Pairing Rootstocks with Site

In Northern California Vineyards

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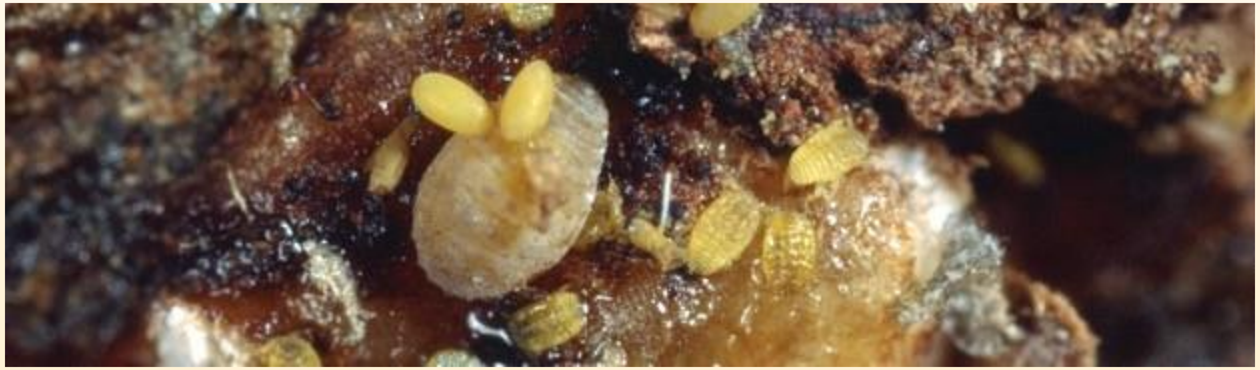
History of Rootstock use

- Originally developed by French viticulturalists in the late 19th century
  - Necessary to combat Grapevine Phylloxera
  - Majority of cultivars bred during this time
  - American *Vitis* species or hybrids

- Most rootstocks are crosses of the "Big 3"
  1. Vitis riparia   Shallow rooting
  2. Vitis rupestris   Semi-drought tolerant
  3. Vitis berlandieri   Lime-soil tolerance



Phylloxera image source: UC ANR IPM

Common uses for rootstocks today

- Pest tolerance
  - Grapevine Phylloxera
  - Nematodes
- Abiotic stress tolerance
  - Limited water
  - Anoxic inundation
  - Dry farming
  - Lime-heavy soils
  - Poor quality soils
  - Soil salinity
- Vine ~ Site efficiency
  - Erosion control
  - Increase/Decrease vigor
- Biotic stress tolerance
  - Disease resistance
- Modifying site and fruit
  - Influence fruit characteristics
  - Modify soil health

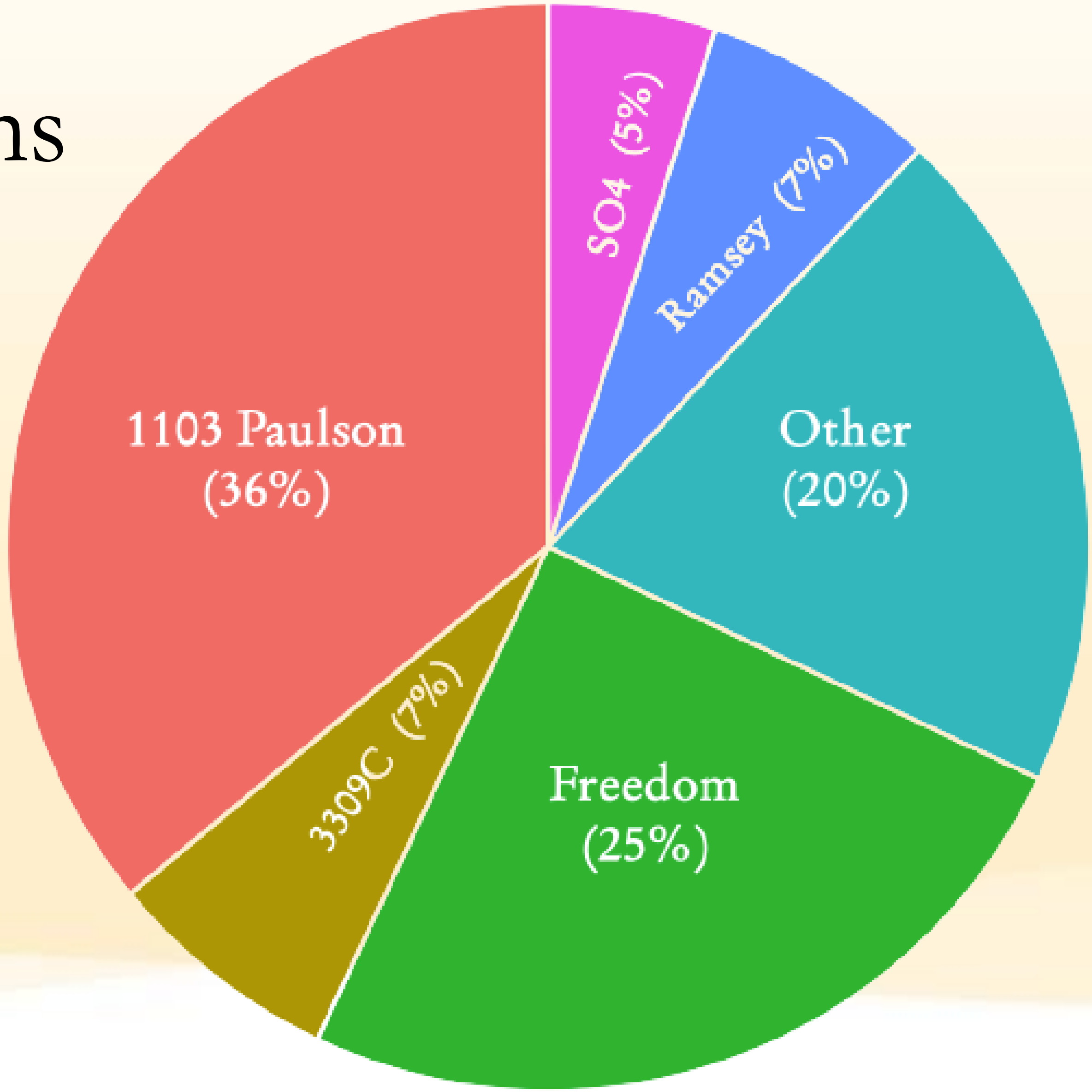
Most common rootstock cultivars planted

- Popular rootstock cultivars exist for a number of reasons:
  - Adapted to common site conditions
  - Resistant to common stressors
  - Ease of propagation in nurseries
  - No requirement to put the rootstock name on wine bottles

- Most common rootstock cultivars in CA:
  - 1103 Paulsen (*V. berlandieri x V. rupestris*)
  - Freedom (*V. labrusca x riparia x champinii x vinifera*)
  - Ramsey (*V. champinii*)
  - 3309 C (*V. riparia x V. rupestris*)
  - SO4 (*V. berlandieri x V. riparia*)

Limited Rootstock Options

- The trend holds true across California
- Some viticultural regions utilize one cultivar disproportionately (e.g., Freedom)
- Some rootstocks are used universally (e.g., 1103P)
- Data is sparse for rootstocks; These data were collected in 2022



Impacts of Limited Selection

- Nurseries produce what sells
- The popular rootstocks may not be the best choice in some vineyards
- Less common cultivars may perform better at a given site, but may also be unavailable in a chosen nursery
- Hundreds of rootstock cultivars with unique traits
    - "Don't try to pick the right rootstock, just avoid picking the wrong one" – Andy Walker

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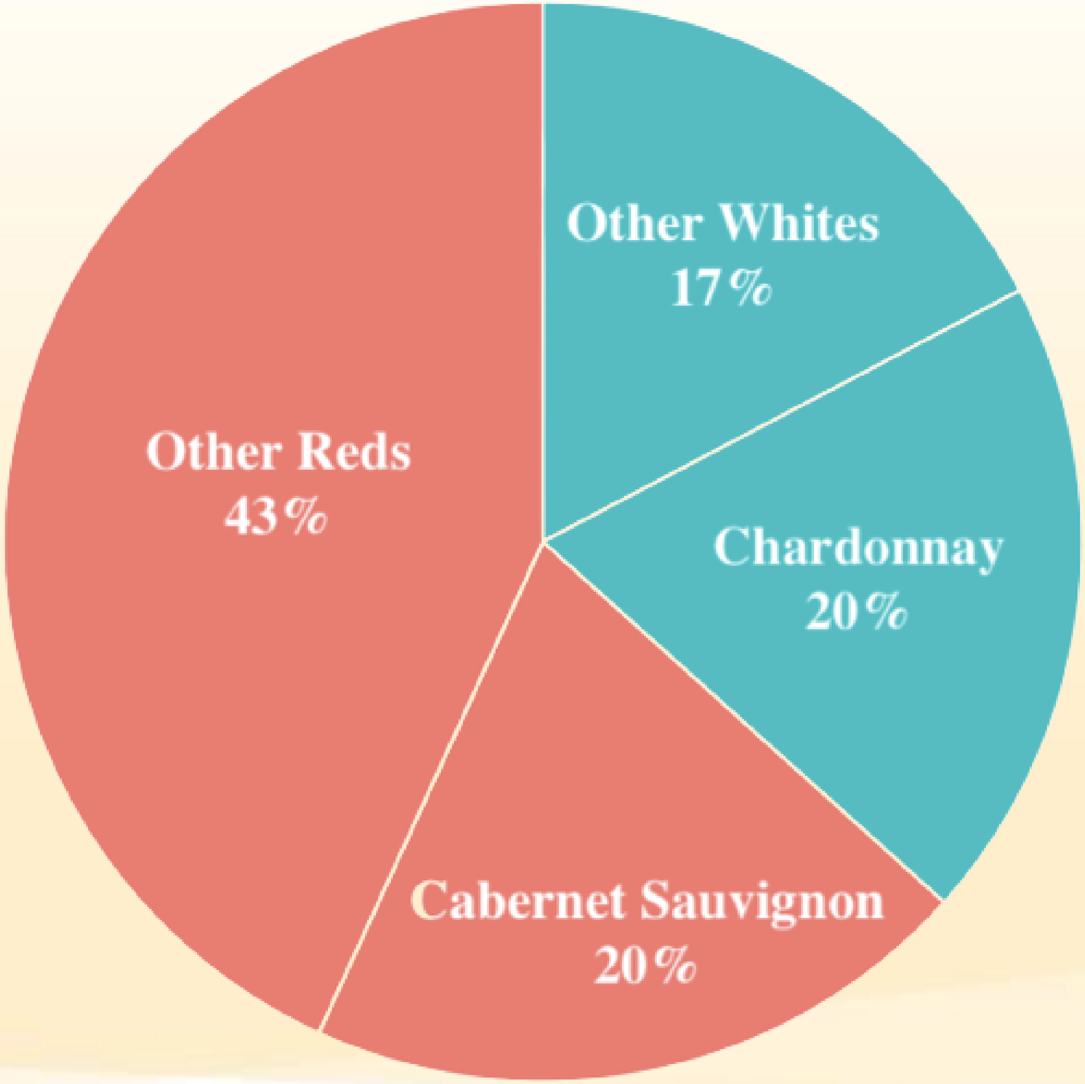
Scion Variety Bottleneck

- Market limitations on profitable cultivars
- Bottleneck down to two scions
- Wide range of climate adaptation in scions

Examples of desirable characteristics:

i. Late budbreak (avoid frost)
ii. Moderate vigor (less water demand)
iii. Early fruit maturity (maybe)

e.g., Sémillon; Tempranillo



CA Grape Acreage Report (2020)

Rootstocks for pests

- There are many commercial rootstocks available for the purpose of pest tolerance

All Rootstocks	Grape Phylloxera
Many Rootstocks	Nematodes
Some Rootstocks	GFLV

- There are few rootstocks available that were *developed* with a pest in mind:

039-16	Nematodes
GRN 1-5	Nematodes

Sources of Pest Tolerance in Grapevines

- Most pest tolerance in grapevines occur in rootstocks

- Sources vary, but mostly are attributed to wild grapevines with varying tolerance traits

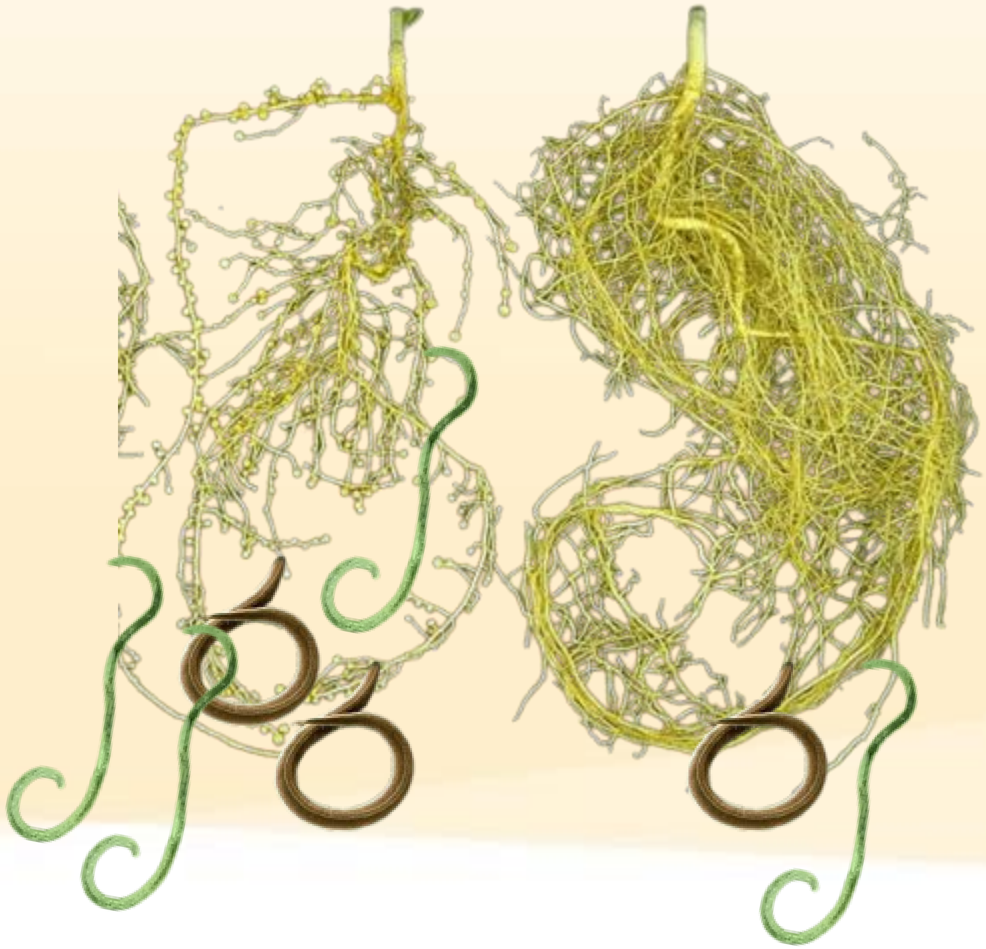
- e.g., *Muscadinia rotundifolia* is one of the rare sources of Ring Nematode resistance

Pest Resistant or Pest-Tolerant Rootstocks?

