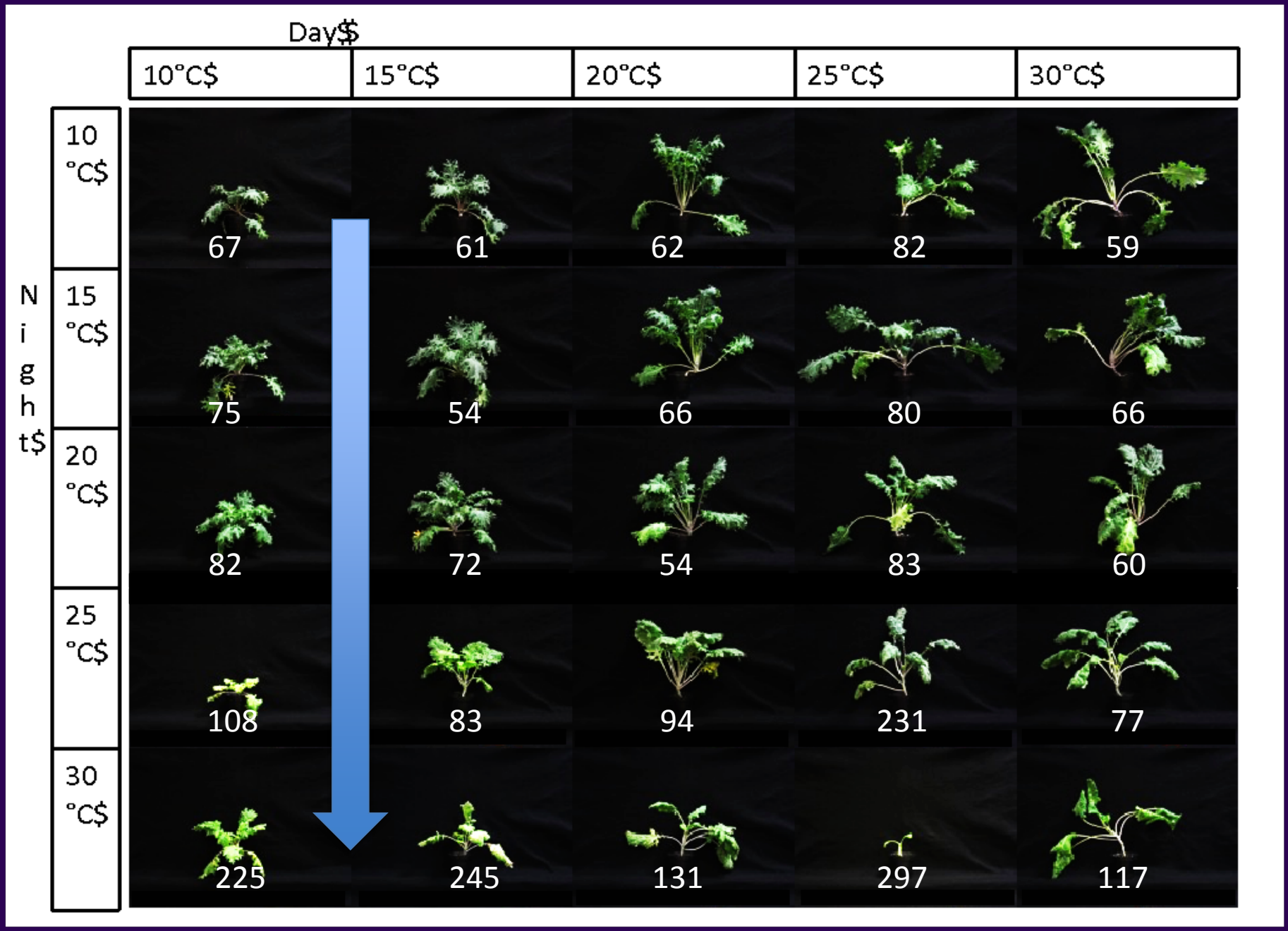


Greens purchased in stores (especially imported from out of state) likely has little to no vitamin C content.

