

Non-Halophyte Brassicaceae Species in Brackish Water Aquaponics

Jill C. Fisk*, Leo J. Fleckenstein, and Andrew J. Ray

jill.fisk@kysu.edu

Research Assistant, School of Aquaculture
Kentucky State University Land Grant Program



COLLEGE OF
AGRICULTURE,
COMMUNITY, AND
THE SCIENCES



United States Department of Agriculture
National Institute of Food and Agriculture

Kentucky Shrimp Production

- Intensive RAS production
- Challenges:
 - Salt is costly, want to reuse water as much as possible
 - Effluent discharge is a challenge due to salts
- Nitrate reduction via aquaponics will help solve this problem!



Brassicaceae Family

- aka Cruciferae
 - Mustards, cabbages, crucifers
 - Horseradish, broccoli, Brussel sprouts, kohlrabi, kale
 - 350+ genera with over 3000 species worldwide
- Contains both halophyte and non-halophyte species, annuals and perennials



<https://sustainablefoodcenter.org/latest/gardening/kohlrabi-adds-crunch-and-sweetness-to-spring-recipes>



<https://kirbiecravings.com/spicy-garlic-brussels-sprouts-stalk/>



<https://www.thespruce.com/growing-horseradish-plants-in-the-vegetable-garden-1403461>

Kale Winterbor F1 Hybrid

- *Brassica oleracea*
- Blue-green savoyed foliage
60-90cm height
- Heat and cold tolerant
- 60 day maturation
- Multiple harvests
- Established market



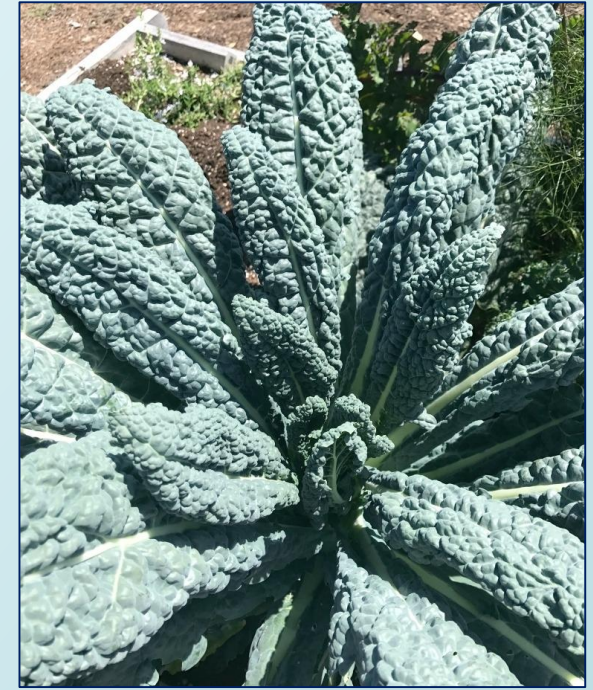
Kale at 20 ppt

Kale Toscano

- *Brassica oleracea*
- Dinosaur kale, heirloom
- Blue heavily savoyed foliage
- 60-90cm height
- Heat and cold tolerant
- 60 day maturation
- Multiple harvests
- Established market



<https://www.rhomarket.com/Product/2429?pGuid=d0220fdf-ed2f-4ce4-9d15-f8d06c002247>



<https://www.kitchengardenseeds.com/media/catalog/product/cache/1/thumbnail/0dc2d03fe217f8c83829496872af24a0/k/a/kale-tuscanlacinato-1-w.jpg>



Toscano at 15 ppt



Toscano at 20 ppt

Mustard Green Wave

- *Brassica juncea*
- Bright green frilled foliage, lightly savoyed
30-45cm height
- Heat and cold tolerant
- 45 day maturation
- Multiple harvests
- Established market



<https://www.johnnyseeds.com/vegetables/greens/mustard-greens/green-wave-organic-mustard-green-seed-377G.html>



<https://www.siskiyouseeds.com/products/mustard-green-wave>



Mustard acclimating to salt

Pac Choi Joi Choi F1

- *Brassica rapa var. chinensis*
- Dark green foliage, white stems
30-40cm height
- Heat and cold tolerant
- 50 day maturation
- Single or multiple harvest
- Established market



<https://www.johnnyseeds.com/vegetables/greens/pac-choi-bok-choy/joi-choi-f1-green-seed-507.html>



Pac Choi at 15 ppt

Tatsoi

- *Brassica rapa var. narinosa*
- Dark green cupped foliage
20-25cm height
- Not heat tolerant
- 45 day maturation
- Single or multiple harvest
- Established market



https://www.johnnyseeds.com/vegetables/greens/asian-greens/tatsoi-organic-asian-green-seed-2897.html?q=tatsoi&lang=en_US&start=1



Tatsoi at 10 ppt

Scurvy Grass - Spoonwort

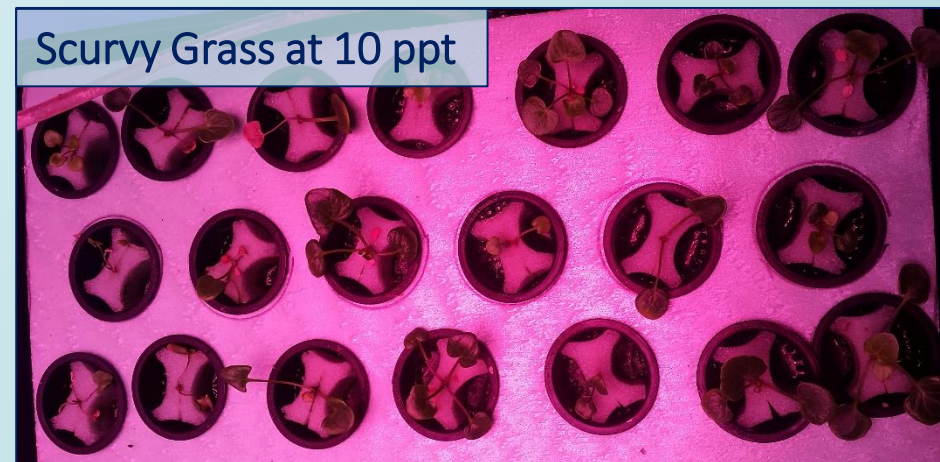
- *Colchlearia officianalis*
- Dark green succulent foliage
5-20cm height
- Heat and cold tolerant
- 60 day maturation
- Tender perennial
- Single or multiple harvest
- Halophyte, limited market



<http://coastalgreenfingers.weebly.com/brassicaceae-cruciferae-cabbage-family.html>



<https://www.bolster.eu/scurvy-grass-cochlearia-officinalis/p117>



Experimental Conditions

- Heated & insulated building, 1875 ft²
- LED lighting, 12-hour timer
 - Average PAR 218 $\mu\text{mol m}^{-2}/\text{s}^{-1}$
- Continuous air circulation
- Salinity acclimation usually 2 weeks
 - Crystal Sea[®] Marine mix
- 18 L tanks (3 replicates per treatment)
- 4 plants per tank
- 2.5 cm polystyrene foam
- 5 cm air stone
- Three experiments



Experimental Protocols

Plant Metrics

- Leaf Area Index (LAI)
Measures total surface area of harvested foliage
- Chlorophyll Content Index (CCI)
Measures chlorophyll content of a given area ($\mu\text{mol}/\text{m}^{-2}$)
Chlorophyll fluorescence is useful in detecting plant stress



https://www.licor.com/env/products/leaf_area/LI-3100C/index



https://www.forestry-suppliers.com/Documents/1507_msds.pdf

Data Analysis

- Water Quality:
Repeated measures ANOVA
- Harvest Data:
One-way ANOVA
- Friedman Test for non-normal distribution
- Results significant when $p < 0.05$