- **Tolerance** is the common mechanism in plants
  - Tolerance refers to the plant's capacity to withstand damage (e.g., Phylloxera feeding)
  - Mostly reference to feeding damage
- **Resistance** is commonly used, but not as common of a trait
  - Resistance means limiting damage from the pest
  - This may be through reducing reproduction or fitness of the pest or limiting feeding efficiency
  - e.g., White Mustard in a mono-cover

Limitations of Pest Tolerance/Resistance

- Most resistance or tolerance of pests in plants occurs in the rootstock
  - Some exceptions
  - e.g., PD and PM-resistant scions
- Soil-borne pests are most targeted for development of tolerance traits
- Rootstocks and/or scions are **unable** to eliminate a pest problem
  - Only able to tolerate the damage caused by pests or limit the pest's population growth
  - Pests will persist in the rhizosphere



New rootstocks for pest tolerance (GRNs)

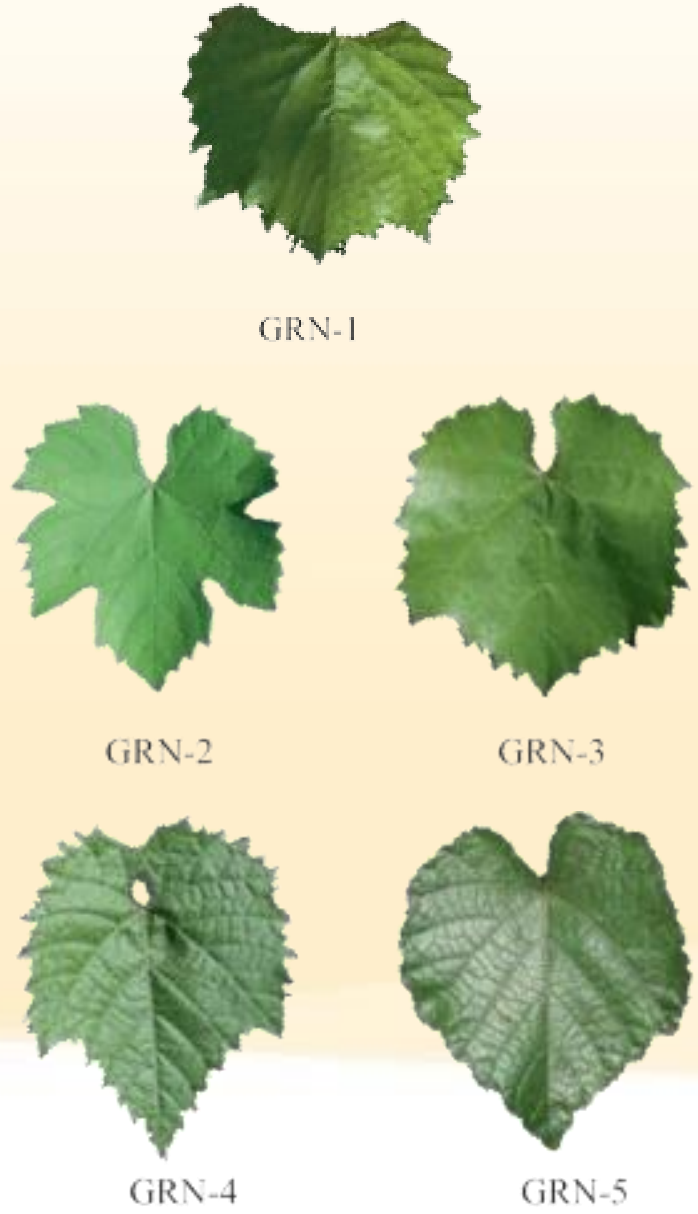
- New rootstocks have been developed to combat specific pest pressures
- Most well-known are the Grapevines Resistant to Nematodes (GRN) series
  - GRN1 = *V. rupestris x M. rotundifolia*
  - GRN2 = *V. rufotomentosa x V. champinii*
  - GRN3 = *V. rufotomentosa x V. champinii x V. monticola*
  - GRN4 = *V. rufotomentosa x V. champinii x V. monticola*
  - GRN5 = *V. champinii x V. berlandieri x V. riparia*

Rootstock	Parents	Rooting & Graftability	Scion Vigor	Dagger Nematode	Root Knot Nematode	Ring Nematode	Citrus Nematode	Lesion Nematode
UCD GRN-1	*V. rupestris* *M. rotundifolia*	Moderate	Moderate	✓	✓	✓	✓	~
UCD GRN-2	*V. rufotomentosa* *V. champinii*	Good	High	✓	✓	X	X	~
UCD GRN-3	*V. rufotomentosa* *V. champinii* *V. monticola*	Good	High	✓	✓	~	~	~
UCD GRN-4	*V. rufotomentosa* *V. champinii* *V. monticola*	Good	Moderate to High	✓	✓	~	~	~
UCD GRN-5	*V. champinii* *V. berlandieri* *V. riparia*	Moderate to Poor	Low to Moderate	✓	✓	✓	~	✓

✓ = Resistant
~ = Moderately Resistant
X = Moderately Susceptible or Susceptible

GRN 1 – A unique offering

- Vitis rupestris x Muscadinia rotundifolia
- Both parents have issues in vineyards
  - *V. rupestris* carries the same risks as planting a scion on its own roots
  - *M. rotundifolia* is known for being difficult to root and graft in nurseries
- GRN 1 offers the best of both parents
  - Rare source of ring nematode resistance
  - ≈ 80% graft success from dormant cuttings
  - Moderate to high vigor in grafted scions



Pest and disease responses to climate change

As a result of the indirect impacts of:

1. Increased average temperatures
2. Increased winter temperatures
3. Changes in developmental timing of predators/parasitoids
4. Changes in distribution and range of host plants

We expect to see changes in:

1. Pest and disease migratory behavior
2. Over wintering success
3. Species interactions
4. Effectiveness of pest predators and parasitoids

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Insect responses to climate change

Insects can respond to climate change in several ways, however three major responses that have been cited are [9] :

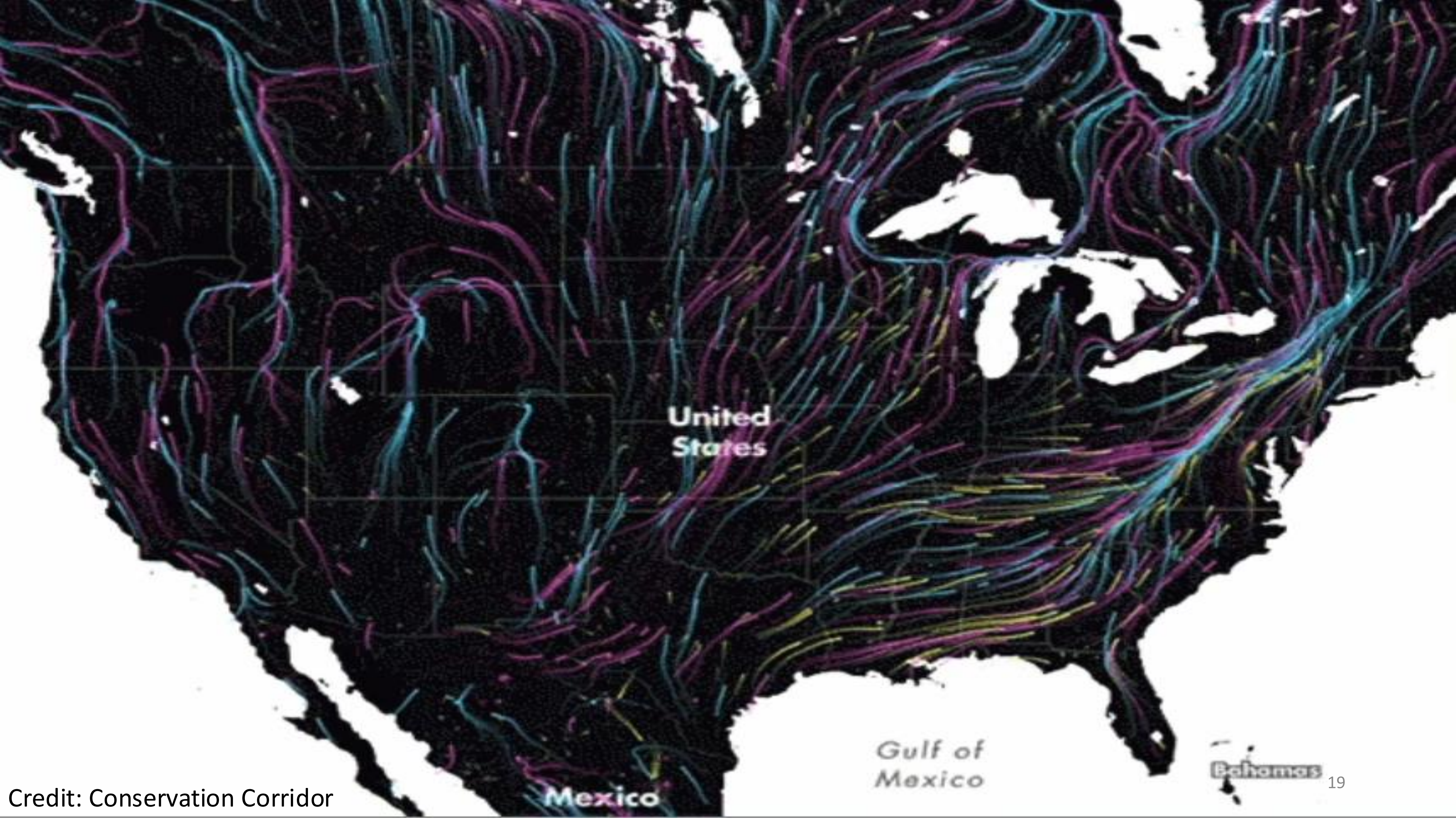
1. Moving to a climate more suitable to them
2. Shifting their phenology to correspond with the local changes in environmental conditions, or
3. Adapt to the new conditions and the associated impacts on the ecosystem

9. Deepa S Pureswaran, Audrey M Maran, and Shannon L Pelini. Chapter 18 - insect communities, 2021.

Climate change impacts on vineyard pests

- Increasing temperatures can alter the climate of a given region
- Vineyard pests will likely move as their preferred climate migrates to new regions
- Most often, they may move North and toward coastlines

1. David W Wolfe, Lewis Ziska, Curt Petzoldt, Abby Seaman, Larry Chase, and Katharine Hayhoe. Projected change in climate thresholds in the northeastern u.s.: implications for crops, pests, livestock, and farmers. Mitigation and Adaptation Strategies for Global Change, 13:555– 575, 2008. ISSN 1573-1596. doi: 10.1007/s11027-007-9125-2.
2. Holly A. Ameden and David R. Just. Pests and agricultural production under climate change, 2001.



Credit: Conservation Corridor

Overwinter Recovery – *Xylella fastidiosa*

Overwinter recovery from Pierce's Disease relies on cold Winter temperatures < 53 ºF for prolonged periods [11]

Warmer winter temperatures could impede the phenomenon of overwinter recovery

Winter temperatures in California have risen around 2 ºF since the 1970s [12] and made overwinter recovery of *X. fastidiosa* less likely to occur in hotter regions.

11. Helene Feil and Alexander H. Purcell. Temperature-dependent growth and sur- vival of xylella fastidiosa in vitro and in potted grapevines. Plant Disease, 85 (12):1230–1234, 2001. doi: 10.1094/PDIS.2001.85.12.1230

12. Tapan B Pathak, Mahesh L Maskey, Jeffery A Dahlberg, Faith Kearns, Khaled M Bali, and Daniele Zaccaria. Climate change trends and impacts on california agriculture: A detailed review. Agronomy, 8, 2018. ISSN 2073-4395. doi: 10.3390/agronomy8030025.