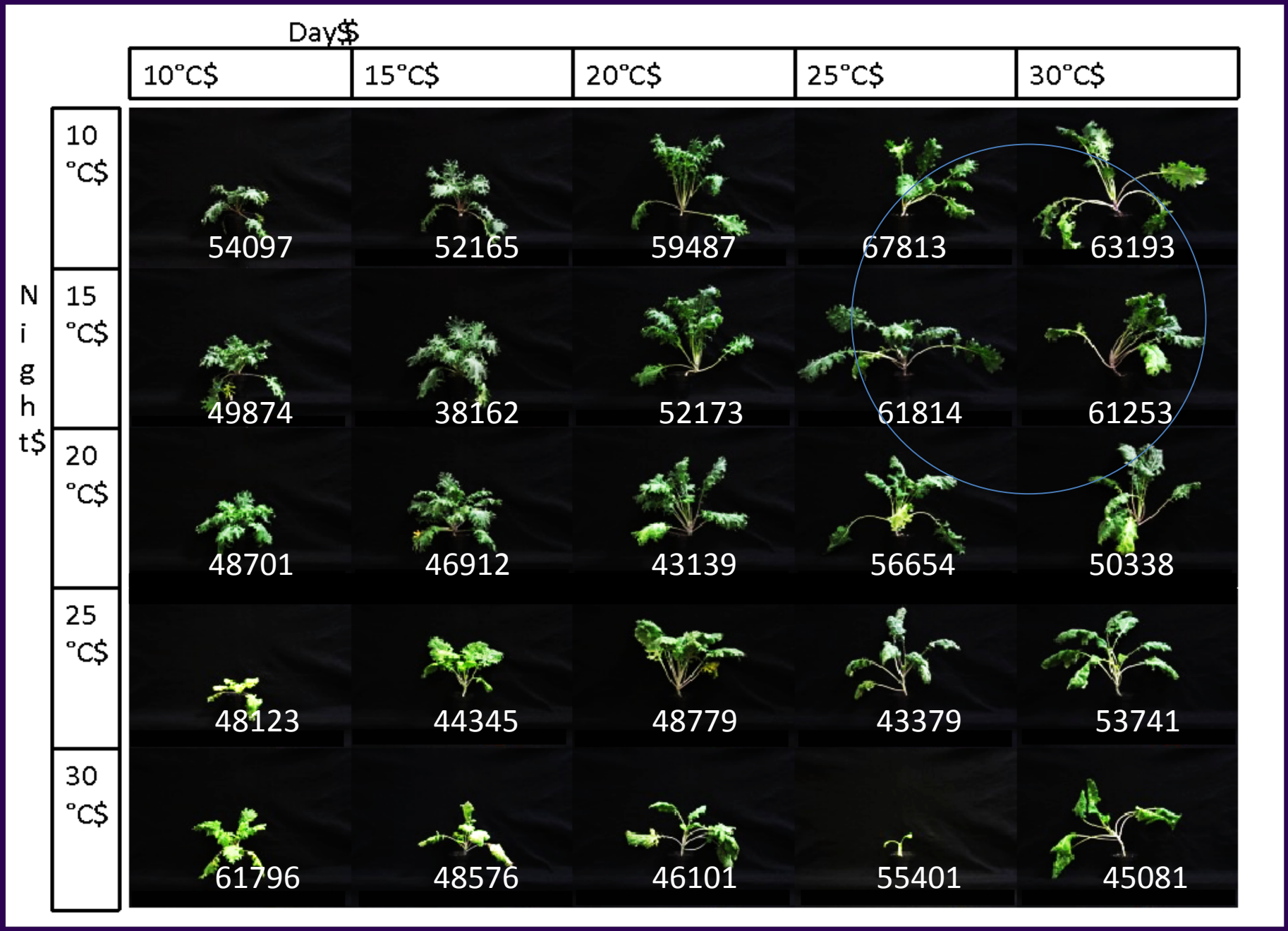




Effect of day and night temperature on kale vitamin C content (mg/100 g tissue)



Effect of day and night temperature on kale iron content (ppm/100 g tissue)



Effect of day and night temperature on kale potassium content (ppm/100 g tissue)