Salinity Tolerance Experimental Design

- Treatments: 0, 5, 10, 15, 20 ppt. salinity
- 50 mL Fox Farm Grow Big Liquid Fertilizer (3-2-6) in each tank
- 21-day trial



Five Salinities Prior to Stocking



Salinity Tolerance Kale Winterbor F1 Harvest

Treatment	Height (cm)	CCI	# Leaves	LAI (cm ²)	Wet Weight (g)		Dry Weight (g)			Ratio
					Stems+Leaves	Leaves	Roots	Leaves	Roots	
0	29.7 ^a	14.2 ^b	15.1 ^a	622.8 ^a	52.0 ^a	47.4 ^a	7.0 ^a	3.2 ^{ab}	0.4 ^a	0.12
5	25.1 ^b	17.3 ^b	14.7 ^a	676.0 ^a	38.3 ^{ab}	35.1 ^{ab}	6.3 ^a	3.5 ^a	0.5 ^a	0.13
10	18.2 ^c	26.5 ^a	13.6 ^{ab}	372.1 ^b	23.9 ^{bc}	22.1 ^{bc}	3.3 ^b	2.1 ^{bc}	0.2 ^b	0.11
15	15.0 ^d	28.8 ^a	12.0 ^b	248.7 ^{bc}	18.2 ^c	16.7 ^c	3.3 ^b	1.9 ^c	0.2 ^b	0.12
20	12.8 ^d	24.6 ^a	9.8 ^c	172.1 ^c	14.3 ^c	12.6 ^c	2.6 ^b	1.6 ^c	0.2 ^b	0.11

*Different superscript letters denote a significant difference between treatments