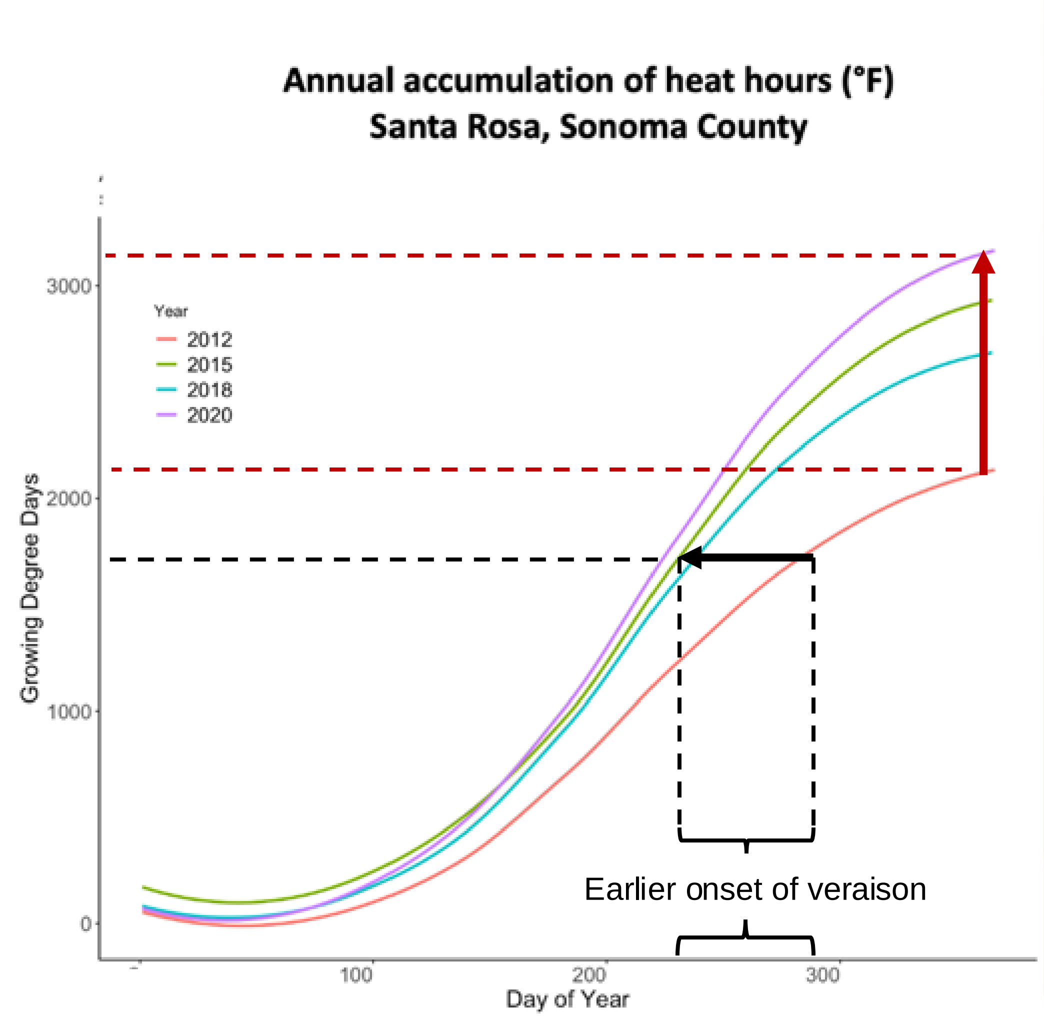
Abiotic Stress and Rootstock Selection

Increasing Temperatures

In Central Europe the impact of warming climates has been documented in Bernáth et al. 2021

Between 1985 and 2018

- Budbreak: 5-7 days earlier
- Flowering: 7-10 days earlier
- Berry maturity: 18 days earlier
- Harvest: 8-10 days earlier



Cumulative heat accumulation in Santa Rosa, California in 2012, 2015, 2018, and 2020. (Data from https://cimis.water.ca.gov)

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Most impactful abiotic stressors in vineyards

- Heat
- Frost/Freeze
- Solar Radiation
- Drought
- Inundation
- Chemical Drift
- Physical Damage

- ➢ Berry shrivel/Phenolic Degradation
- ➢ Green tissue damage/Trunk splitting
- ➢ Sunburn/Phenolic Degradation
- ➢ Yields/Senescence/Decreased PS
- ➢ Abiotic root system/Senescence
- ➢ Burn on living tissues
- ➢ "Tractor Blight"

Climate change impacts on abiotic stress

- Ambient temperatures are steadily increasing
  - Most significant impact on winter temperatures
  - Less overwinter curing and better pest survival
- Overall heat accumulation hours are increasing
  - Also reaching high values earlier in the year
- Precipitation patterns are less predictable
- Extreme weather events are less predictable:
  - More impactful where growers are unprepared
  - Spring frost in areas where they are unexpected
  - Prolonged heatwaves in cool-climate areas

Stressor Responses

No natural immune system

- Additive resistance
- Defense compound synthesis
- Abiotic stressors redirect resources

Can tolerate many stressors, but there are limits to what a vine can handle

Stressors in Vineyards

Abiotic stressors

- Frost damage
- Heat
- Drought

Biotic stressors

- Animal Pests
- Plant Pests (weeds)
- Diseases

Vine health ~ available resources + (abiotic stress) + (biotic stress)

Disease Expression

- Host-Pathogen interaction is broadly impacted by environmental conditions
- Certain abiotic stressors can increase susceptibility of grapevines to pathogens or trigger symptomatic expression of the pathogen [10]
- Fungal trunk diseases
  - Have expressed more symptoms in vines than usual in N. Coast
  - Two years of extreme drought followed by late spring frost and summer rains

10. A Songy, O Fernandez, C Clʼement, P Larignon, and F Fontaine. Grapevine trunk diseases under thermal and water stresses. Planta, 249:1655– 1679, 2019. ISSN 1432-2048. doi: 10.1007/s00425-019-03111-8.

Susceptibility of stressed vines to pests and diseases

Water stress has been shown to increase transmission of *Xylella fastidiosa* in grapevines [13]

Combined biotic and abiotic stress responses in plants often involve numerous signaling pathways

Plants can tailor their response to specific stress combinations through hormone signaling, receptors, and transcription factors [14]

13. Celia Del Cid, Rodrigo Krugner, Adam R Zeilinger, Matthew P Daugherty, and Rodrigo P P Almeida. Plant Water Stress and Vector Feeding Preference Mediate Transmission Efficiency of a Plant Pathogen. Environmental Ento- mology, 47(6):1471–1478, 09 2018. ISSN 0046-225X. doi: 10.1093/ee/nvy136.
14. Venkategowda Ramegowda and Muthappa Senthil-Kumar. The in- teractive effects of simultaneous biotic and abiotic stresses on plants: Mechanistic understanding from drought and pathogen com- bination. Journal of Plant Physiology, 176:47–54, 2015. ISSN 0176-1617. doi: https://doi.org/10.1016/j.jplph.2014.11.008.

Temperature Increases Impact Pathogen Success

Heatwaves have increased in frequency and severity

Fungi tolerance to high temps is bookended

- Unless they can adapt to hotter climates; opening more niches for themselves
- *Candida auris* – human fungal pathogen simultaneously emerged

Viral temperature ranges are similarly problematic

- However, viruses can adapt rapidly to new conditions

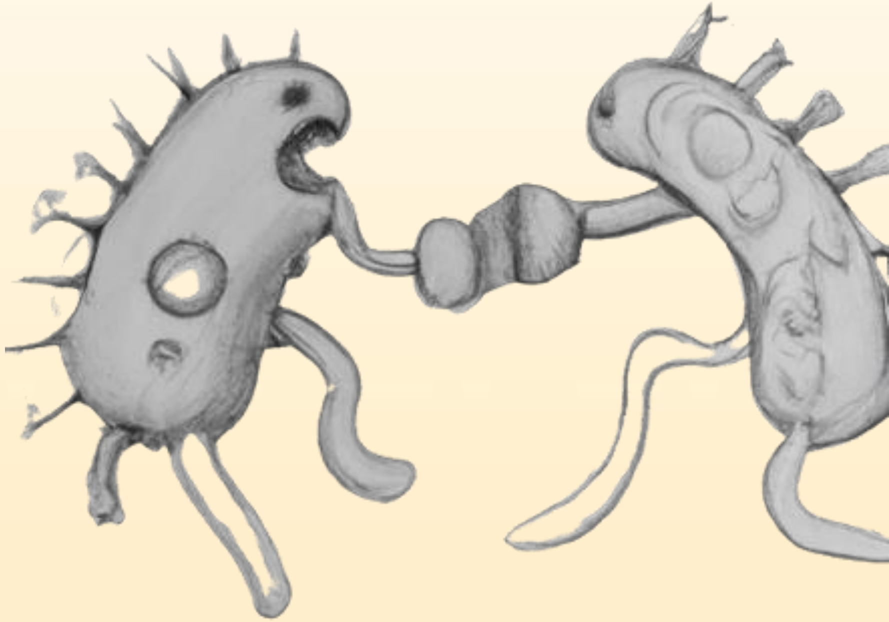
Bacterial adaptation

Bacteria can also adapt to new conditions relatively quickly

- Quick generations
- Plenty of genetic mutations

However, there are plenty of bacterial species present in our environment that are already adapted to hotter and drier conditions

This might result in a shift in localized-species composition if competing bacteria exist in the same niche



Xylella fastidiosa – Pierce's Disease

Present in California for at least 200 years

19th century

- Wiped out grapes in S. California

1960s-80s

- Nearly wiped-out Temecula Viticulture

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Xylella fastidiosa – Pierce's Disease

- Negative impacts were limited to hotter and drier S. California for hundreds of years
- With increased average temperatures we are starting to see impacts elsewhere
- Was already present, but would be 'killed off' each winter by the cold temperatures

Increased Ranges – Pests and Diseases

- Changes in temperature, CO_2 levels, water availability, and frequency of extreme weather events are likely to expand the range of existing insect pests in the vineyard

- Preference for a given climate can help predict the spread of pathogens like GTDs using weather data and on-the-ground observations

- Some pests/pathogens be more generalized than others and have higher potential to spread

Combined Stressors

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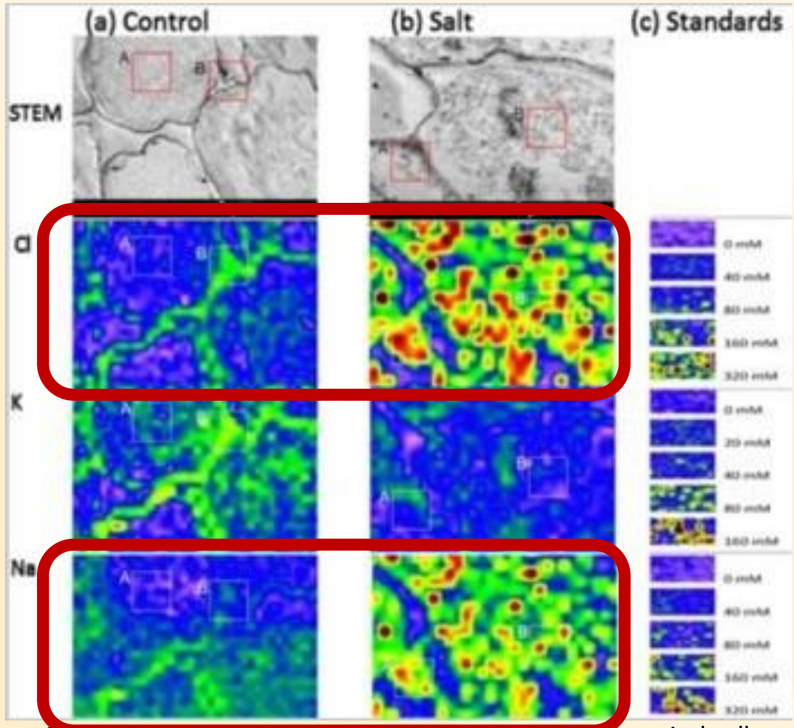
Research – Rootstocks for Salinity Tolerance

Elemental Sequestration/Compartmentalization

- Ion Subcellular Compartmentalization:
  - Cl^-, Na^+, K^+
  - (Ca^{2+} and Mg^{2+})

- Parenchyma and Cortical Cells
  - Sequester Na^+ and Cl^- before they get into the xylem
  - Limits NaCl movement to leaf tissues



TEM-EDX imaging of elemental ion composition in cortical cells of *P. euphratica*. *Credit: (Chen et al. 2014)*