Vitamin C

Fiber

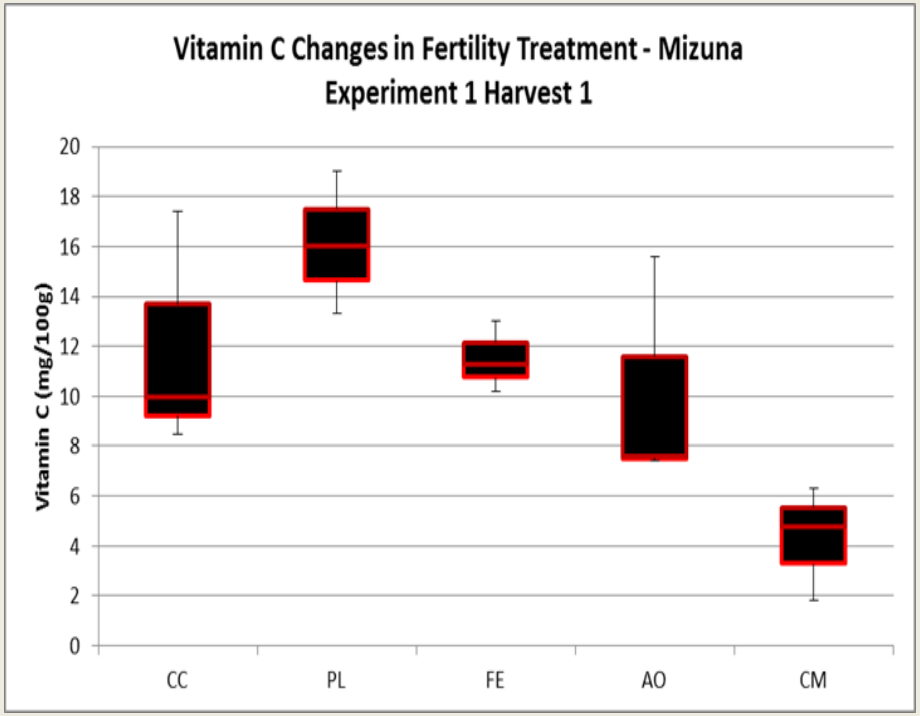
Fresh Weight

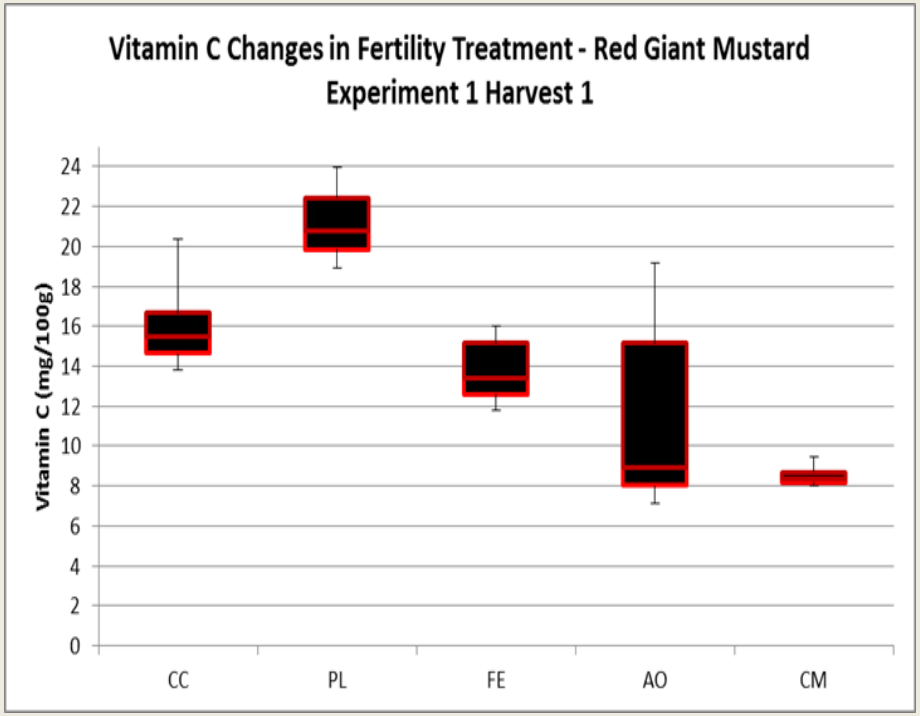
Day Temperature C° (0800-1600 HR)

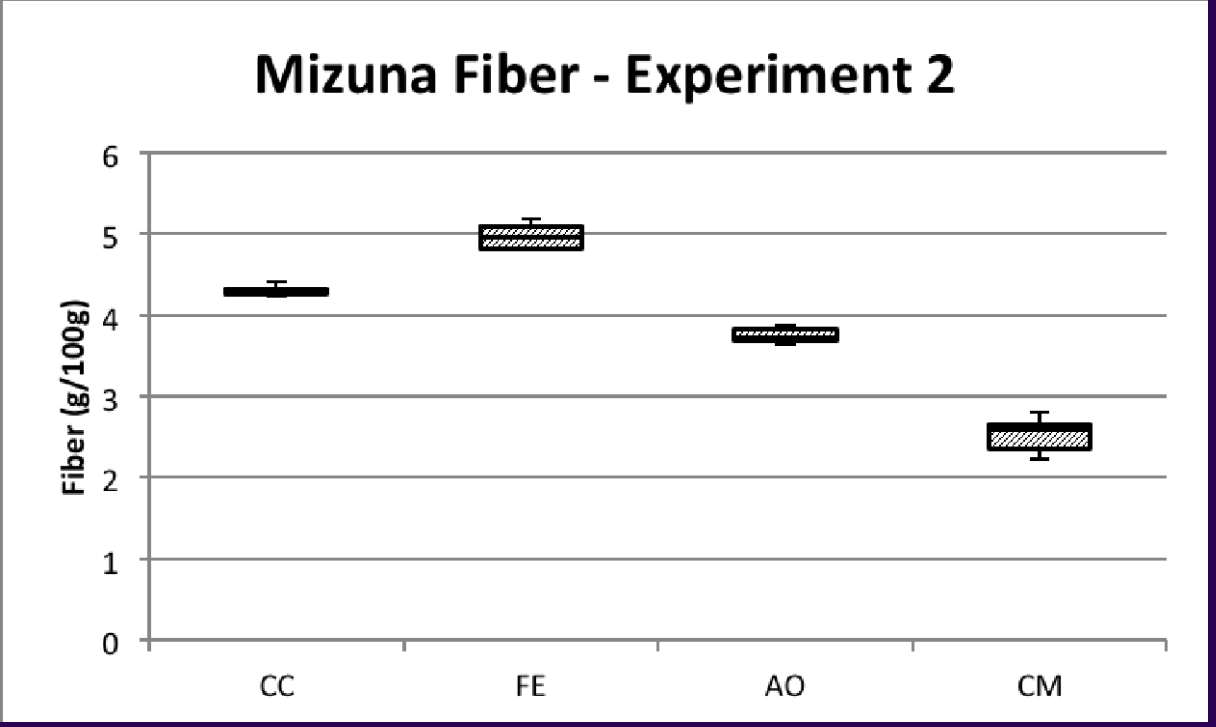
Night Temperature C° (1600-800 HR)

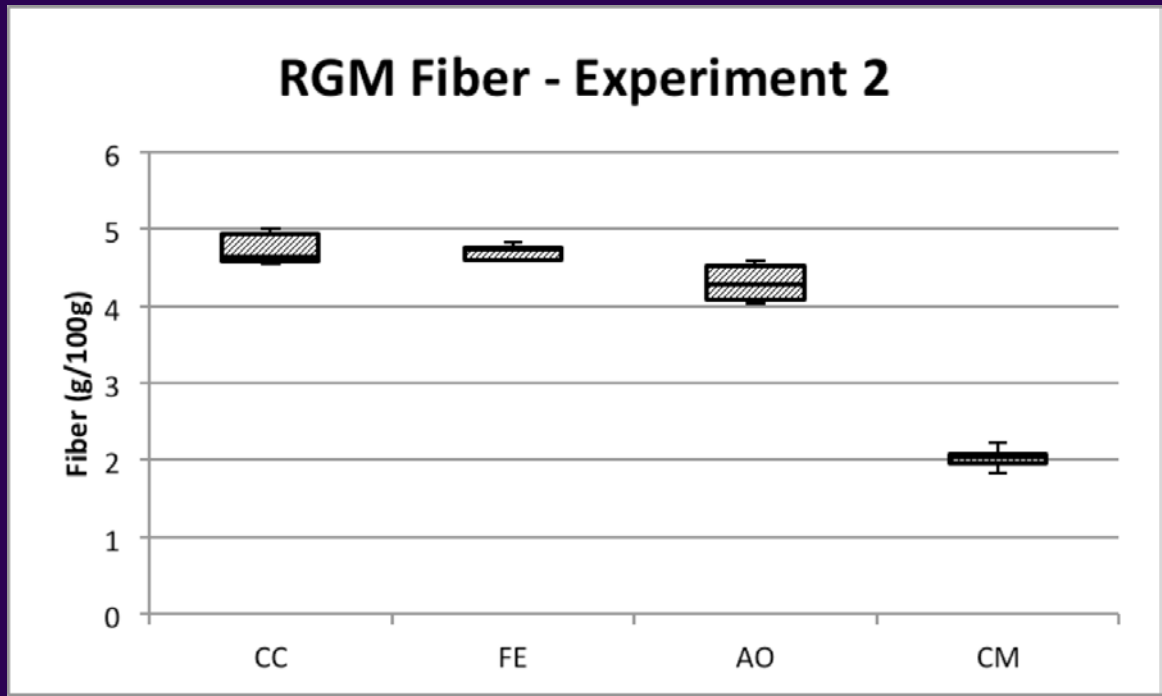
(Carlson, 2015)