Kale 0ppt



Kale 10ppt



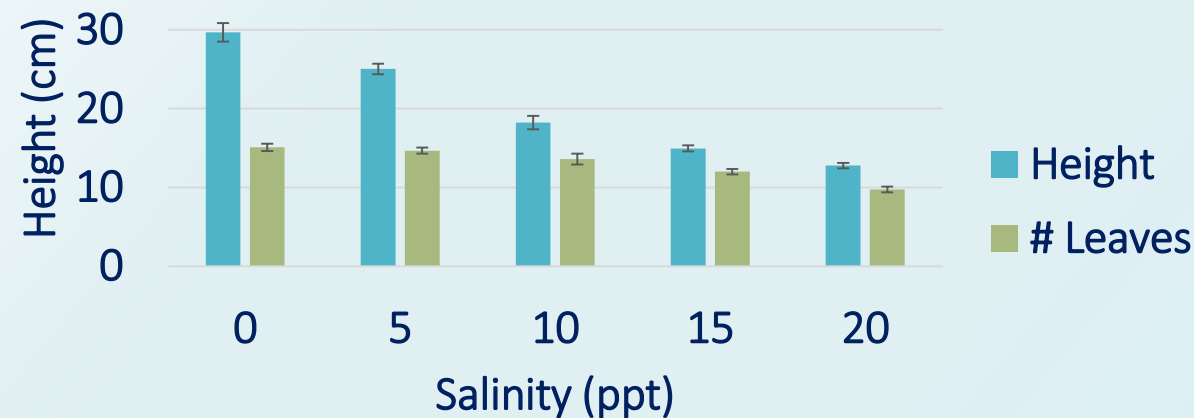
Kale 15ppt



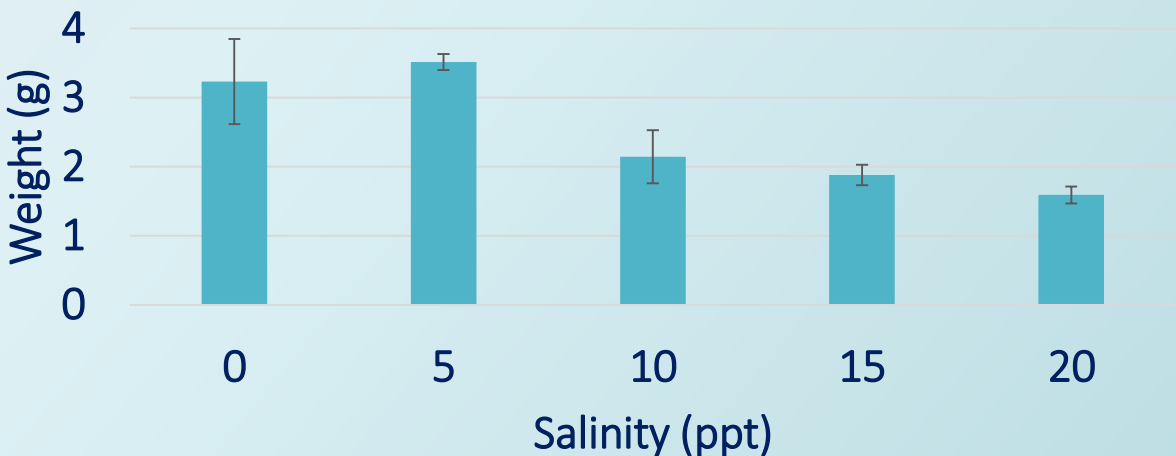
Kale 20ppt

Salinity Tolerance Winterbor F1 Harvest

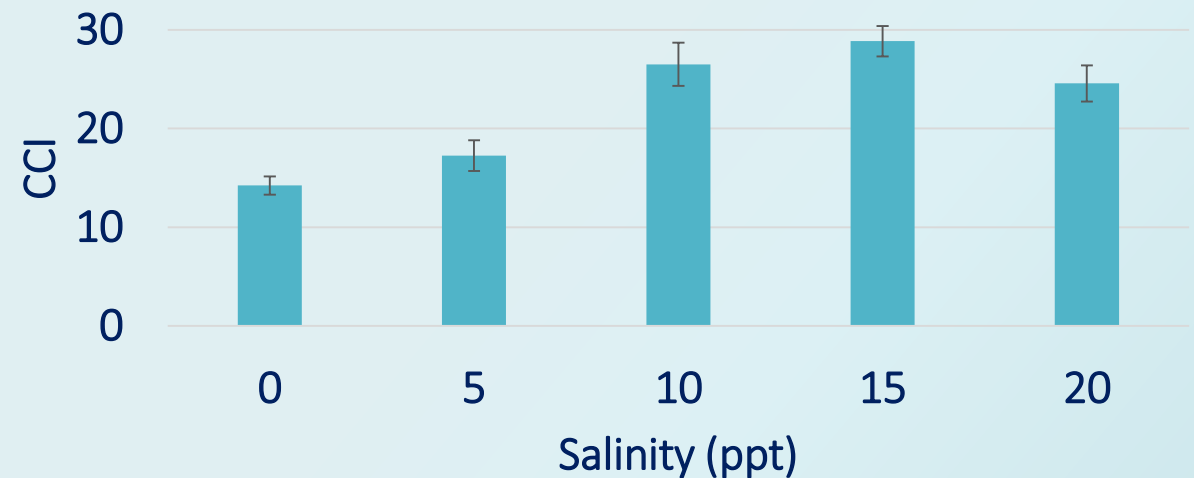
Plant Height & Number of Leaves



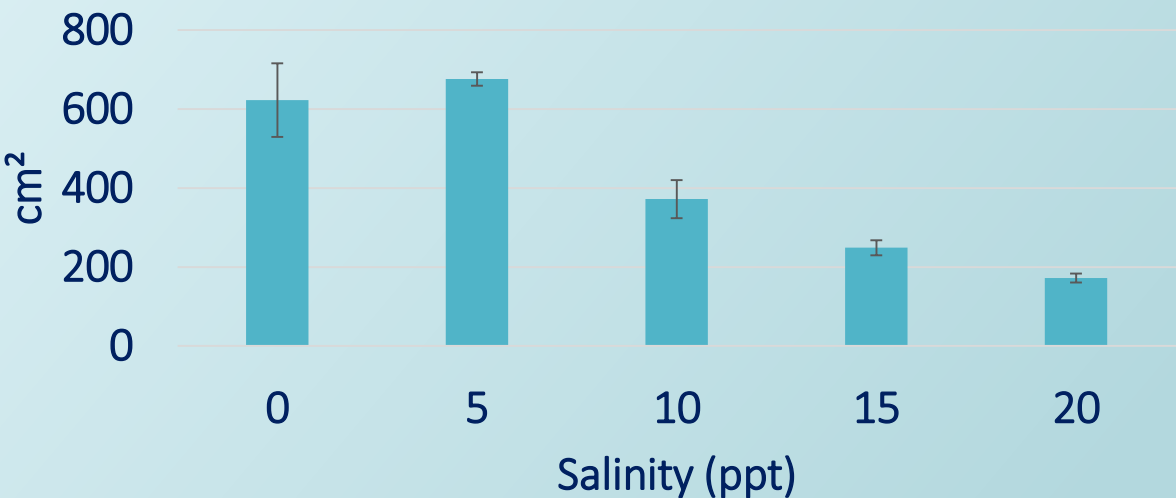
Plant Biomass Dry Weight



Plant Chlorophyll Content Index



Plant Leaf Area Index (LAI)



Kale Winterbor F1 Hybrid



Kale Winterbor Root Growth



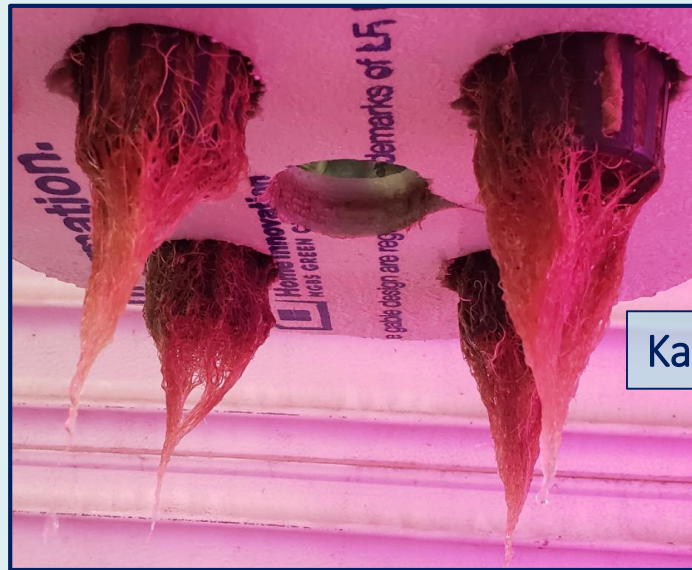
Kale at 0 ppt



Kale at 5 ppt



Kale at 10 ppt



Kale at 15 ppt



Kale at 20 ppt

Salinity affects
root systems

Salinity Tolerance Kale Toscano Harvest

Treatment	Height (cm)	CCI	# Leaves	LAI (cm ²)	Wet Weight (g)			Dry Weight (g)		
					Stems+Leaves	Leaves	Roots	Leaves	Roots	Ratio
0	46.1 ^a	28.9 ^{bc}	20.2 ^a	1626.8 ^a	131.2 ^a	110.9 ^a	14.0 ^a	9.8 ^a	1.8 ^a	0.18
5	34.4 ^{ac}	62.0 ^a	19.6 ^a	1854.6 ^a	140.1 ^{ac}	118.9 ^{ac}	15.0 ^{ac}	14.6 ^a	2.3 ^a	0.16
10	28.0 ^{bc}	47.6 ^{ac}	16.3 ^{ac}	604.6 ^{ac}	64.2 ^{bc}	53.9 ^{bc}	10.9 ^{ac}	5.6 ^{ac}	1.0 ^{ac}	0.18
15	23.1 ^b	57.4 ^a	15.7 ^{ac}	426.4 ^{bc}	50.1 ^{bc}	43.0 ^{bc}	9.0 ^{ac}	4.4 ^{bc}	0.8 ^{bc}	0.19
20	22.1 ^b	65.0 ^a	13.0 ^{bc}	368.6 ^{bc}	41.3 ^b	35.8 ^b	8.7 ^{bc}	4.6 ^{bc}	0.8 ^{bc}	0.17

*Different superscript letters denote a significant difference between treatments