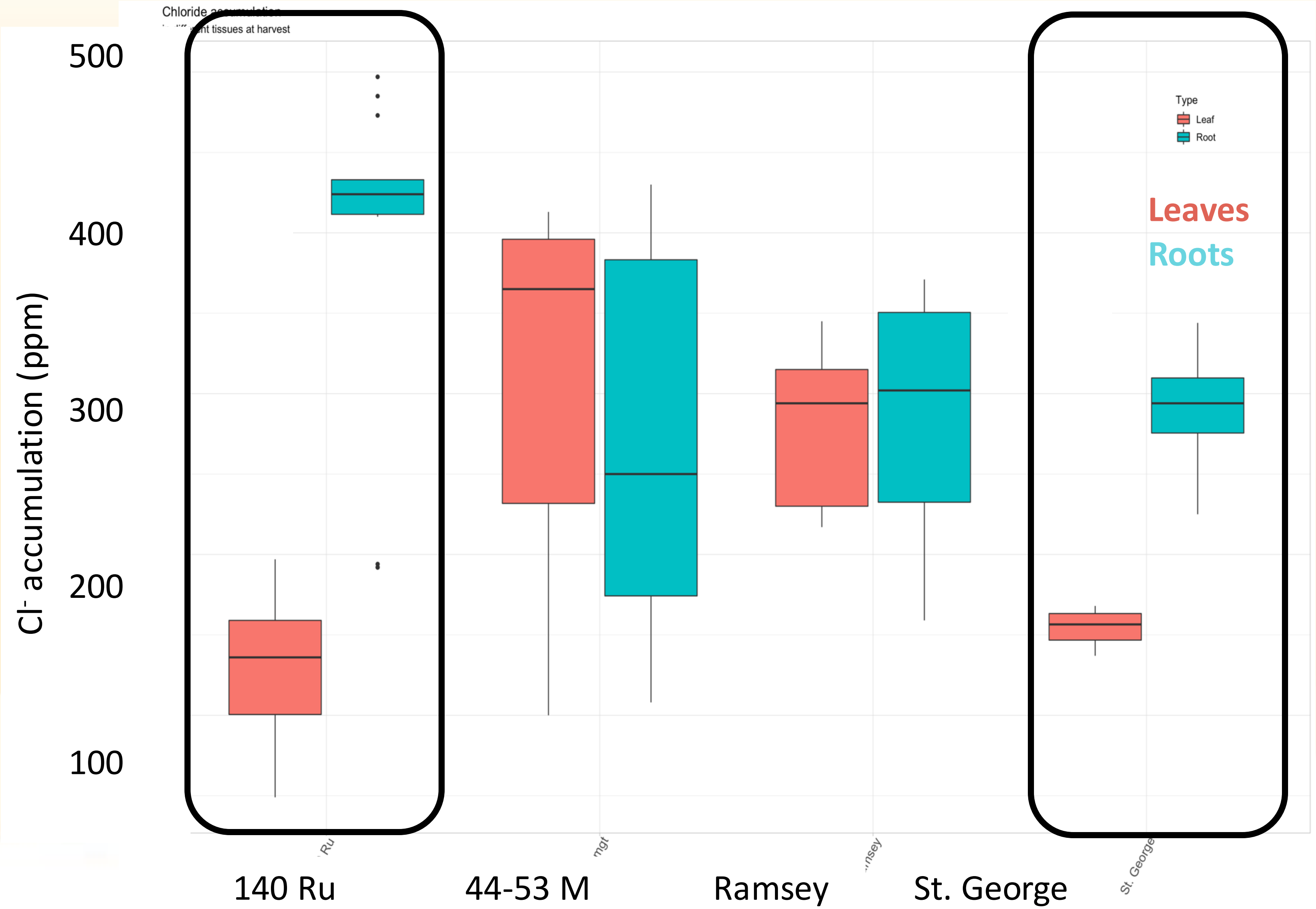
Variability in Sequestration

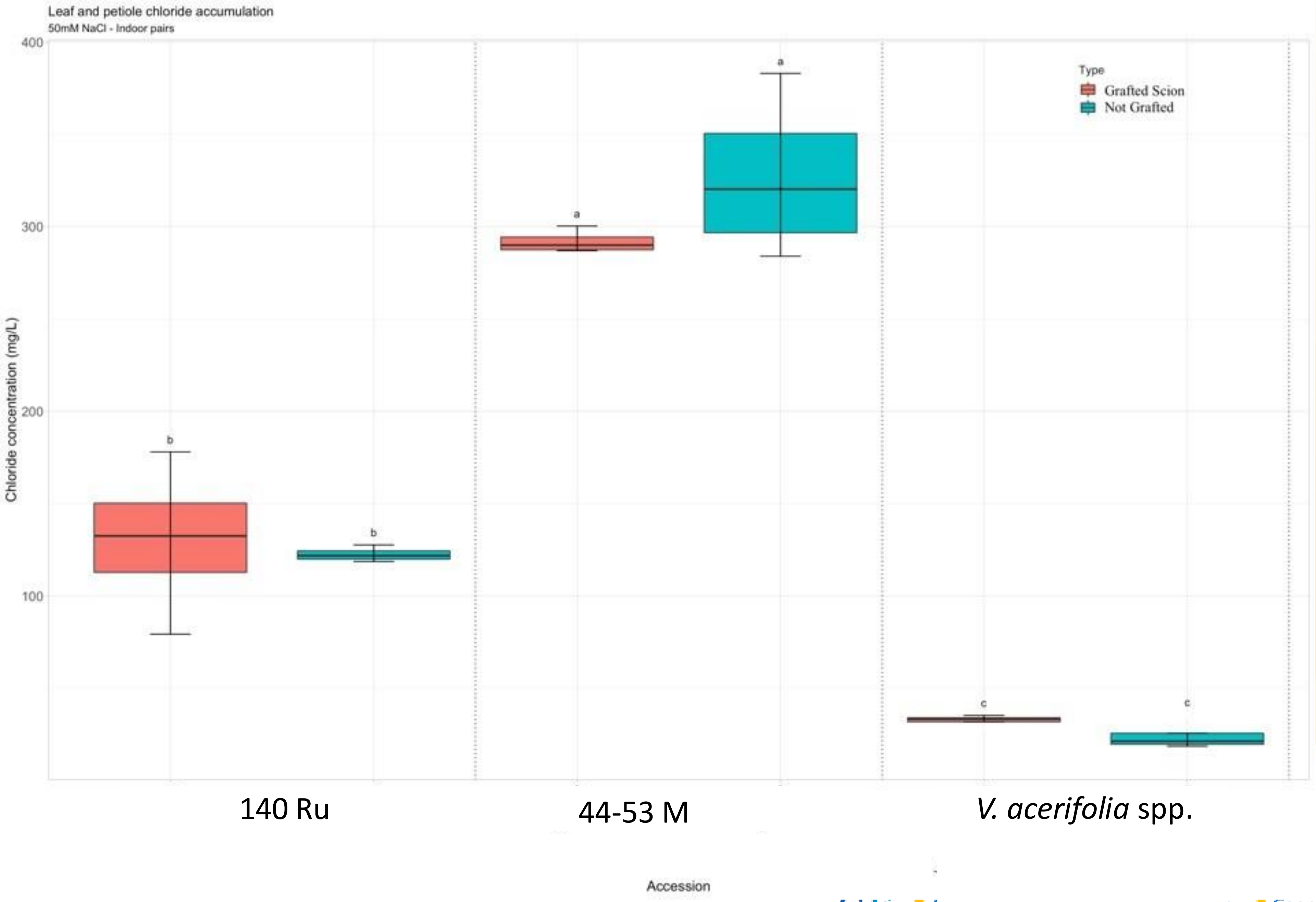
- Data from this study showed differences in leaf/petiole salinity
- No differences in root salinity
- The trait of salt-tolerance in grapevines likely occurs during the long-distance transport of chloride from root to shoot.
- Continuous variability suggests Cl-tolerance may be a complex trait

	Leaf and Petiole tissue $[Cl^-]$ 75 mM NaCl		Root tissue $[Cl^-]$ 75 mM NaCl	
Accession	$[Cl^-](mg \cdot L^{-1})$	Post hoc	$[Cl^-]$ $(mg \cdot L^{-1})$	Post hoc
18113-077	98.00 ± 28.2	a	327.67 ± 82.36	a
18113-008	85.67 ± 26.2	ab	257.5 ± 91.3	a
18113-055	83.75 ± 27.3	abc	286.42 ± 70.6	a
18113-038	81.59 ± 19.7	abcd	366.00 ± 42.4	a
18113-018	78.67 ± 20.3	abcde	294.75 ± 34.5	a
18113-046	76.42 ± 12.2	abcdef	298.92 ± 26.2	a
18113-058	75.83 ± 35.7	abcdefg	355.83 ± 122.9	a
18113-076	73.67 ± 21.1	abcdefgh	345.75 ± 42.5	a
GRN3	67.67 ± 26.4	abcdefghi	145.5 ± 27.8	a
18113-048	66.5 ± 22.6	abcdefghi	256.17 ± 45.2	a
18113-043	47.83 ± 15.6	bcdefghij	371.08 ± 93.1	a
18113-026	36.09 ± 8.8	cdefghij	234.92 ± 58.9	a
18113-007	33.58 ± 5.2	defghij	228.92 ± 97.0	a
18113-027	32.34 ± 7.5	efghij	404.92 ± 127.9	a
18113-051	28.67± 5.8	fghij	265.58 ± 61.6	a
18113-034	26.92 ± 4.4	ghij	340.67 ± 74.6	a
18113-024	26.42 ± 6.1	hij	288.67 ± 37.3	a
18113-001	23.99 ± 6.8	ij	322.67 ± 96.9	a
V. acerifolia '9018'	15.92 ± 1.6	j	165.5 ± 34.5	a
p value	2.20^{-16} ***		0.054	

Table 1.4. Accumulated leaf + petiole combined tissue, and root tissue, Cl^- concentration at harvest following 21 day application period for 75 mM NaCl applied treatment; representative accessions from each Tukey posthoc group

Evidence in Grapevines




Leaf and petiole chloride accumulation
50mM NaCl - Indoor pairs
Chloride concentration (mg/L)
400
300
200
100
Type
Grafted Scion
Not Grafted
a
a
b
b
c
c
140 Ru
44-53 M
V. acerifolia spp.
Accession

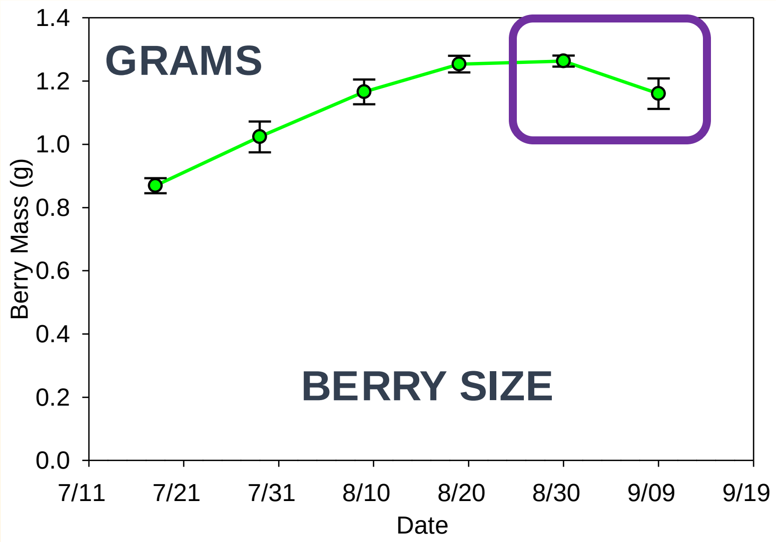
Rootstock Recommendations

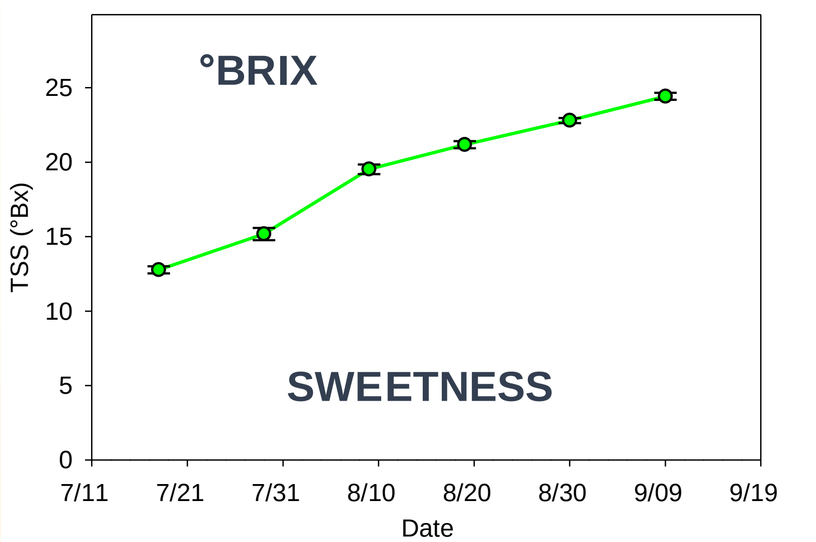
Strong Salt Excluders	140 Ru, Schwarzmann, St. George, 99R
Lower Potential Salt Exclusion (yield maintenance)	1103 P, 110 R
Poor Exclusion Potential (yield mostly maintained)	Ramsey (a.k.a. 'Salt Creek')
Poor Salt Excluders (yield reductions)	039-16, 44-53 M, Dog Ridge, V. vinifera (own roots)

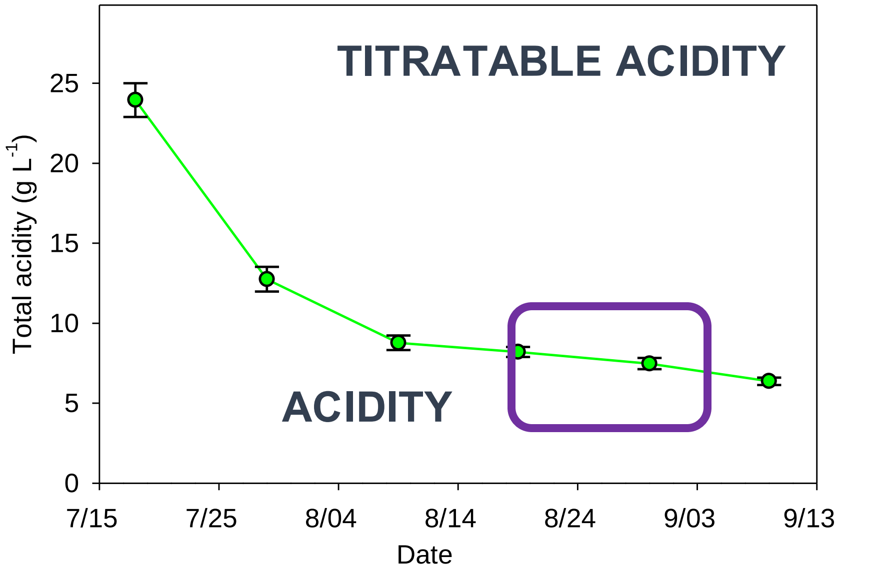
- Some of these rootstocks may be difficult to find at a nursery
- Be sure to check that you're getting the rootstock you wanted
- Avoid *V. riparia*-based rootstocks in saline environments; yield declines
  - e.g. 101-14, 5C, Riparia 'Gloire'