Media Effects on Mizuna and Red Giant Mustard Vitamin C levels






Mizuna Fiber - Experiment 2
Fiber (g/100g)
0
1
2
3
4
5
6
CC
FE
AO
CM

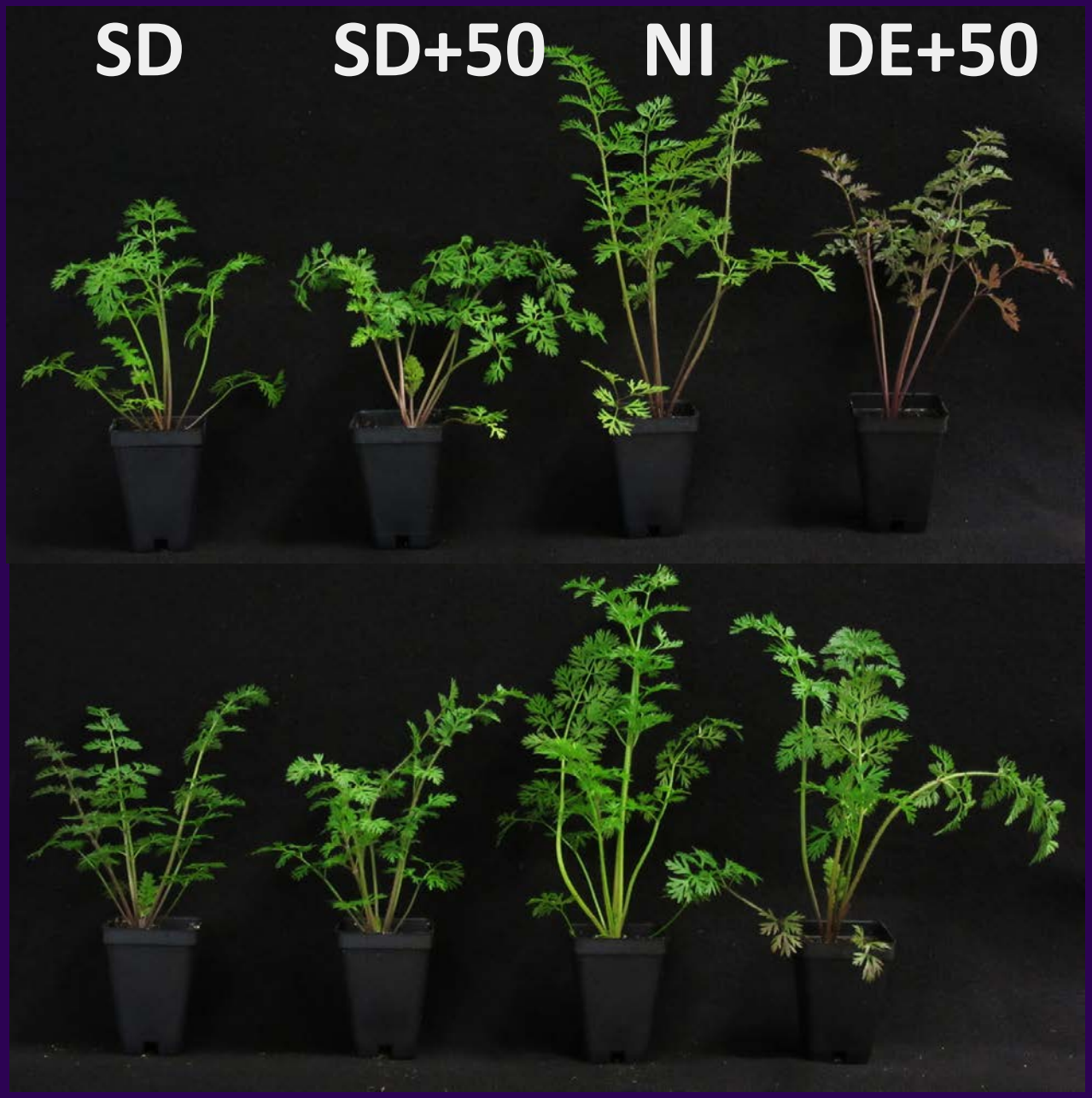

RGM Fiber - Experiment 2
Fiber (g/100g)
0
1
2
3
4
5
6
CC
FE
AO
CM

Root crops as new potted plants:
Radishes (15 varieties), Beets (10 varieties), Onions (6 varieties)