Kale 0ppt



Kale 10ppt



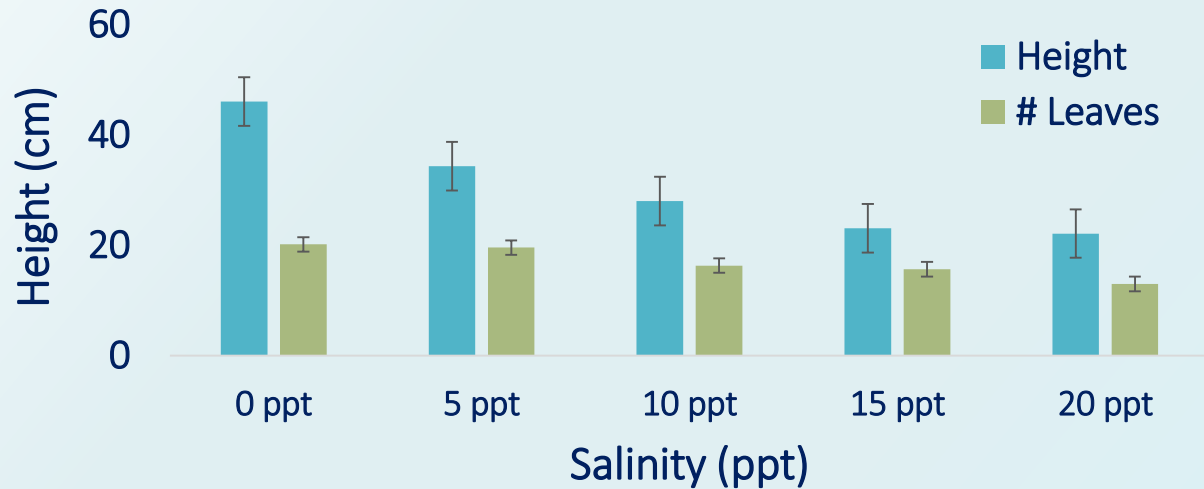
Kale 15ppt



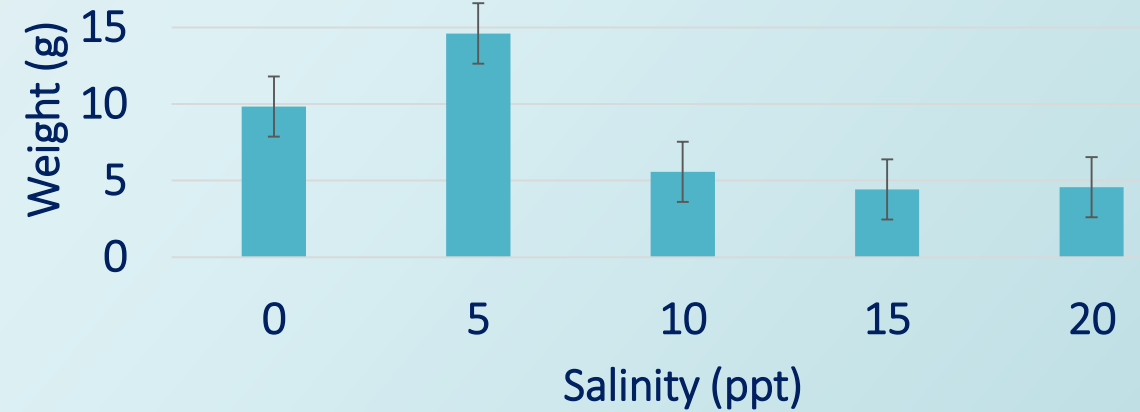
Kale 20ppt

Salinity Tolerance Kale Toscano Harvest

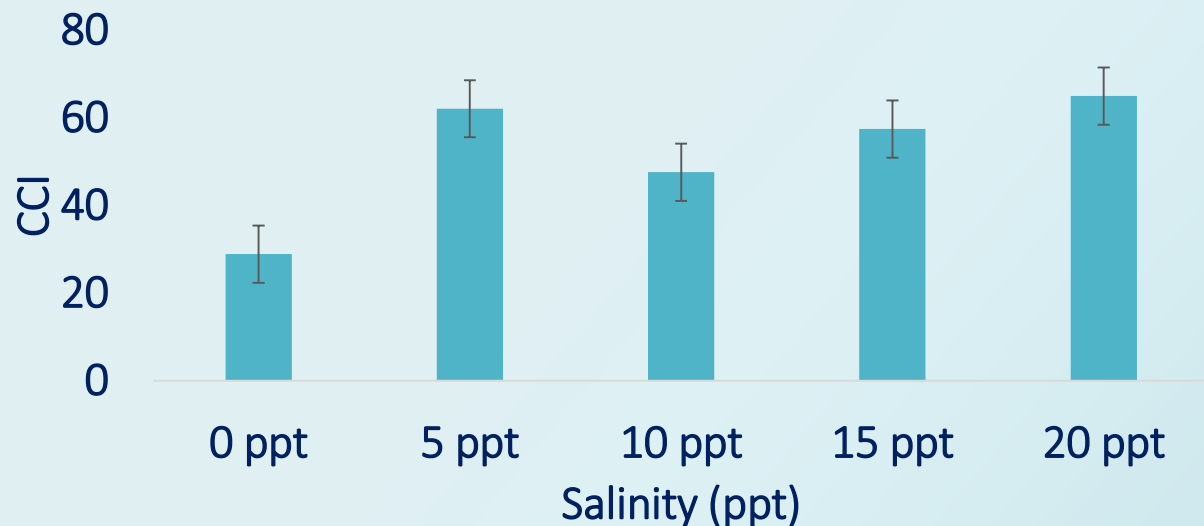
Plant Height and Number of Leaves



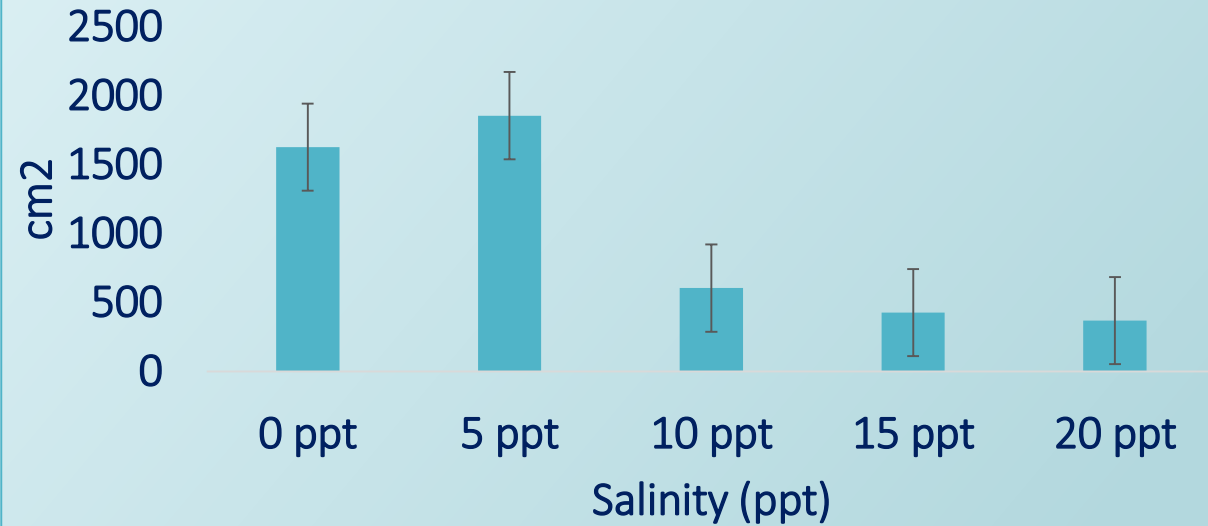
Plant Biomass Dry Weight



Plant Chlorophyll Content Index



Plant Leaf Area Index (LAI)



Kale Toscano



Kale Toscano Root Growth



Toscano at 0 ppt



Toscano at 5 ppt



Toscano at 10 ppt



Toscano at 15 ppt



Toscano at 20 ppt

Salinity Tolerance Pac Choi Harvest

Treatment	Height (cm)	CCI	# Leaves	LAI (cm ²)	Wet Weight (g)		Dry Weight (g)			Ratio
					Stems+Leaves	Leaves	Roots	Leaves	Roots	
0	38.3 ^a	11.8 ^b	14.3 ^a	2336.0 ^a	267.6 ^a	225.4 ^a	12.9 ^{ac}	8.6	0.8	0.08 ^b
5	30.8 ^{ac}	24.8 ^{bc}	13.7 ^a	1357.6 ^a	142.3 ^{ac}	122.2 ^{ac}	13.9 ^a	6.3 ^a	0.8	0.13 ^a
10	22.3 ^{cd}	44.0 ^{ac}	15.2 ^{ac}	801.5 ^{ac}	77.8 ^{cd}	68.4 ^{cd}	9.1 ^{ac}	4.2	0.6	0.13 ^a
15	16.6 ^{bd}	60.9 ^a	10.7 ^{bc}	507.3 ^{bc}	43.6 ^{bd}	39.5 ^{bd}	5.6 ^{bc}	3.3	0.5	0.15 ^a
20	13.7 ^b	40.4 ^{ac}	9.8 ^b	233.4 ^{bc}	23.6 ^b	21.0 ^b	4.3 ^b	2.8 ^b	0.4	0.15 ^a

*Different superscript letters denote a significant difference between treatments