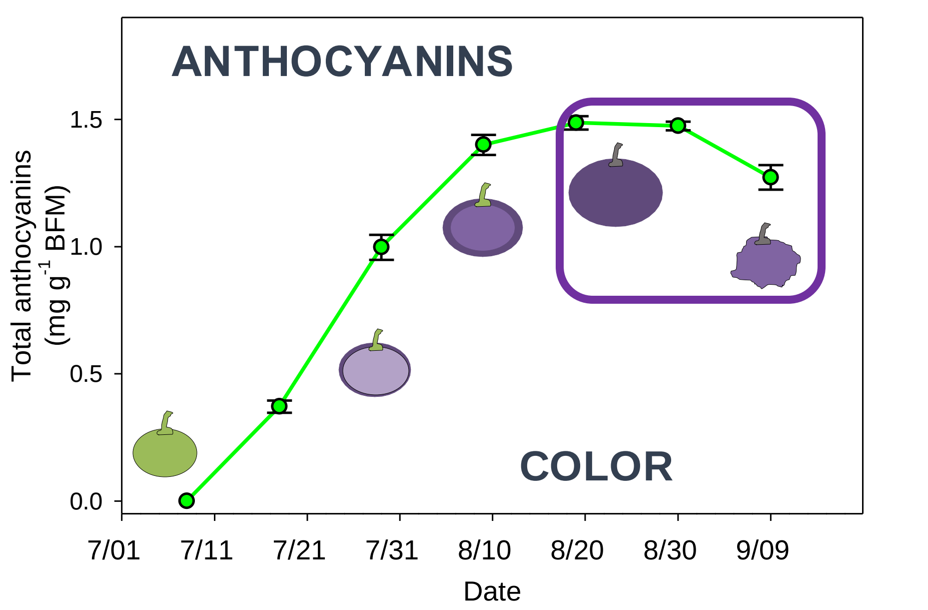
Research – Shade nets for sun mitigation

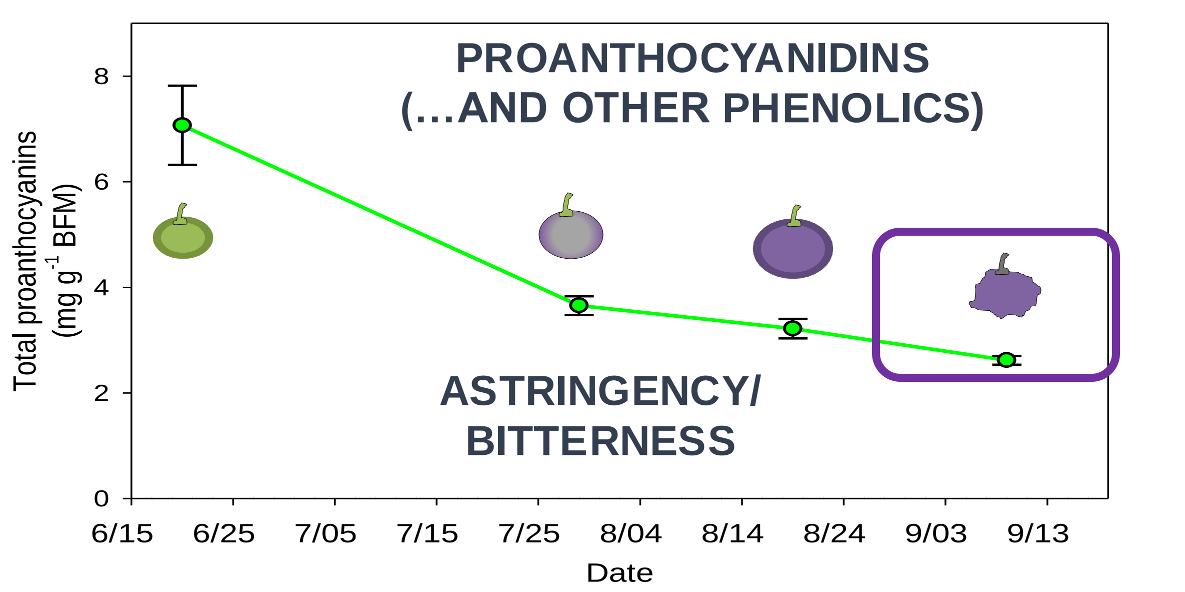
- Sun and heat damage are major concerns
- Often canopy is enough to limit damage
- In cooler climates, leaf removal might be necessary to ensure proper ripening
- Leaf removal + heatwave = berry damage
- Artificial Shading!











Credit: K. Kurtural

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Shade nets to mitigate heat damage

Artificial shading nets

- **Decreases direct solar radiation on fruit**
- **Decreases fruit zone temperatures**
- **Reduces number of sun-damaged clusters**
- **Improves or retains final quality of berries**

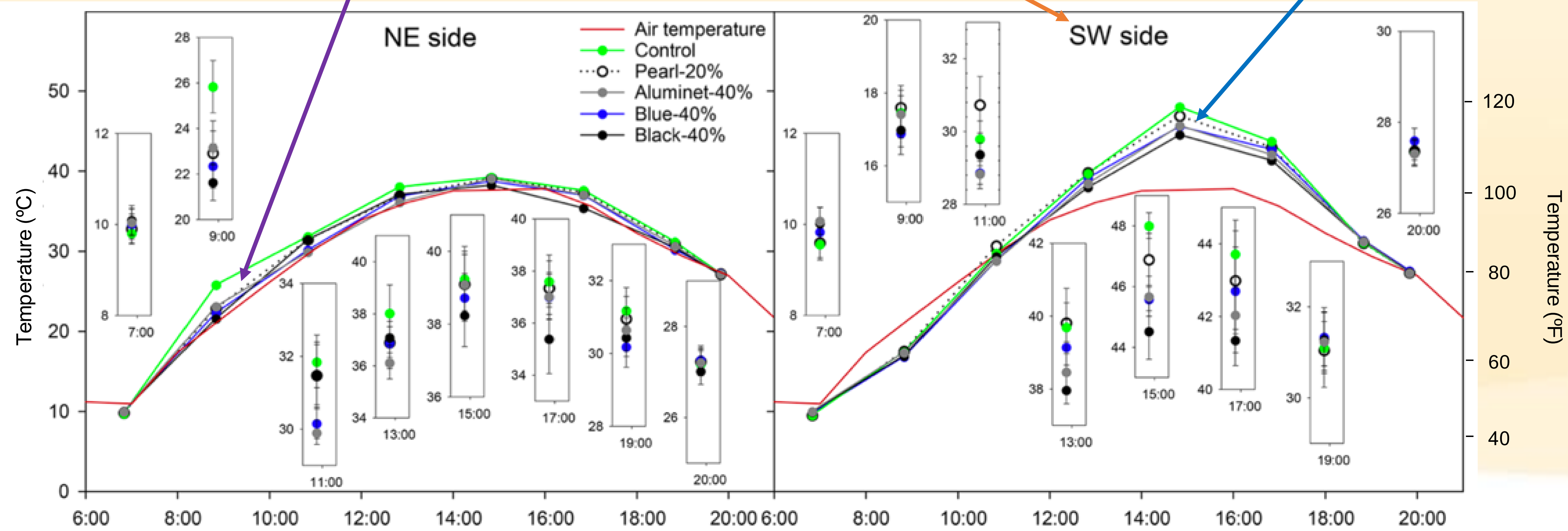
Different colored shade nets applied to Cabernet Sauvignon in Oakville, CA in 2017.

Effects of Shade Netting on Berry Temperatures

Very effective when either side is in direct sunlight

Impact last longer on the more exposed side of the canopy

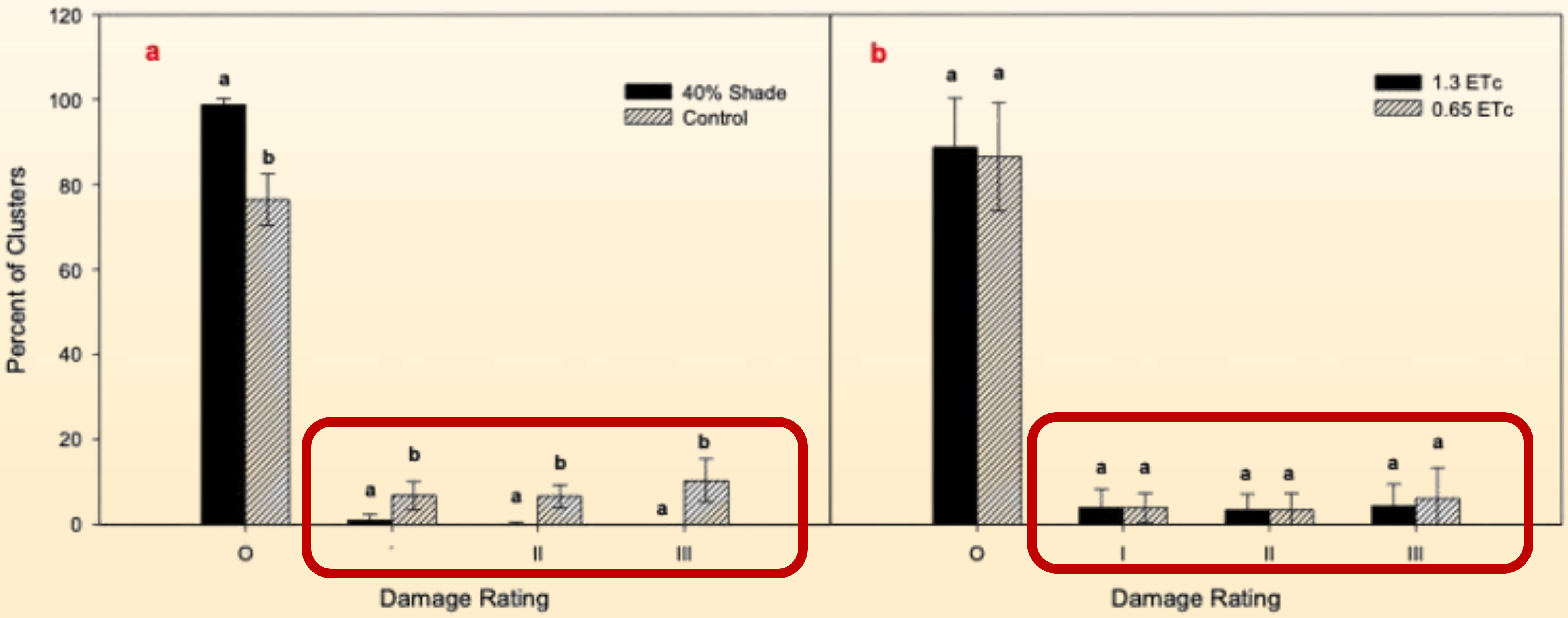
Can be up to **5 ºF cooler** under the canopy [2]



Cabernet Sauvignon fruit zone air temperatures measured under different colored shade nets in Oakville, CA in July 2016 (figure from Martínez-Lüscher et al. 2017)

