Heat Stress Mitigation and Strategies

Protecting Grapevines from Extreme Weather

Christopher Chen, Ph.D.
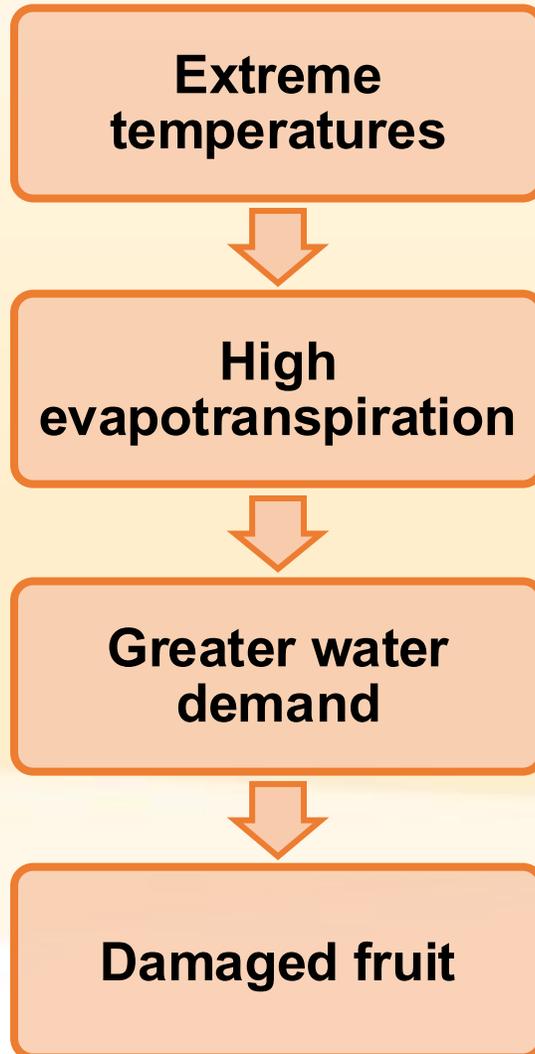
UCCE – Integrated Vineyard Systems Advisor
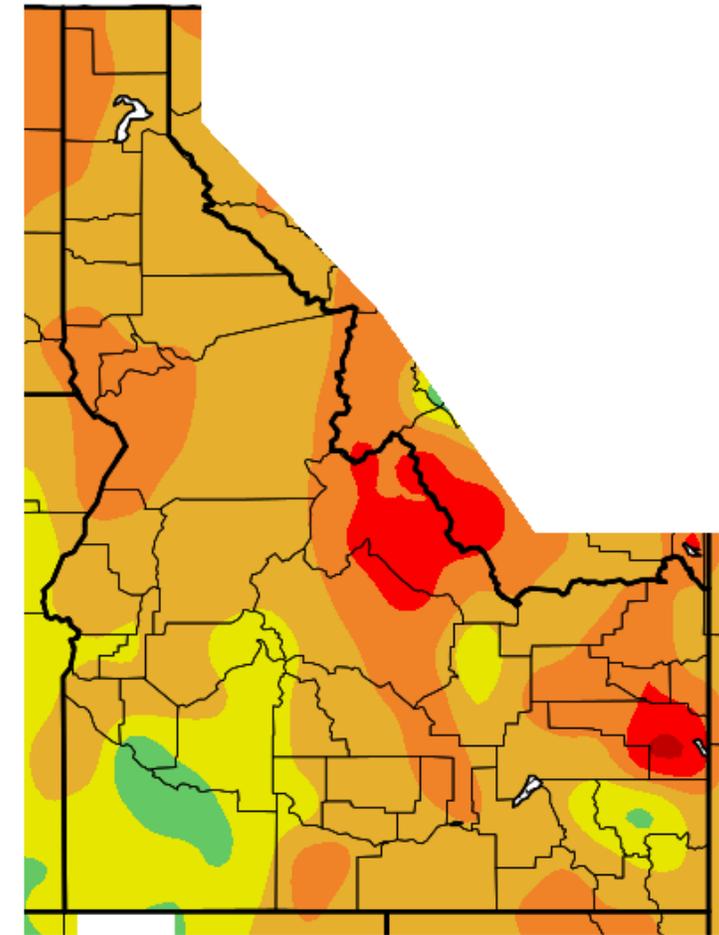
North Coast