Pac Choi 0ppt



Pac Choi 15ppt



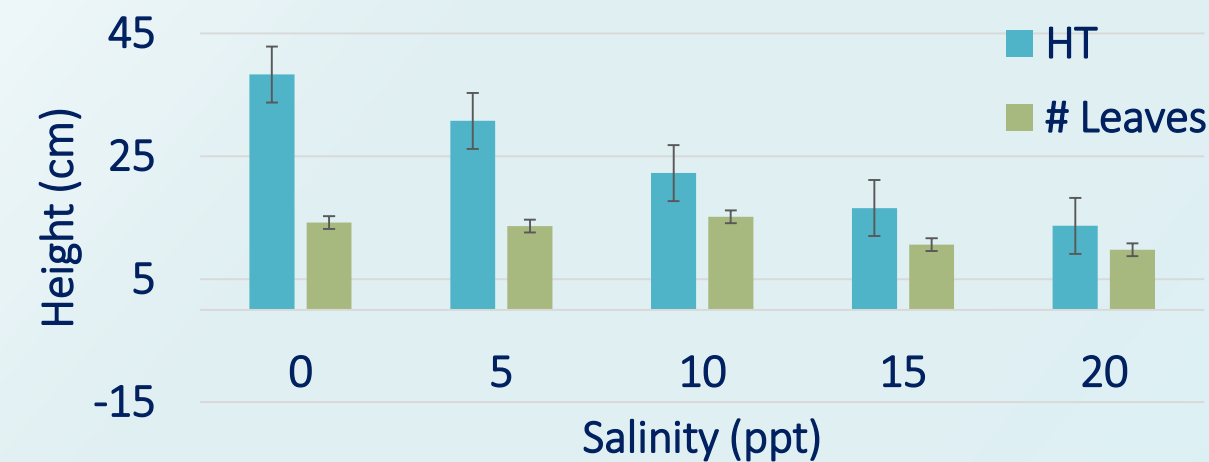
Pac Choi 15ppt



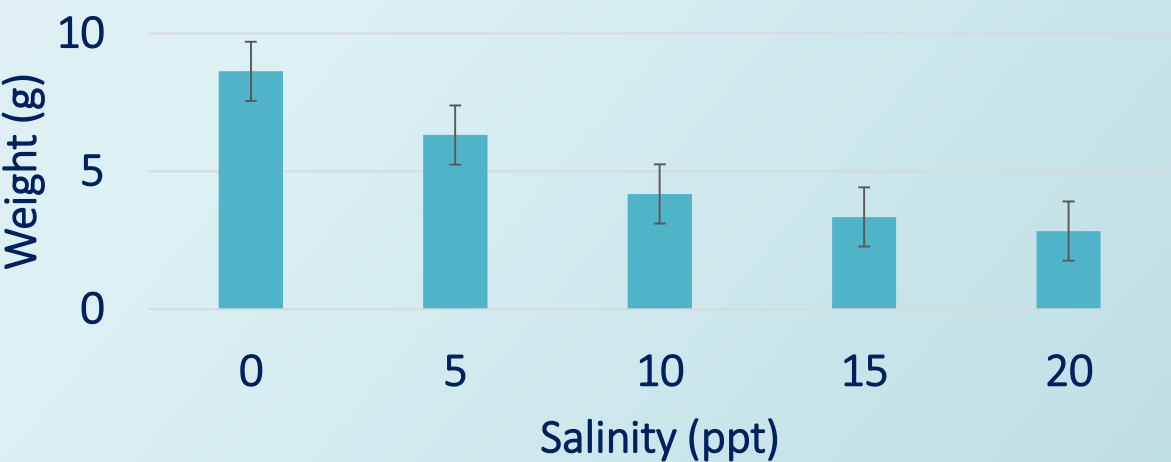
Pac Choi 20ppt

Salinity Tolerance Pac Choi Harvest

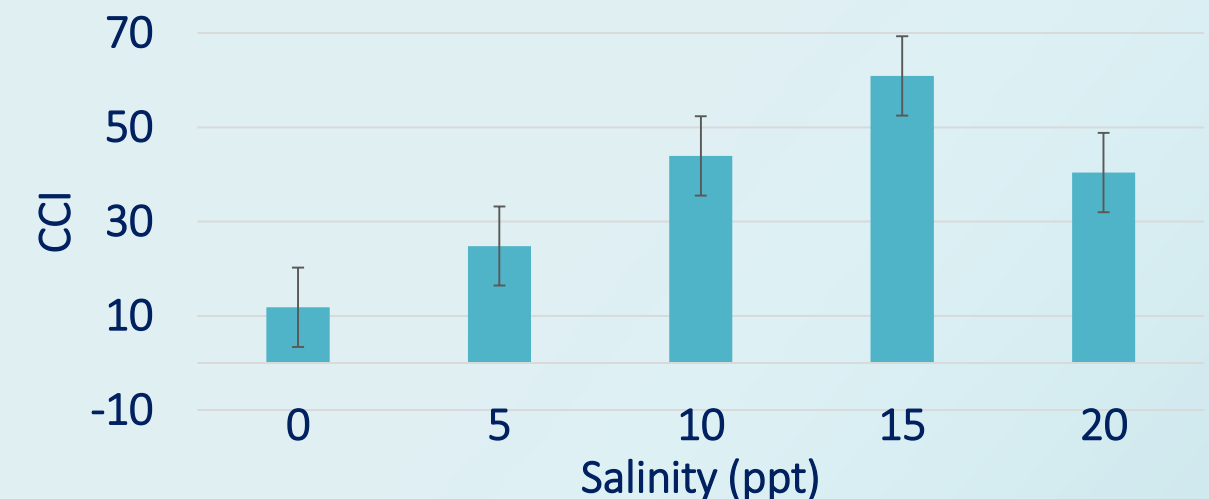
Plant Height and Number of Leaves



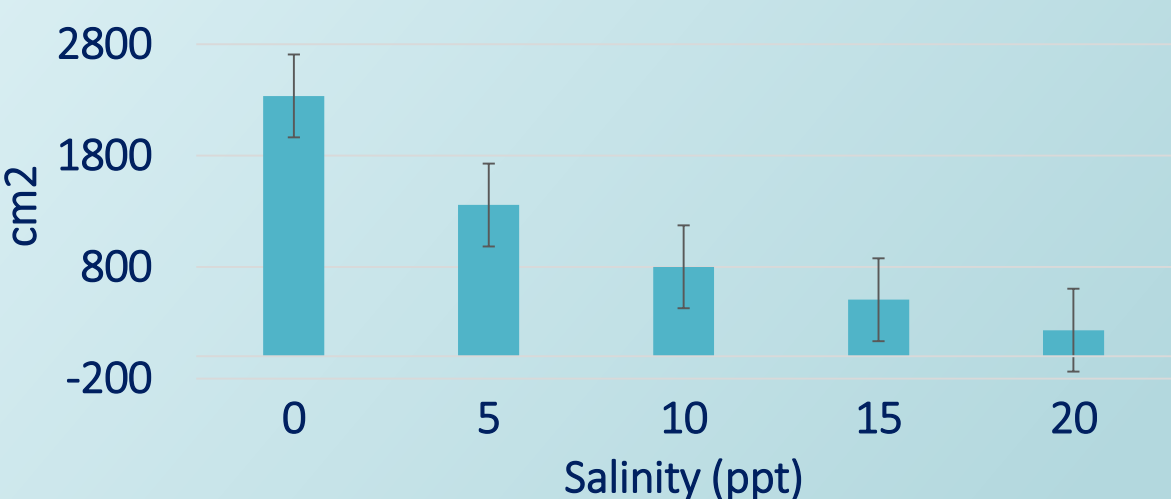
Plant Biomass Dry Weight



Plant Chlorophyll Content Index



Plant Leaf Area Index (LAI)