Black shade net applied

Modified Irrigation



Least Damage

Most Damage

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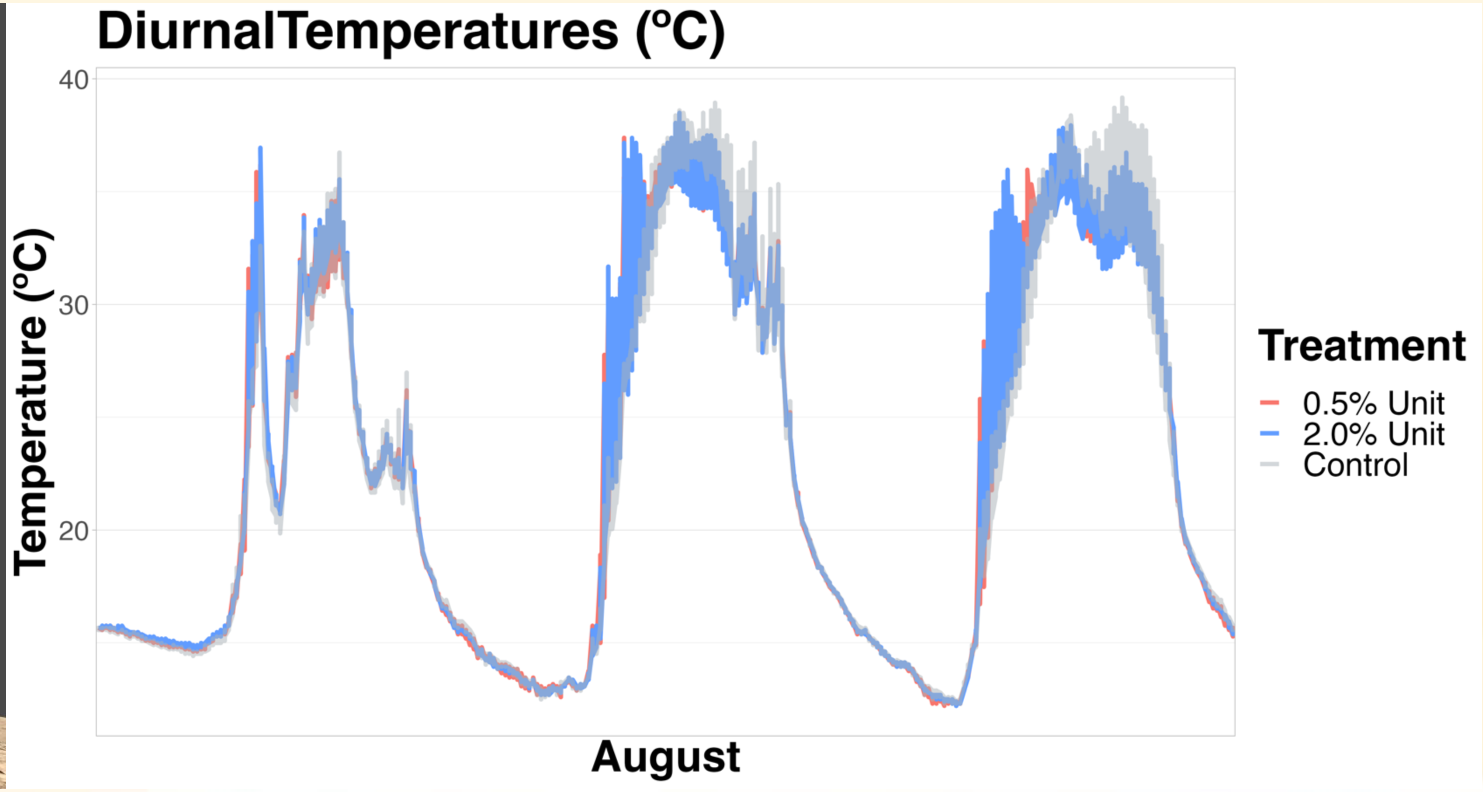
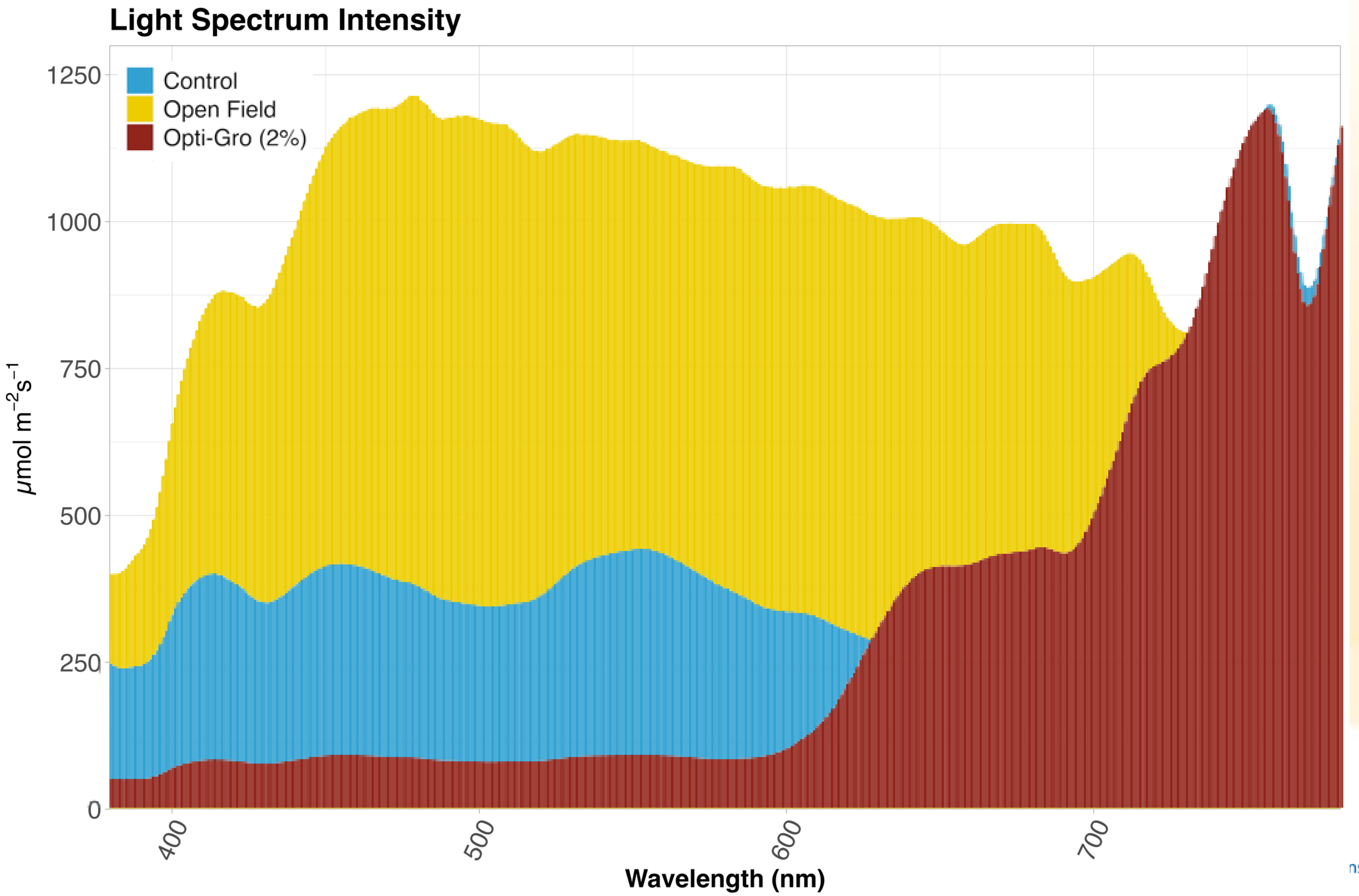
Study – Light modification cones (Opti-Gro)





Light Spectrum Intensity
Control
Open Field
Opti-Gro (2%)
1250
1000
750
500
250
0
μmol m⁻²s⁻¹
400
500
600
700
Wavelength (nm)

nsion

	0.5% Opti-Gro		2% Opti-Gro		Control		p-value		
	Mean	HSD	Mean	HSD	Mean	HSD	Treatment	Date	Trt:Date
Shoot Length (Inches)	55.75 ± 1.47	a	65.38 ± 1.75	b	52.37 ± 1.38	a	< 0.001***	< 0.001***	0.804
Shoot Diameter (Inches)	0.29 ± 0.024	a	0.32 ± 0.019	a	0.28 ± 0.018	a	0.507	0.003 **	0.325
SWP (-Bars)	-8.08 ± 0.51	a	- 7.45 ± 0.34	a	- 8.45 ± 0.19	a	0.138	0.02*	0.762

Study – Light Modification Cones (Opti-Gro)

- Useful for replants
- Decreased max temperatures during heatwaves
- Increased canopy temperatures during cold periods
- Increased 1- and 2-year-old vine shoot growth
- Decreased vine water stress
- Likely increased total light availability to entire vine
- Reduced **direct** light and increased **diffuse** light

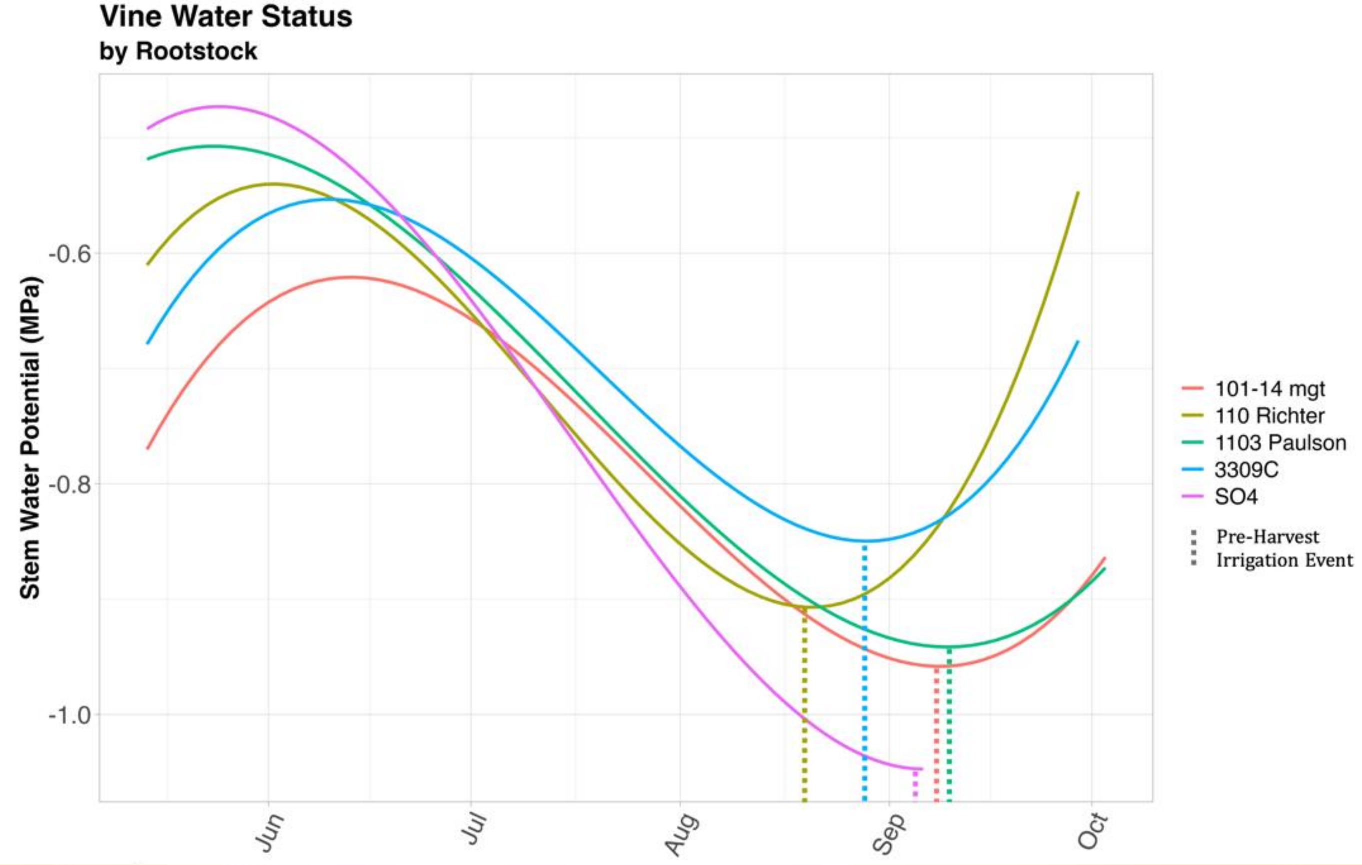
- Mitigates the impacts of extreme weather events

Study – Rootstock selection for drought recovery

- 2022-2023 study conducted across 9 vineyards in CA North Coast
  - Two scions / Five rootstocks
- Main Objectives:
  - Which rootstock is best at recovering from prolonged drought?
  - Identify site characteristics that might impact vine recovery

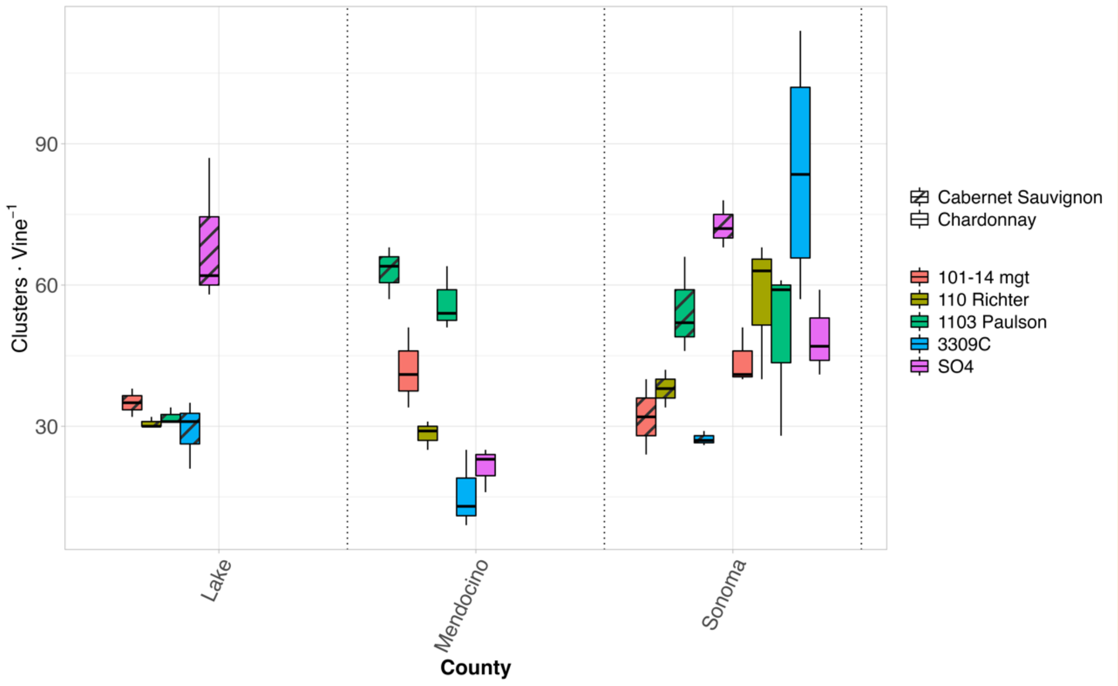
Vine Water Stress

- Measured as Stem Water Potential (SWP)
- Recovery after drought stress varied by rootstock
  - 110R recovered quickest
  - 3309C & SO4 slowest
- During water limitations, SO4 was most stressed