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Extreme Heat - Trends

Extreme Heat

```
Extreme
temperatures
        ↓
High
evapotranspiration
        ↓
Greater water
demand
        ↓
Damaged fruit
```
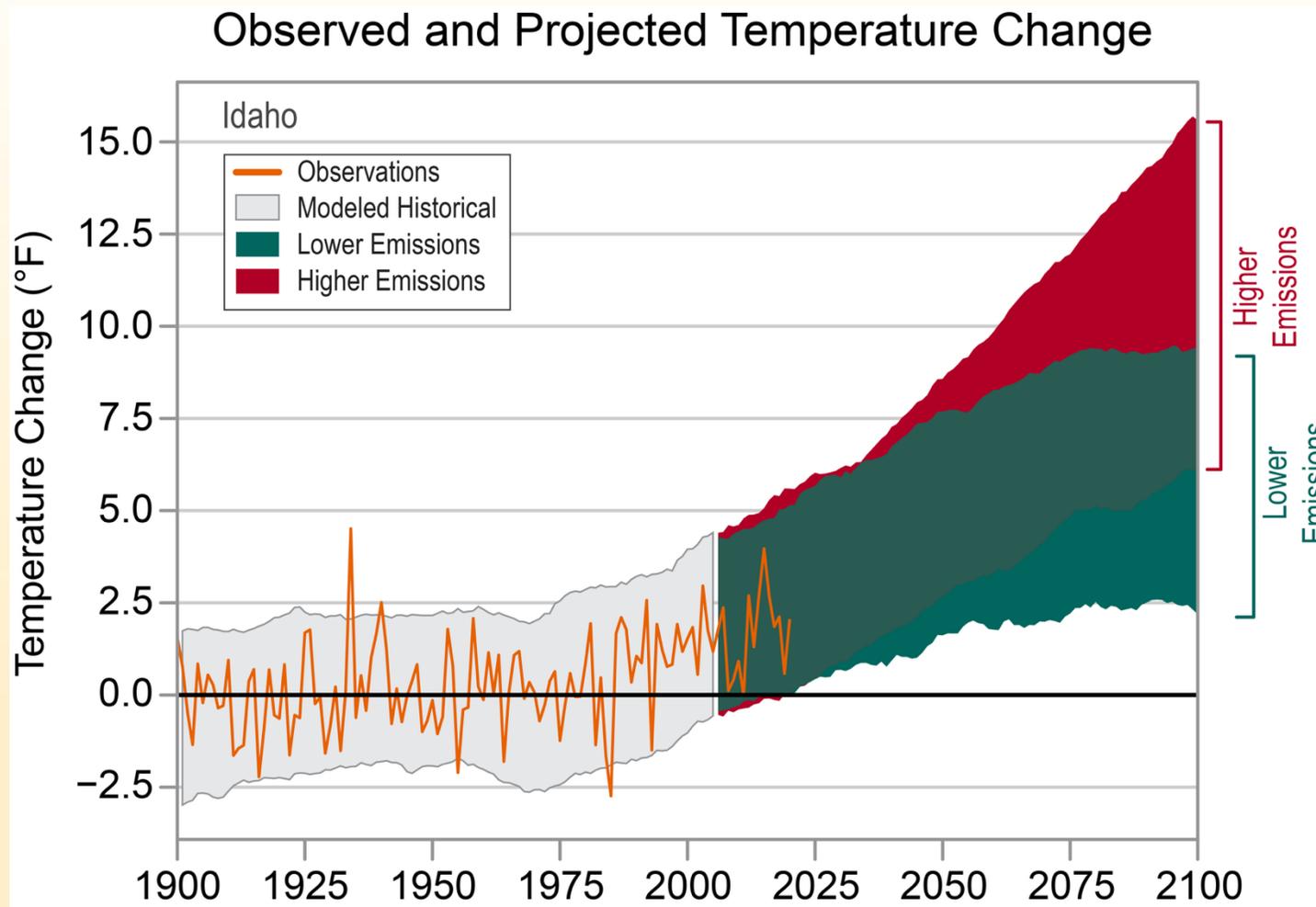