Pac Choi Variation



Pac Choi at 15 ppt

Salinity Tolerance Tatsoi Harvest

Treatment	Height (cm)	CCI	# Leaves	LAI (cm ²)	Wet Weight (g)			Dry Weight (g)		
					Stems+Leaves	Leaves	Roots	Leaves	Roots	Ratio
0	27.5 ^a	25.5	32.8 ^a	957.9 ^a	93.9 ^a	83.6 ^a	4.1 ^a	4.1	0.4 ^a	0.10
5	21.9 ^b	35.3	27.2 ^a	429.3 ^{ac}	46.6 ^{ac}	40.5 ^{ac}	3.9 ^a	1.9 ^a	0.2 ^a	0.11
10	10.7 ^c	43.8 ^a	16.5 ^{ab}	258.3 ^{ad}	17.9 ^{bc}	15.5 ^{bc}	2.2 ^{ab}	1.5	0.2 ^{ab}	0.16
15	8.7 ^{cd}	35.4	9.9 ^b	107.0 ^{bcd}	8.3 ^b	7.2 ^b	1.2 ^b	0.7	0.1 ^{ab}	0.12
20	5.0 ^d	17.1 ^b	7.4 ^b	48.5 ^{bd}	4.1 ^b	3.4 ^b	0.7 ^b	0.4 ^b	0.1 ^b	0.16

*Different superscript letters denote a significant difference between treatments