Deep Purple

- 68ºF Day
- 59ºF Night

- 59ºF Day
- 50ºF Night



Yellowbunch

SD SD+50 NI DE+50

0/15

5/10

Burpee White

SD SD+50 NI DE+50

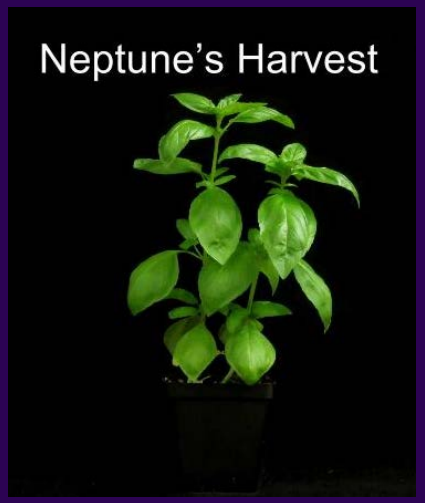
- 20/15
- 15/10

Burpee White

SD SD+50 NI DE+50

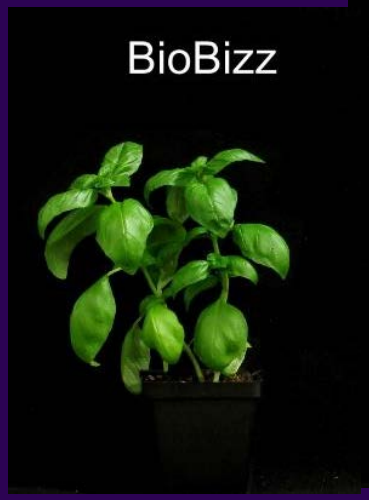
2.0 a

3.5 a

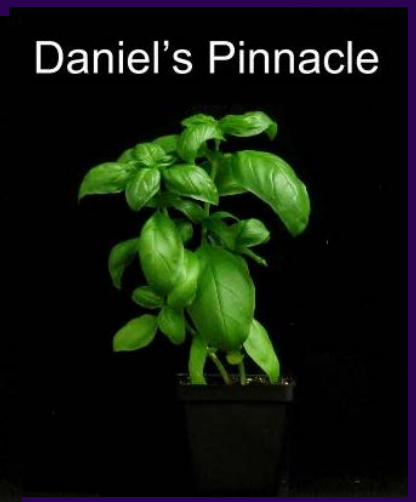


8.9 b

12.9 d



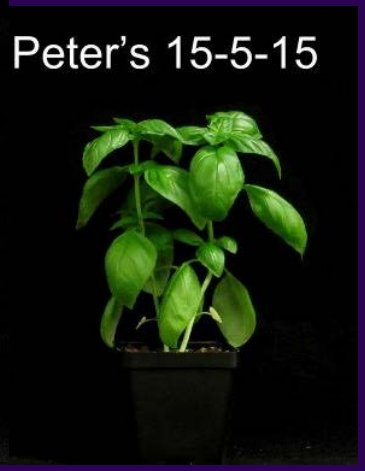
9.7 bc



9.9 bc

11.7 cd

10.9 bcd



10.3 bc

Mushrooms . . . .

- Great opportunity market.
- Protein source
- Vitamins B and D – two vitamins identified with several health benefits.
- Research opportunities
  - Flower induction
  - Increasing health benefits

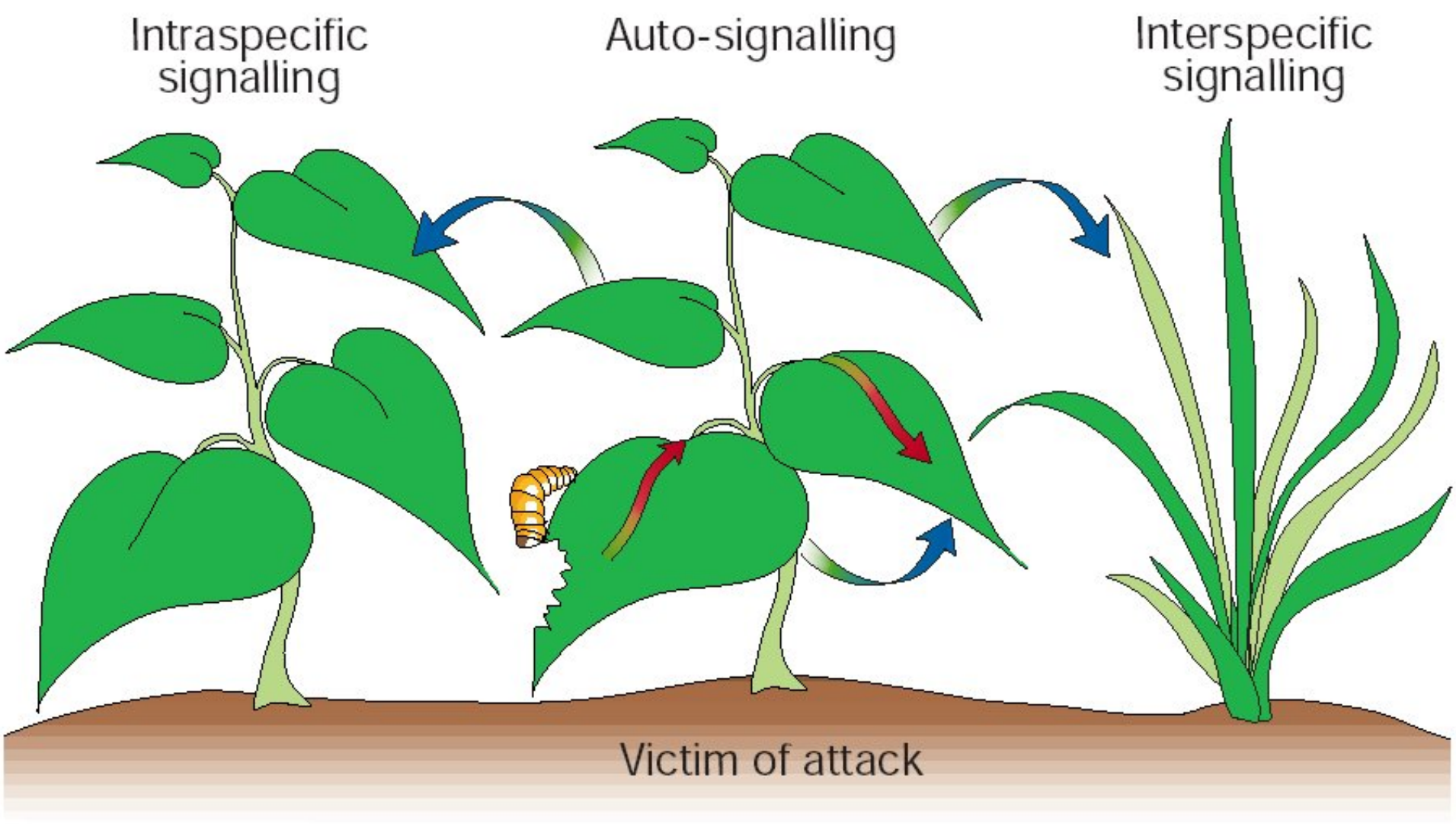
New LED lighting technologies coupled with solar/wind will revolutionize integration of photosynthetic lighting into building designs and energy generation.