Av. Max. Temperature dep from Ave (deg F)
2/23/2023 – 2/22/2026

Generated 2/23/2026 at WRCC using provisional data.
NOAA Regional Climate Centers

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Credit: Western Regional Climate Center (2026)[2]
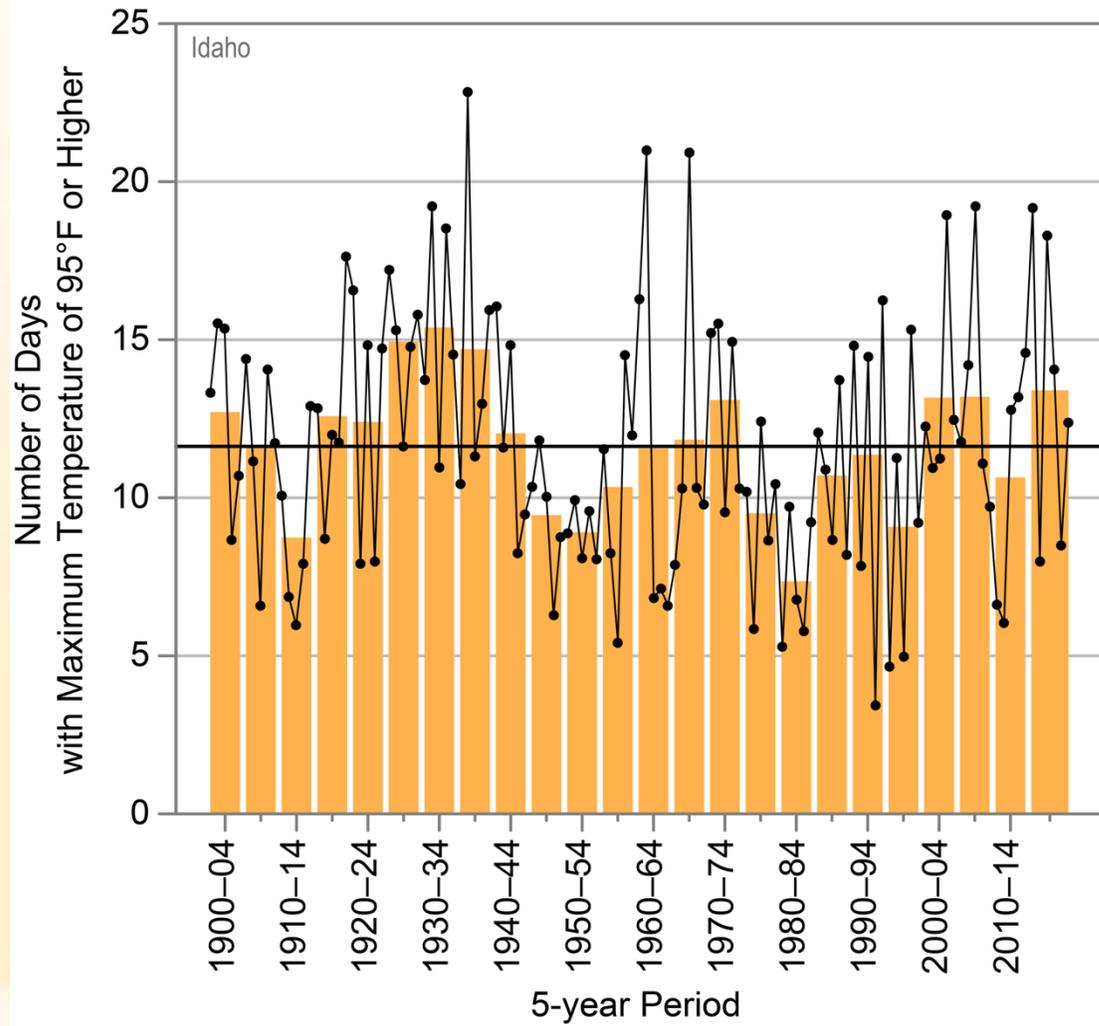
Observed and Projected Temperature Change