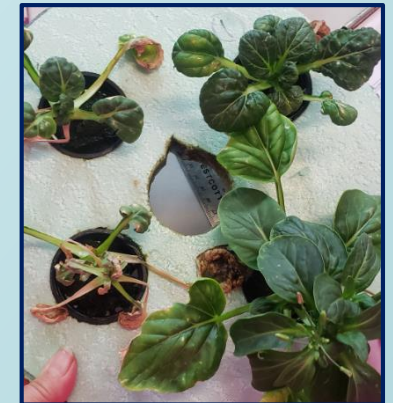
Tatsoi 0ppt



Tatsoi 10ppt



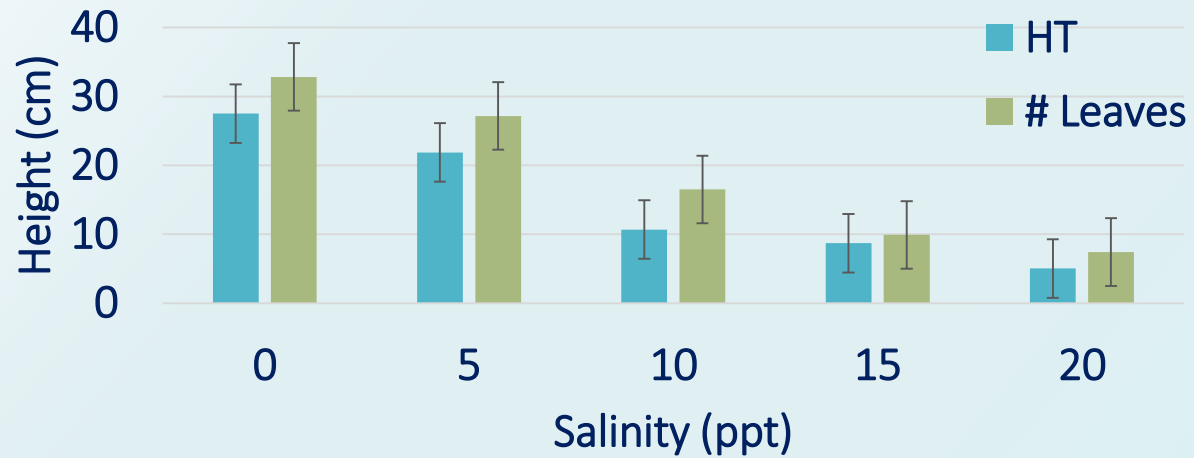
Tatsoi 10ppt



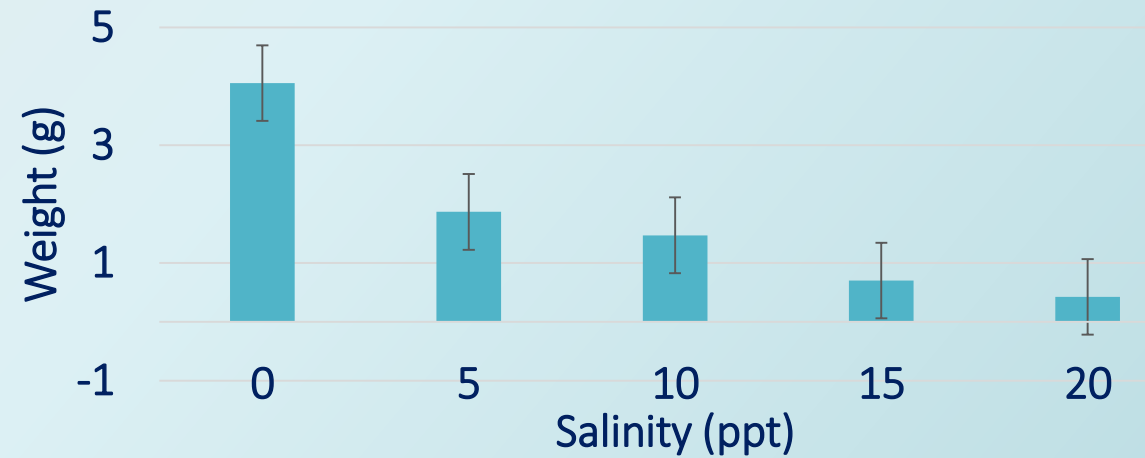
Tatsoi 20ppt

Salinity Tolerance Tatsoi Harvest

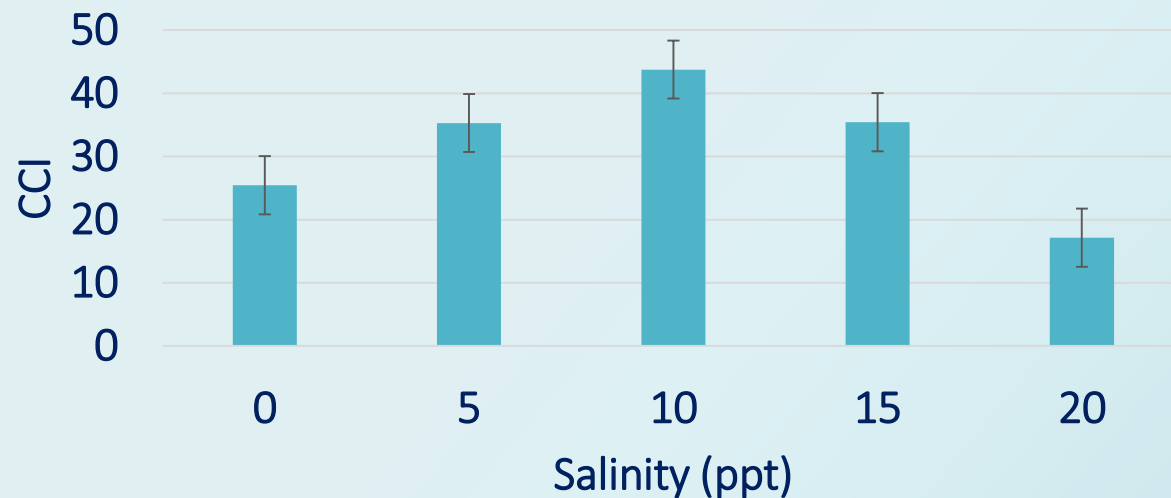
Plant Height and Number of Leaves



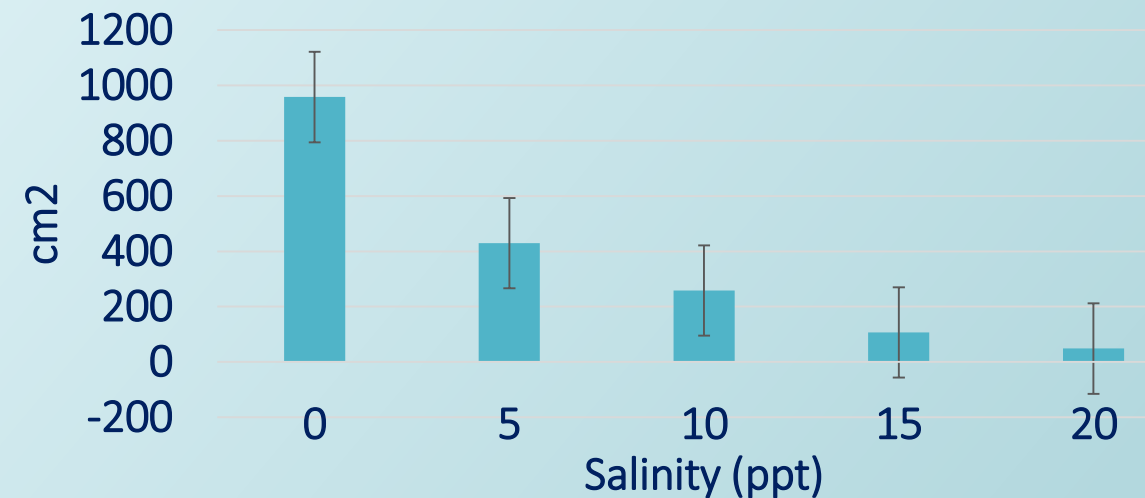
Plant Biomass Dry Weight



Plant Chlorophyll Content Index



Plant Leaf Area Index (LAI)