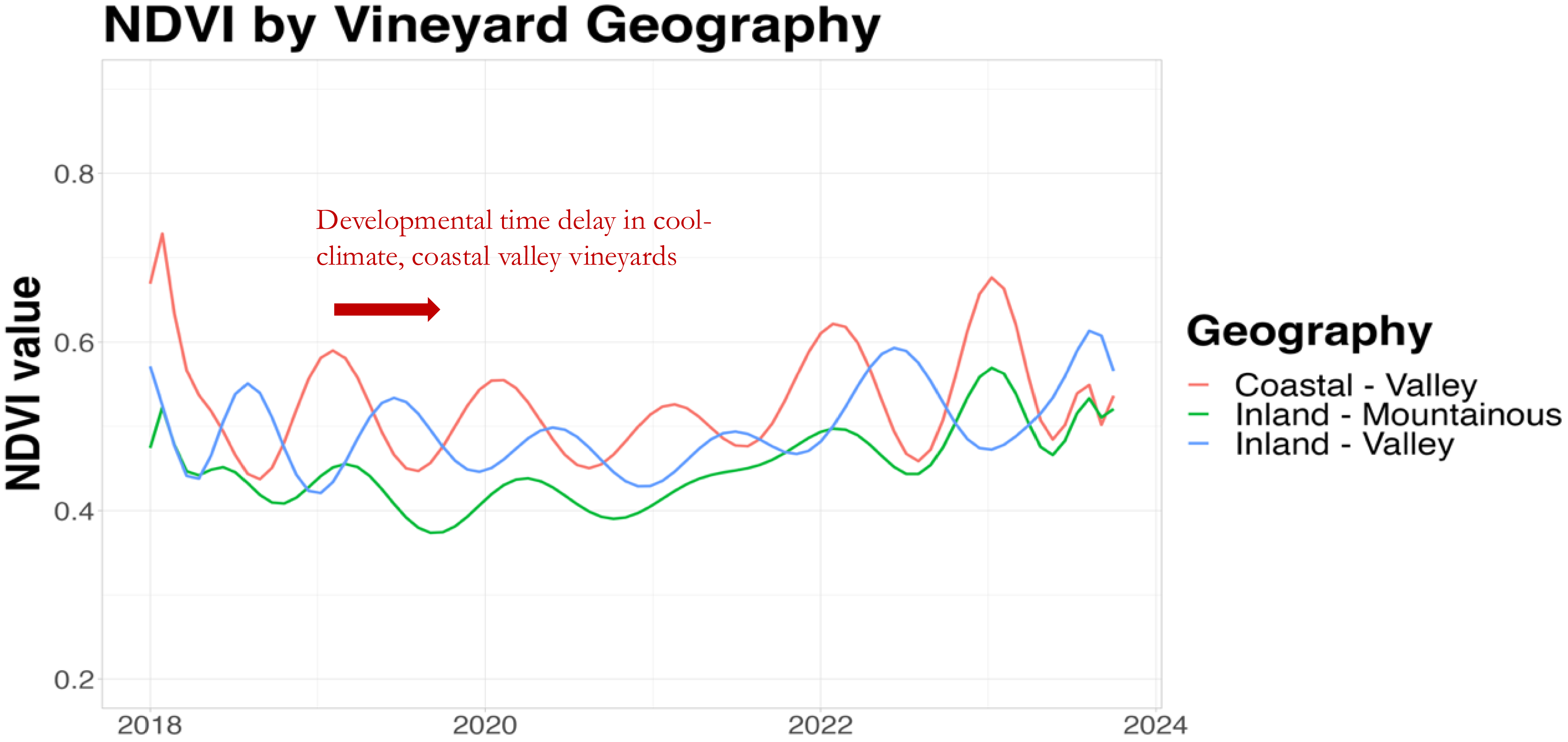


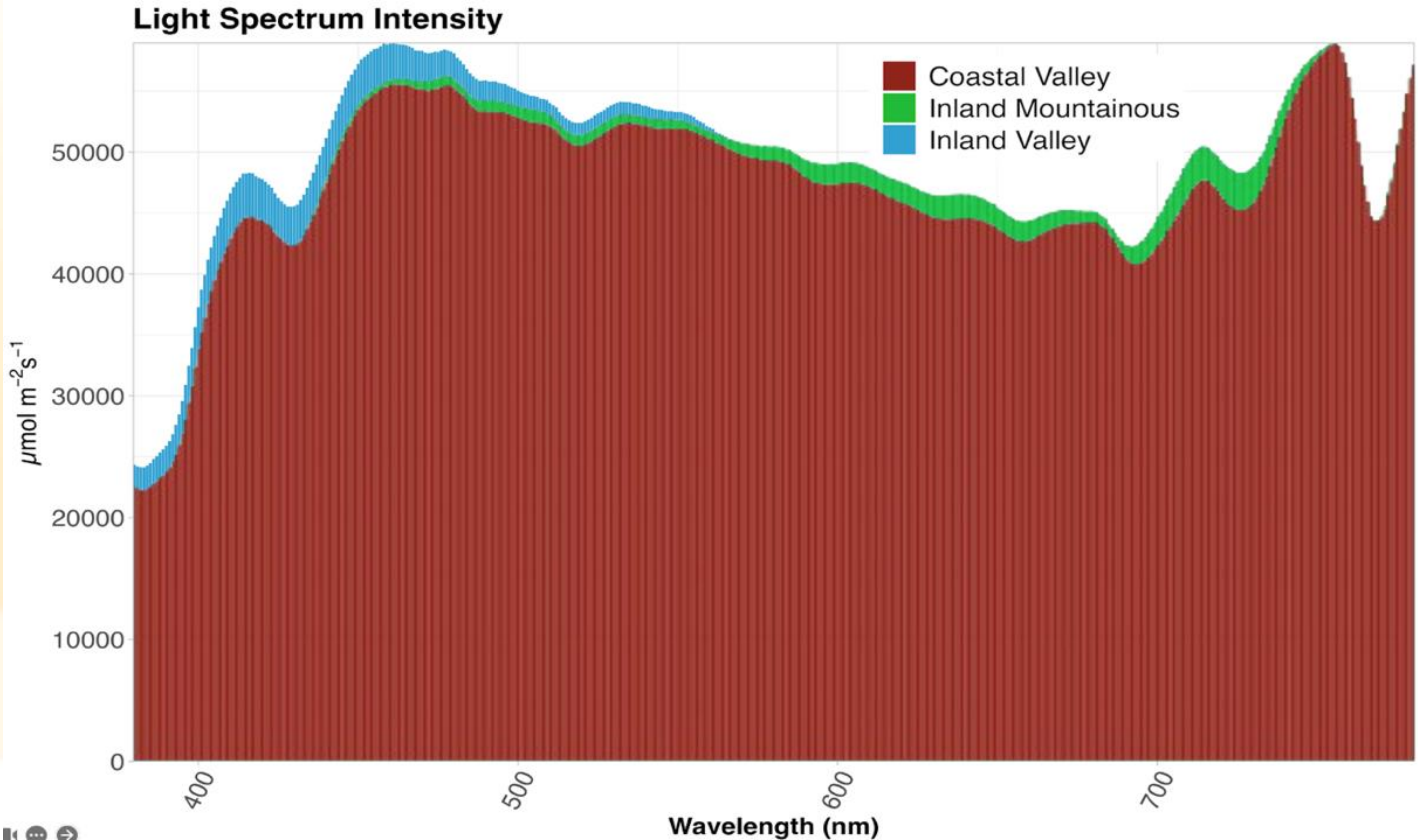
Cluster Counts & Yields

- Since this was the first year in six previous growing seasons that vines were not water limited, cluster counts may vary by susceptibility to long term water stress
- Cluster counts and yields were all significantly impacted by the rootstock, scion, geographic classification, and interaction of these factors
- Overall, can't say much definitively without more research on yield

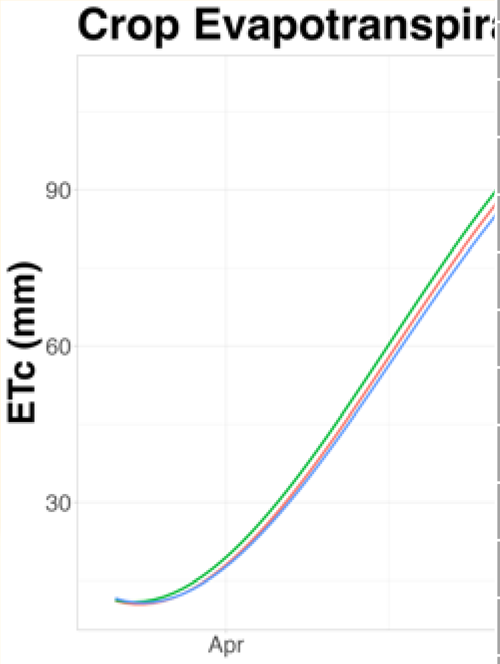


Vine Vigor by Geographic Classification

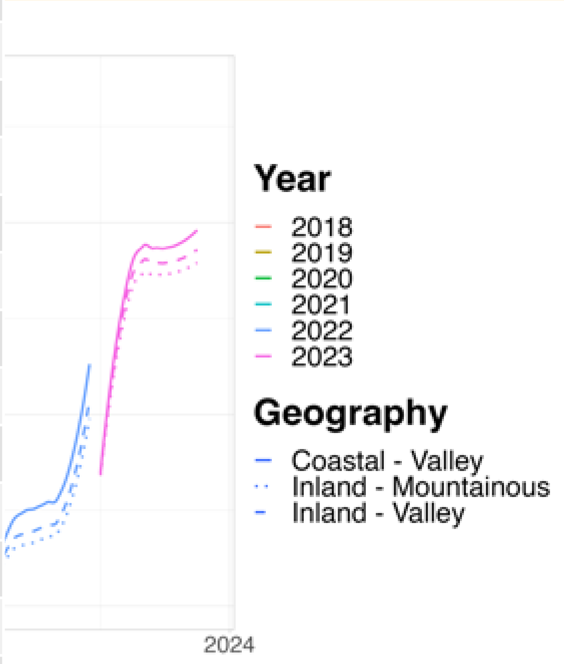



Light Spectrum Intensity
Coastal Valley
Inland Mountainous
Inland Valley
μmol m⁻²s⁻¹
50000
40000
30000
20000
10000
0
400
500
600
700
Wavelength (nm)

Water Availability by Geographic Classification



	Crop Evapotranspiration (ET_c)		
Year	Geography	ETc (mm)	Post-hoc
2022	Inland - Valley	53.31	a
2022	Coastal – Valley	44.28	b
2022	Inland - Mountainous	45.79	b
2023	Inland - Valley	42.66	b
2023	Coastal – Valley	43.50	b
2023	Inland - Mountainous	44.71	b
	Normalized Difference Vegetation Index (NDVI)		
Year	Vineyard	NDVI	Post-hoc
2022	Inland - Valley	0.51	a
2022	Coastal – Valley	0.50	ab
2022	Inland - Mountainous	0.49	ab
2023	Inland - Valley	0.44	b
2023	Coastal – Valley	0.53	a
2023	Inland - Mountainous	0.44	b



Research Take Aways

- Artificial shading can be a useful tool for limiting sun and heat related damage in cold-climate viticultural areas where leaf removal is necessary
- Light-modification technology can help reduce the impact of extreme weather events such as cold-snaps, heatwaves, and poor light availability
- While rootstock selection is a valuable tool for abiotic stress tolerance, the site conditions in and geographic classification of the vineyard are at least as important for abiotic stress tolerance regardless of scion variety

Rootstock and Scion Selection

- To adapt to climate shifts and preserve our viticultural areas, exploring the benefits of new varieties may be necessary

- Cultivars perform best in a climate similar to the one they were developed for

- Try planting "experimental" vines
  - One or two vines for each "test" scion/rootstock
  - See which ones perform best as climates shift
  - Consider planting those when it is time to replant