Temperatures in Idaho (orange line) have risen almost 2°F since the beginning of the 20th century. Shading indicates the range of annual temperatures from the set of models.
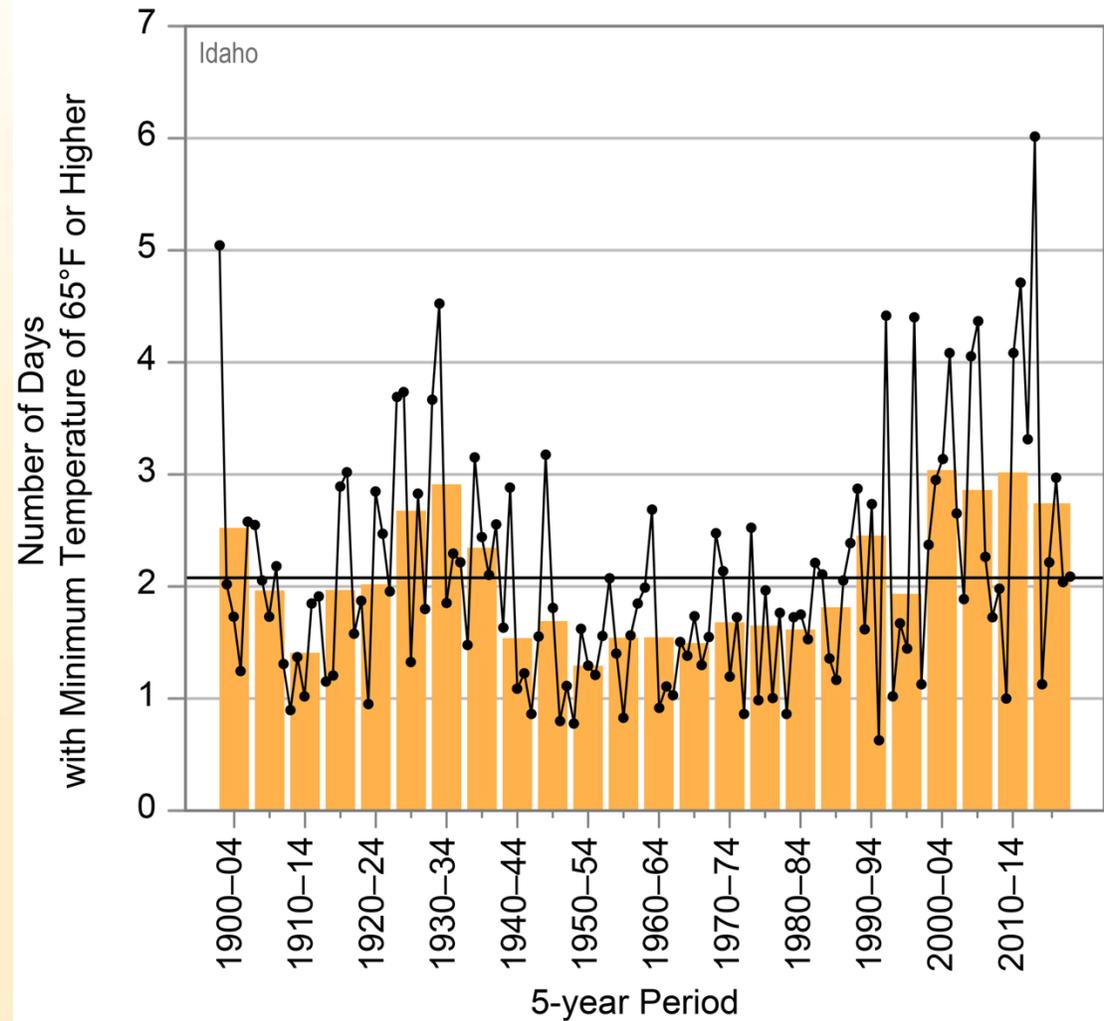
Sources: CISESS and NOAA NCEI