Tatsoi



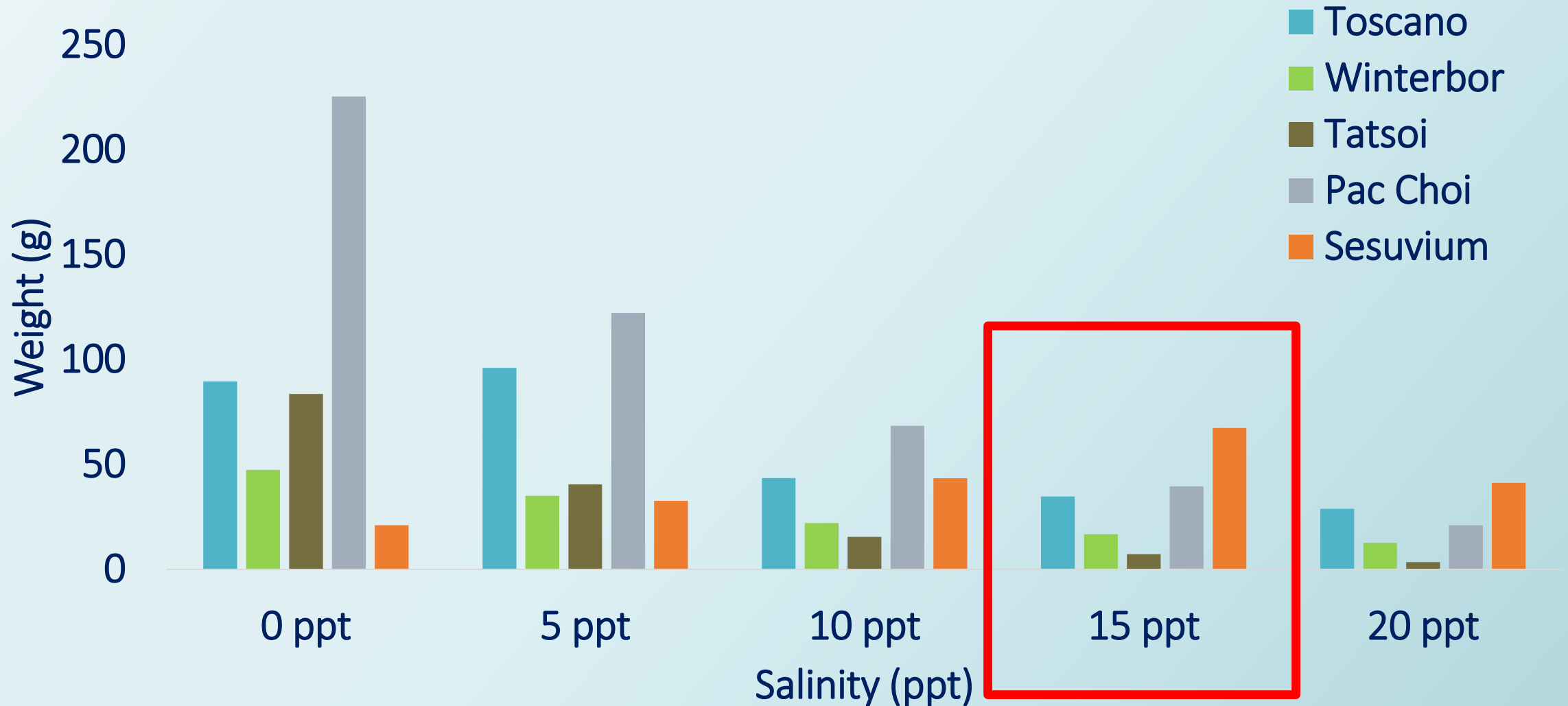
Tatsoi at 5 ppt



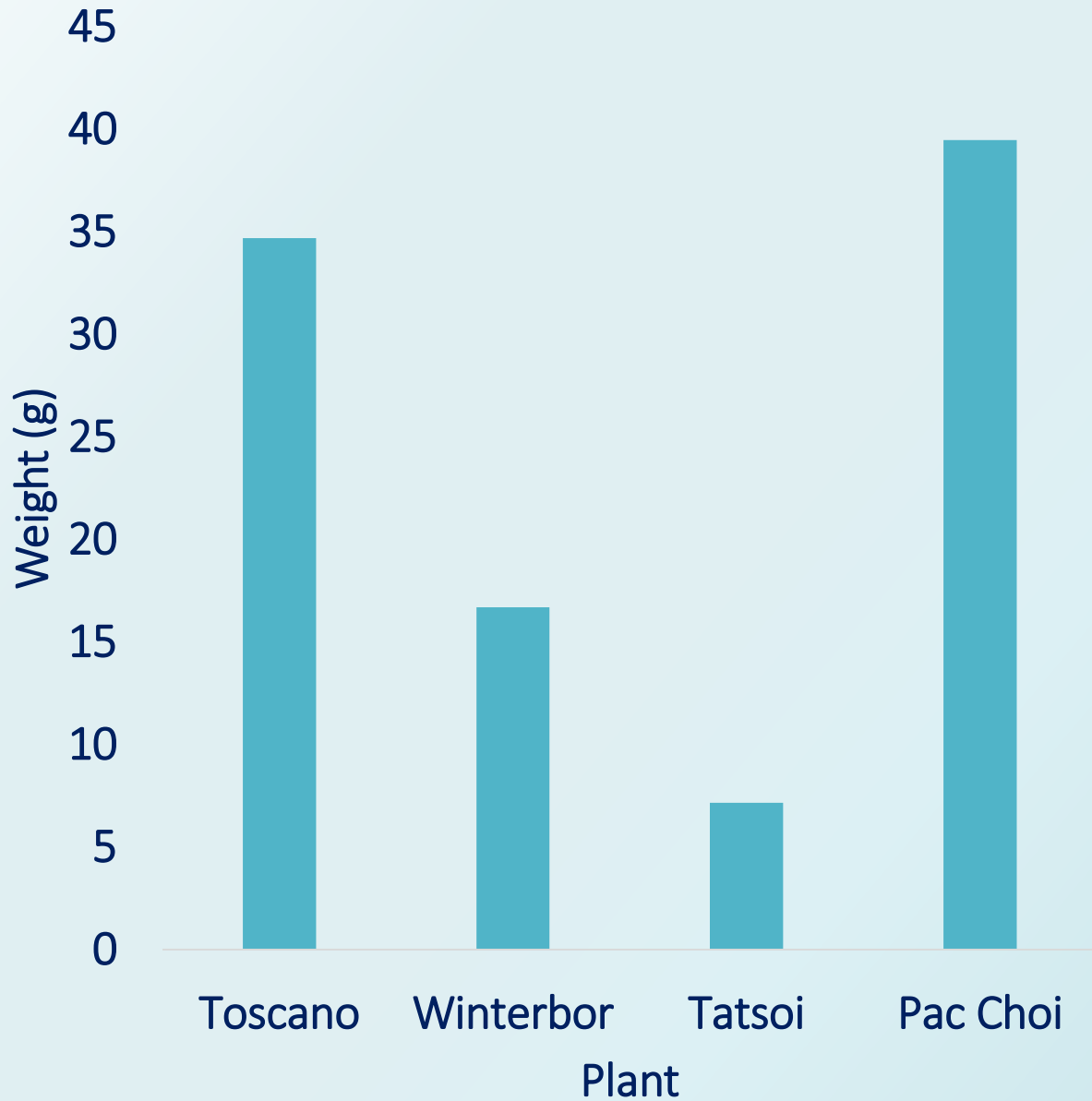
Tatsoi at 10 ppt



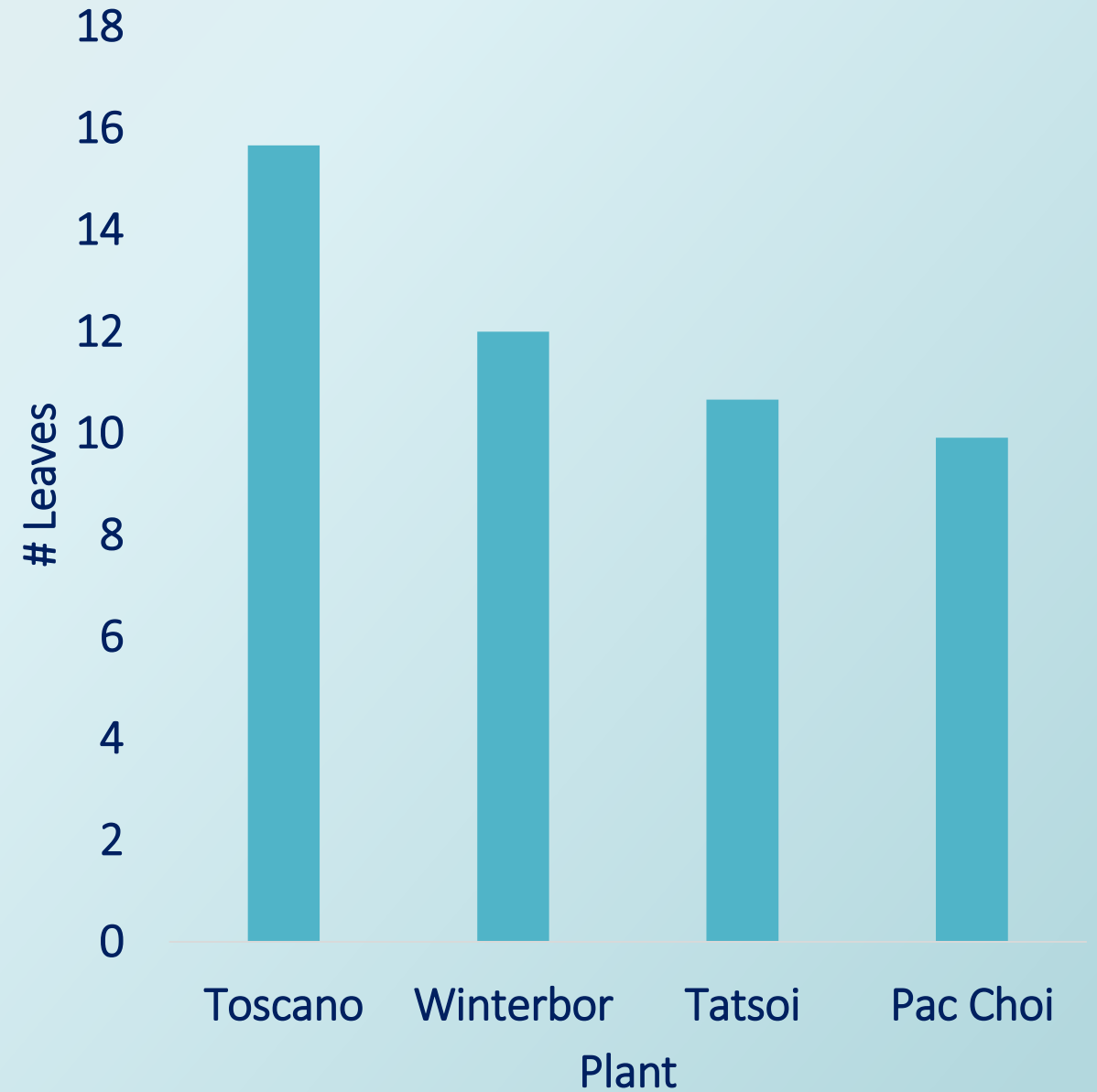
Edible Biomass at Harvest



Edible Biomass at Harvest (15 ppt)



Number of Leaves at 15 ppt



84 Day Shrimp Growout



4 Potential Harvests



Plant Harvest per Growout

Toscana	138.8 g
Winterbor	66.8 g
Tatsoi	28.6 g
Pac Choi	157.9 g



Kale Winterbor F1 Hybrid

One year at 15 ppt!



Summary

- As salinity increases, growth slows
- The evaluated salinities only reduced survival in Tatsoi
- Multiple harvests of older foliage may reduce ionic stress, as salts accumulate in older tissues
- Dry weight biomass roughly 40% lower at 15 ppt. versus 0 ppt.; however, 10 ppt. was not bad
- Kale tastes great at 15 ppt.
- Salt residue can accumulate on plant tissue
 - Monitor air flow to prevent bubbling around crown
 - Rinse plants with fresh water
- Overall encouraging, but there is room for improvement





Future Research

- Further mineral analyses on plants and water
- Nitrate analyses pending
- What is missing or too abundant in shrimp water?
- Coupled aquaponics?
- Grow out with multiple harvests
- Taste-testing and marketing with local chefs, food science researchers, farmers
- Trials with shrimp & reused shrimp water, and nitrate uptake analysis

Thank You!



Funding for this project was provided by the USDA National Institute of Food and Agriculture, 1890 Capacity Building Grant Program

KSU Aquaculture Webpage: <http://www.ksuaquaculture.org/>