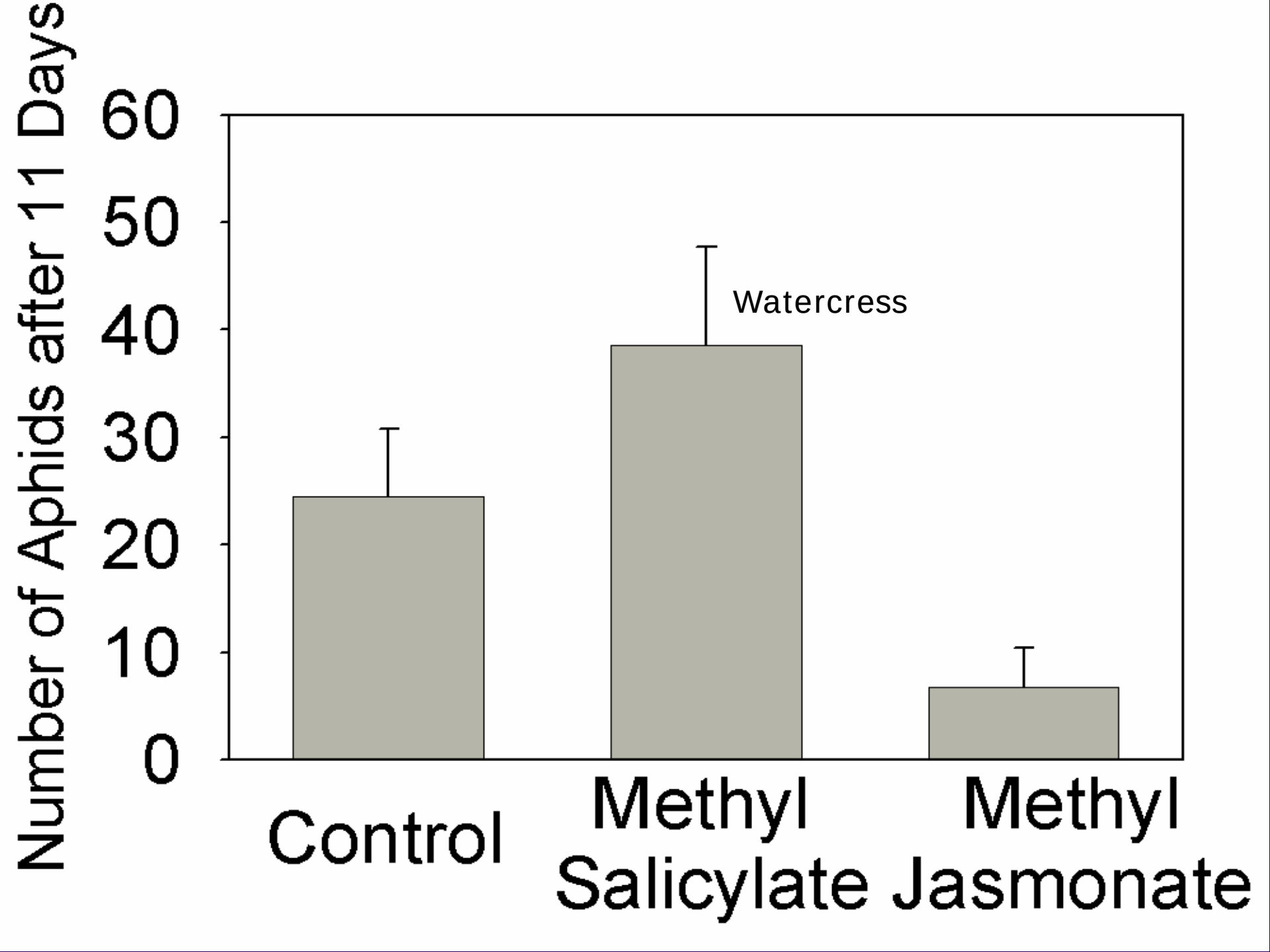
Industry Acknowledgements

- Minnesota Flower Growers and the Minnesota Agriculture Experiment Station
- Floriculture Research Alliance
- American Floral Endowment