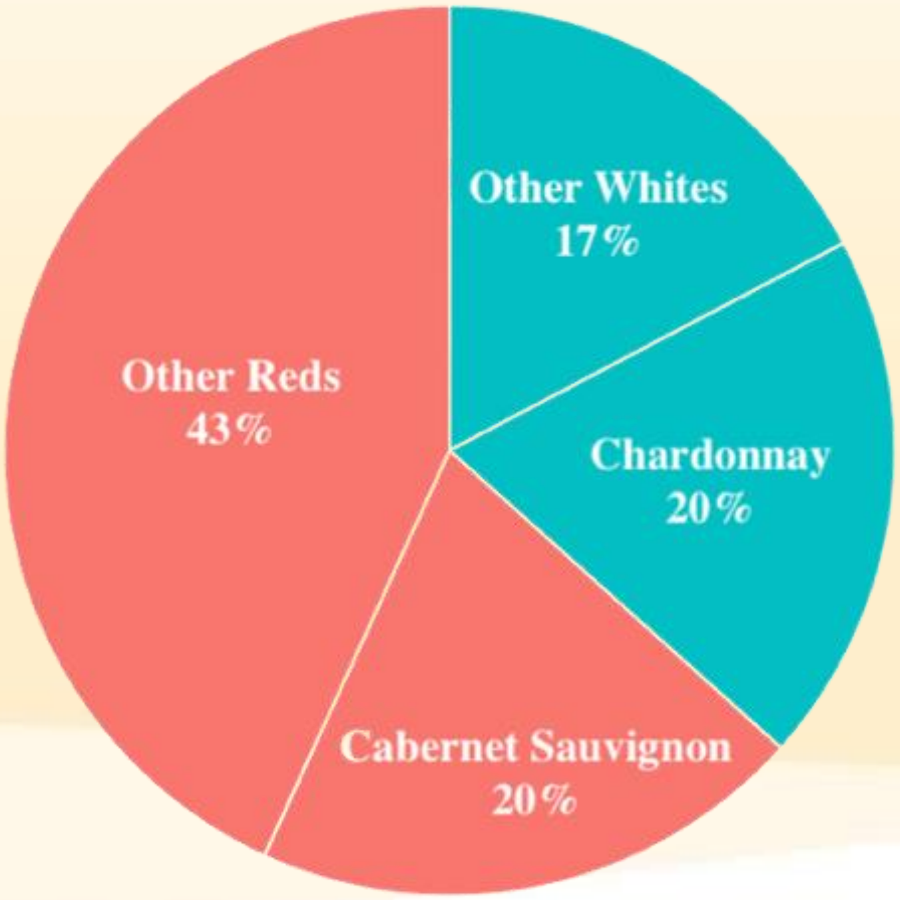
140 Ru

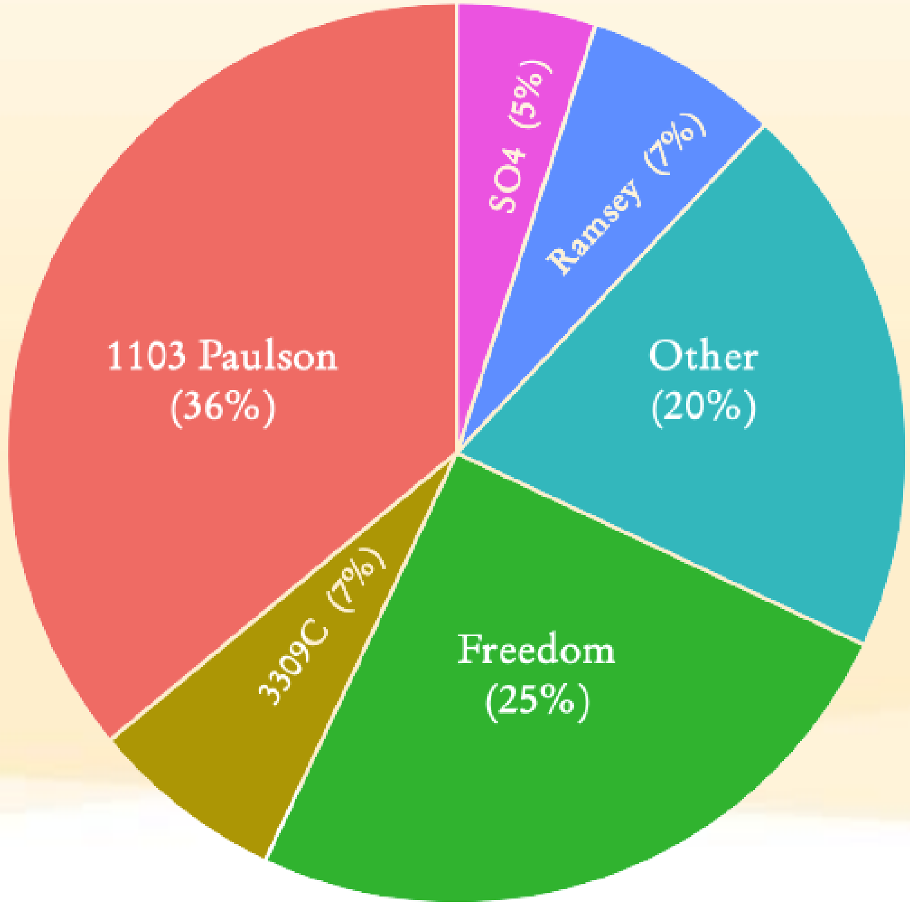
140 Ru – deep rooted

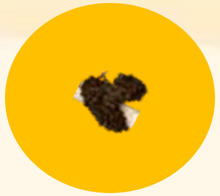
101-14 mgt

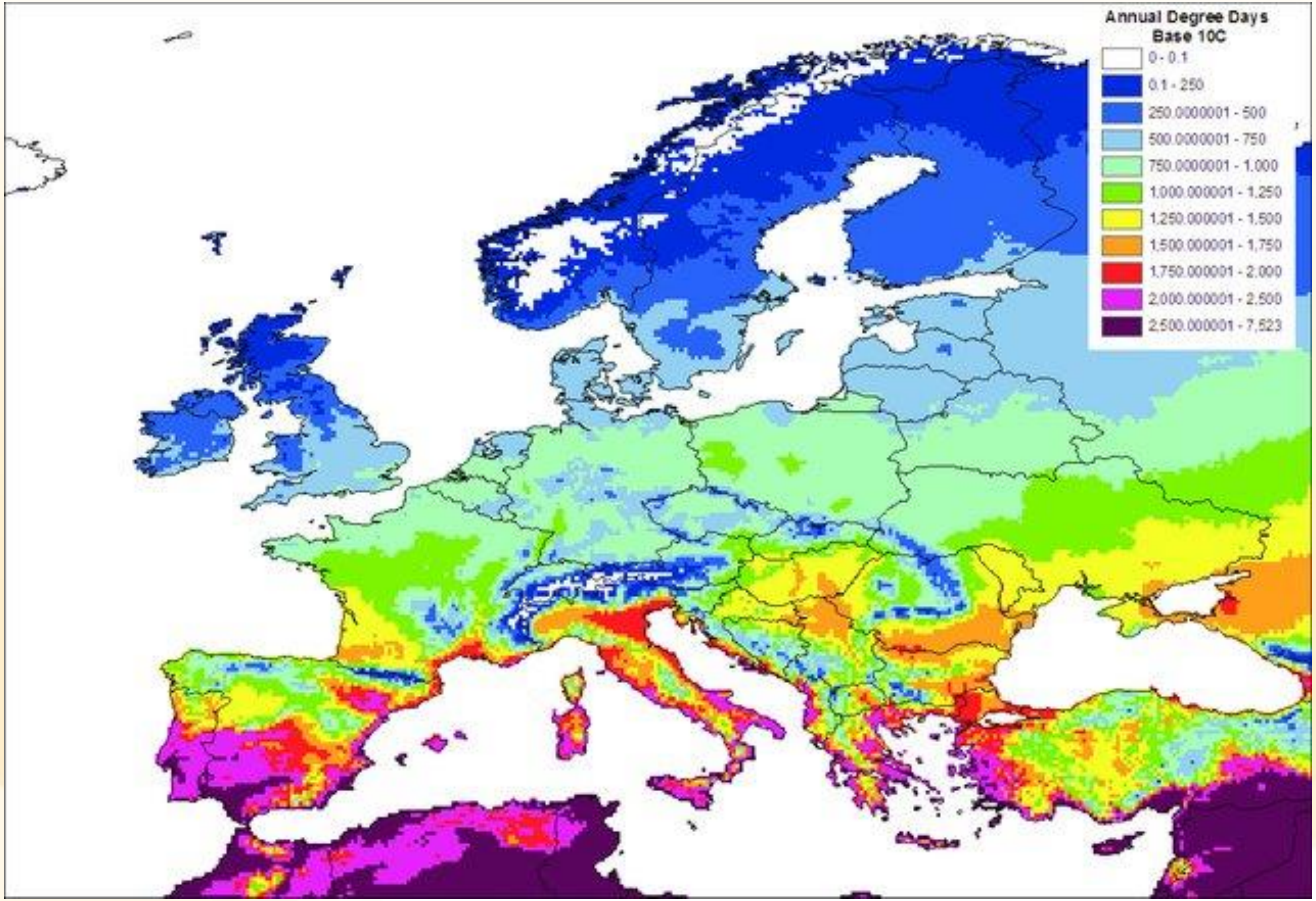
101-14 mgt – shallow rooted

Less is Not More





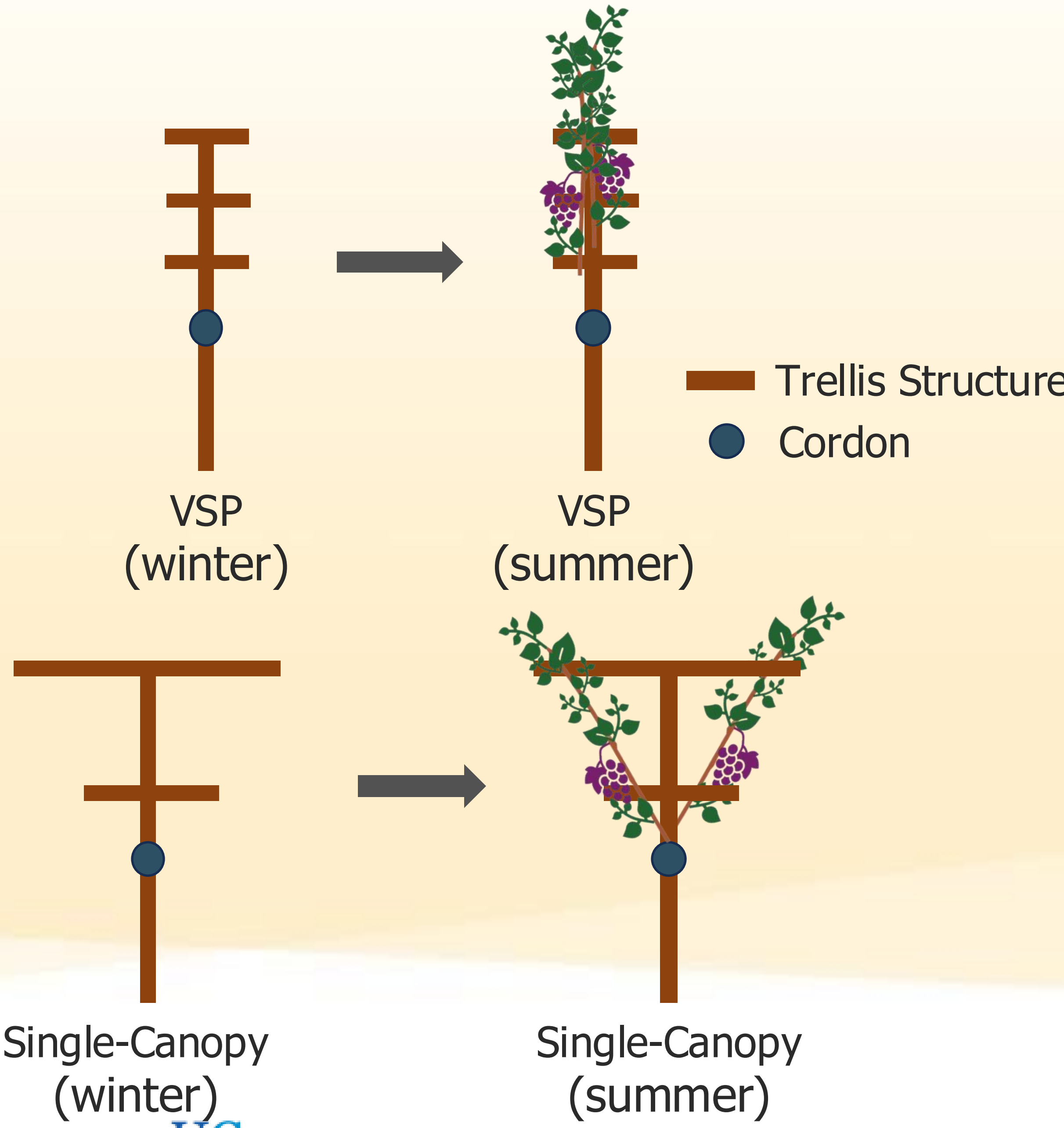



Annual Degree Days
Base 10C
0 - 0.1
0.1 - 250
250.0000001 - 500
500.0000001 - 750
750.0000001 - 1,000
1,000.000001 - 1,250
1,250.000001 - 1,500
1,500.000001 - 1,750
1,750.000001 - 2,000
2,000.000001 - 2,500
2,500.000001 - 7,523

Modified Trellis Design

- VSP – Dominant trellis design
  - Useful for cool-climate viticulture
  - Poor for hot-climate viticulture
  - Primary mechanized trellis

- CA Sprawl / T-Top
  - Vine shades own fruit zone
  - Useful in hot-climate viticulture
  - Somewhat mechanizable
  - Less sun/heat damage than VSP



Pest and Disease Monitoring

- LiDAR Identification
  - Flying insects
  - Identified by differentiating wingbeat frequencies
- Drone-Based Aerial Imagery
  - Capture weak areas in vineyards
  - Areas “at-risk” of pest pressure
- Improved Site Monitoring
  - Improved weather stations
  - Soil monitoring
  - Pheromone traps with sensors

Climate Adaptive Approaches

1. Water Use Efficiency
   - Drought tolerant cultivars
   - Precision irrigation methods
   - Water-efficient cultural practices
   - Better soil-water dynamics
2. Heat/Drought tolerant varieties
   - Research and testing
   - Available and adopted
3. Pest-tolerant rootstocks
   - Identify future pest risks
   - Research and testing
   - Available and adopted
4. Consistent monitoring
   - Look out for new issues
   - Observe and record patterns and trends
   - Get ahead of challenges before they become costly
5. Ready adoption of new practices
   - Growers willing to try out new concepts and practices
   - Increase our climate-resilience greatly

Sources

You can find this presentation at:

1. https://ucanr.edu/sites/chenlab
2. Speaker Presentations

Some original images created by OpenAI Labs Dall-E Program

Thank you

Special thanks to the organizations who provided funding for the data presented (2016-2024)

American Vineyard Foundation

CALIFORNIA GRAPE ROOTSTOCK COMMISSION

Opti-Harvest

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