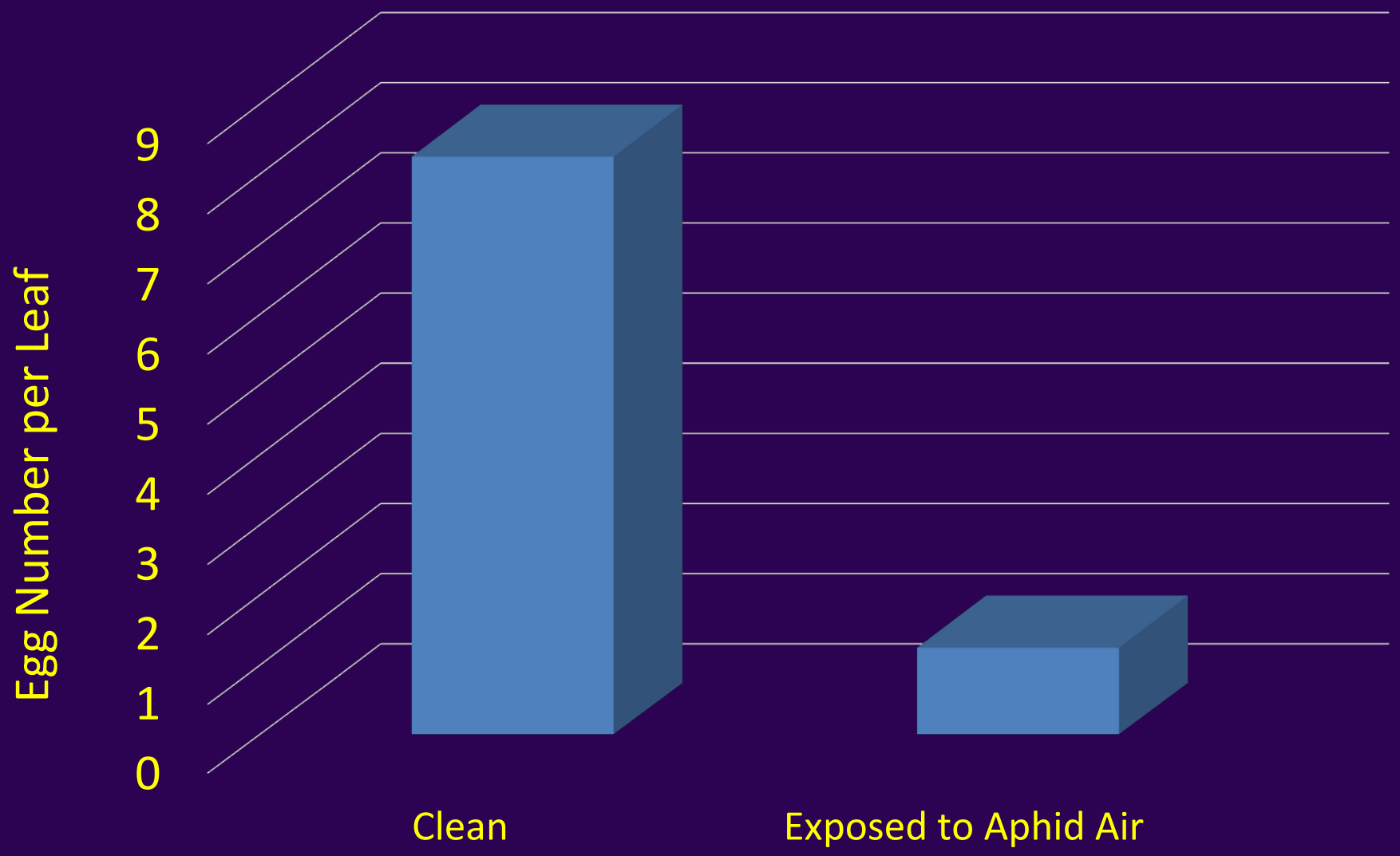
- U of MN Partners:
  - Altman Plants, Inc.
  - Rocket Farms, Inc.
  - Smith Greenhouses, Inc.
  - Green Circle Growers, Inc
  - Wagner's Greenhouse

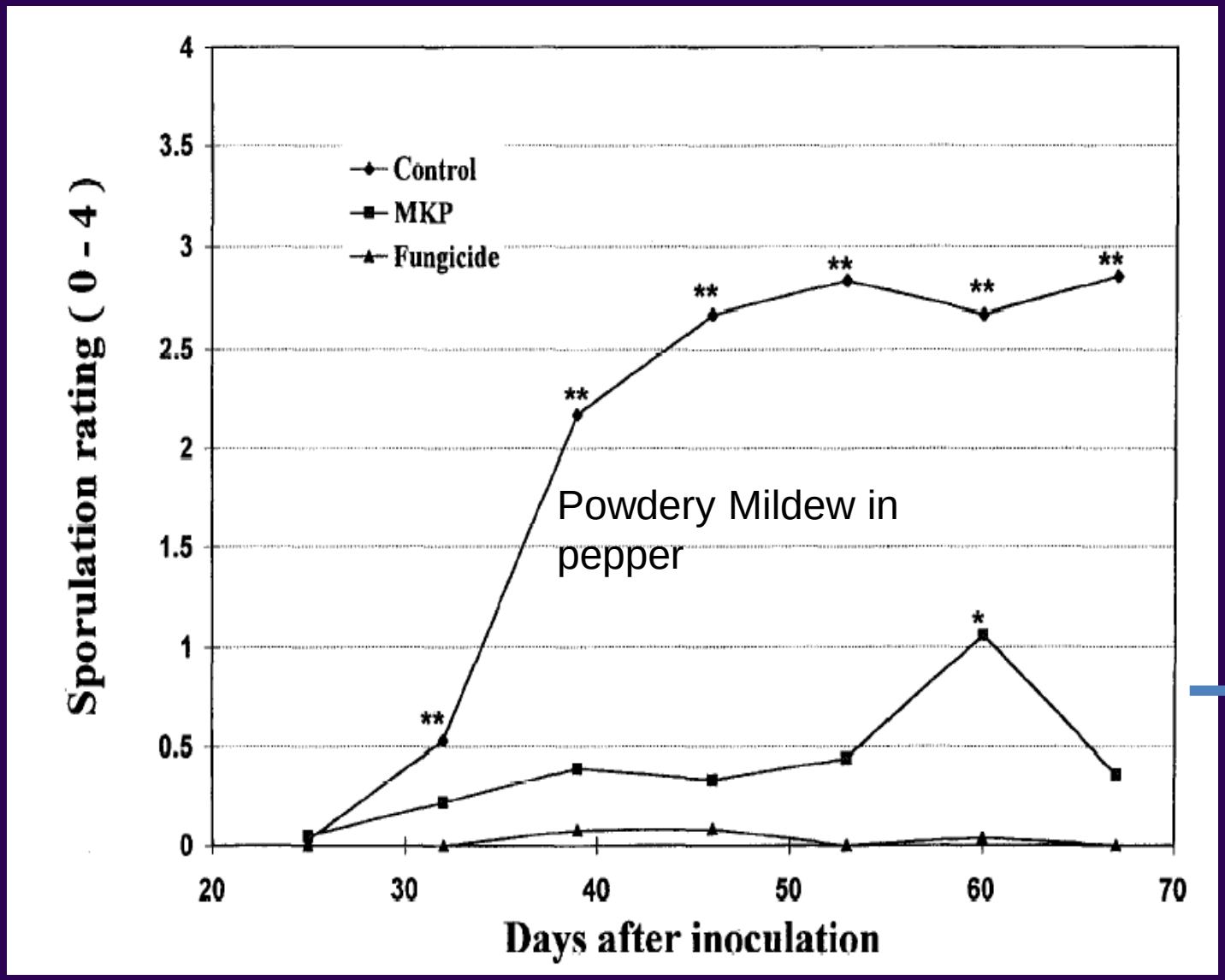
Plant Defense Mechanisms




Number of Aphids after 11 Days
60
50
40
30
20
10
0
Watercress
Control
Methyl Salicylate
Methyl Jasmonate

Lacewing Egg Number (after 3 days)





Weekly treatment with:

water

1% KH_2PO_4 (1.3 oz/gal)

Fungicide

Reuveni et al., 1998

REVENUES

	Grnhse1	*Grnhse2*	*Grnhse3*	*Grnhse4*	*Grnhse5*	*Grnhse6*	*Grnhse7*	***Average***	***Median***
Gross Revenue	$5,527	$1,511	$1,000	$3,600	$5,150	$447	$1,025	$2,609	$1,511
CSA	$5,527	$488		$3,600	$5,000				
Direct Sales		$1,023	$1,000		$150	$447	$1,025		
Operating Revenue	$4,491	$688	$220	$2,580	$3,984	$(527)	$582	$1,717	$688
Operating Revenue per Sq Ft of Growing Space	$9.67	$4.79	$1.04	$13.03	$17.34	$(1.88)	$4.73	$6.96	$4.79
Gross Margin	81%	46%	22%	72%	77%	-118%	57%	34%	57%

© 2015 Regents of the University of Minnesota. All rights reserved.

START-UP COSTS PER GREENHOUSE

	Grnhse1	*Grnhse2*	*Grnhse3*	*Grnhse4*	*Grnhse5*	*Grnhse6*	*Grnhse7*	***Average***	***Median***
Start-up cost	$17,850	$5,797	$73,035	$24,042	$20,679	$20,578	$16,533	$25,502	$20,578
Cost per sq. ft.	$34	$20	$172	$47	$72	$27	$55	$61	$47
Cost per sq. ft. of growing space	$38	$40	$345	$121	$90	$73	$134	$120	$90

- Greenhouses 1 and 5 were most profitable (highest net revenue and ROI)

© 2015 Regents of the University of Minnesota. All rights reserved.

WHAT NEXT?

- More participants…
  - Optimal space utilization for greatest return?
  - How to minimize building costs and keep direct costs consistent per square foot
  - Document marketing costs per market channel
  - Return on lights
  - Document efficiency in use of time

© 2015 Regents of the University of Minnesota. All rights reserved.

KATHY DRAEGER

- Statewide Director, RSDP

© 2011 Regents of the University of Minnesota. All rights reserved.

QUESTIONS

- Please pass any note cards to the front

© 2011 Regents of the University of Minnesota. All rights reserved.

QUESTIONS FOR PRODUCERS

- What are **your** most critical DWG production needs that can be addressed by research?
- (e.g. soil mix, yields, costs, other…)

© 2011 Regents of the University of Minnesota. All rights reserved.

DISCUSSION TOPICS

1. Reaction to research and presentations: Are we asking the right questions? What are we missing?
2. What are some advancements or activities that could improve the DWG production system?

© 2011 Regents of the University of Minnesota. All rights reserved.

DISCUSSION TOPIC

- Given what we have heard today, what are the most pressing topics and questions that require our research attention for the five DWG prototypes?
- What are more broad research questions that can advance DWG technology, use, and adoption?

© 2011 Regents of the University of Minnesota. All rights reserved.

THANK YOU!

- Lunch Time

© 2011 Regents of the University of Minnesota. All rights reserved.