URL: https://statesummaries.ncics.org/chapter/id/

No change in number of very hot days

CISESS and NOAA NCEI

But fewer instances of cold nights

CISESS and NOAA NCEI

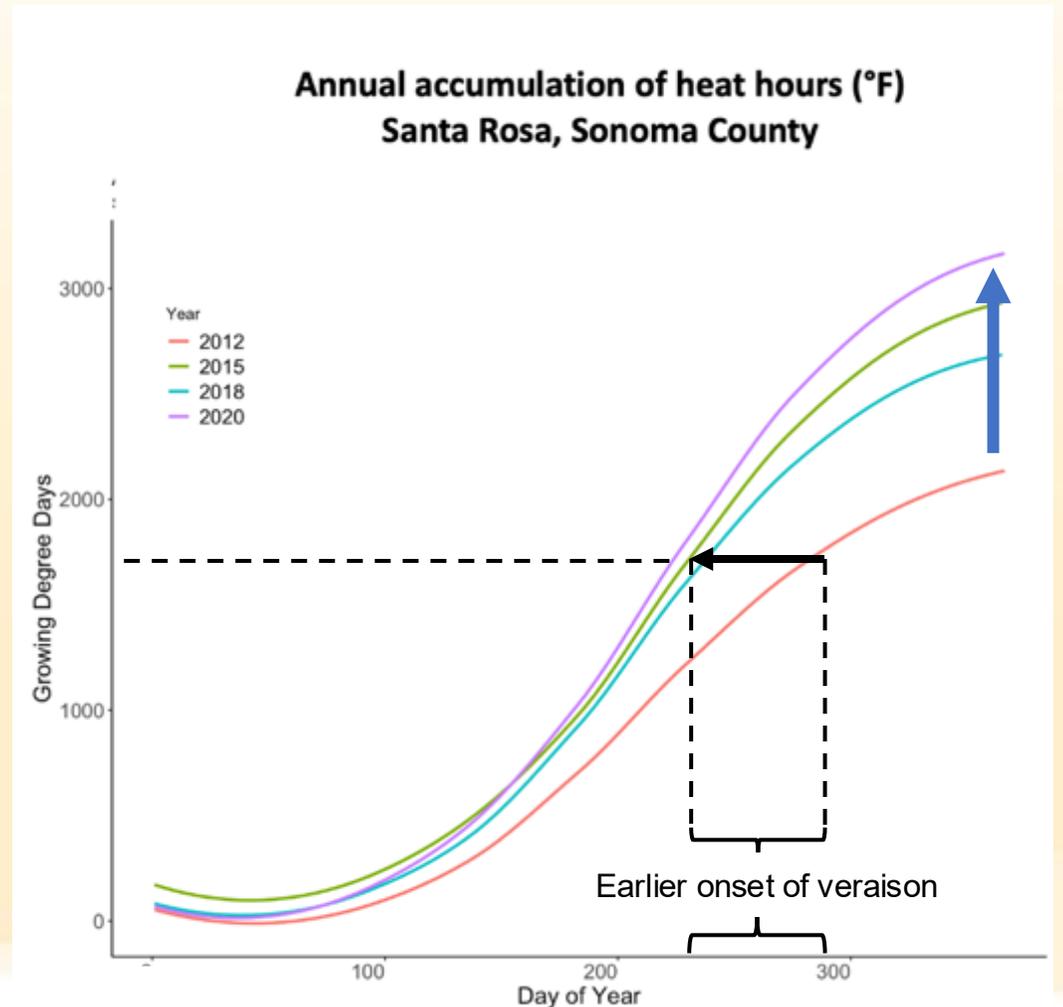# Growing Degree Days

Heat accumulation hours or Growing Degree Days have **trended** upwards and accumulated faster over the past two decades:

In Sonoma County, CA:

➢ Year:	GDDs	DOY
➢ 2012	1800	288
➢ 2015	1800	253
➢ 2020	1800	236

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

Growing Degree Days

This is pronounced in existing winegrowing regions where the climate is, or is close to, defined as **Mediterranean**
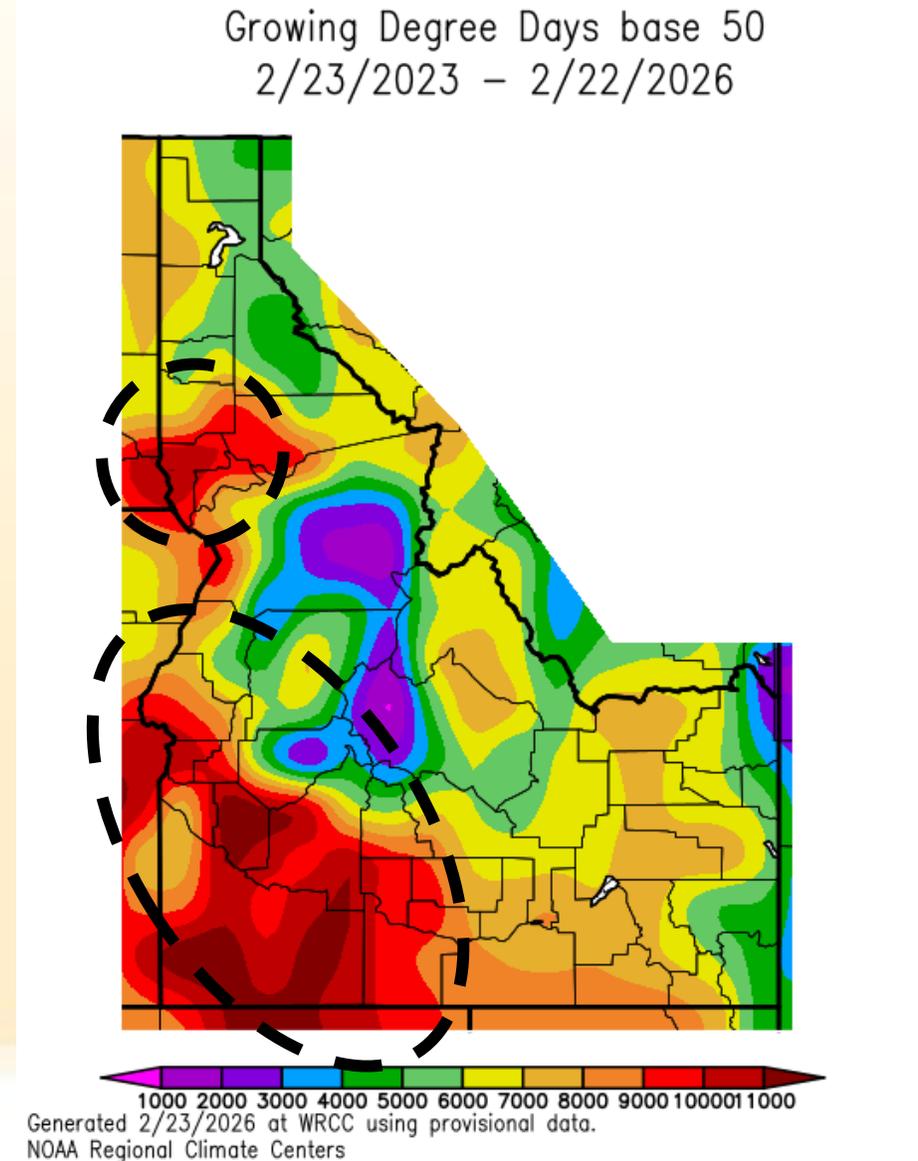
Mediterranean climates are considered **boundary climates** and are more susceptible to small changes than more stable climate types

Stable climates examples:

Deserts

Rainforests

Temperate forests

Credit: Western Regional Climate Center (2026)

Changes in Phenological Timing

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

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Winkler Index

- The Winkler Index is often used in vineyards to identify heat stress risk in a region or specific vineyard

- Using GDDs we can find our region's Winkler Index category

- Regions range from 1 (I) to 5 (V) with 1 being coldest and 5 being hottest

- Winkler Index can help us choose grape varieties that are better at tolerating a given region's accumulated heat

Region/Class	ºF units	ºC units	Climate Type
Region Ia	1500-2000	850-1111	Cold
Region Ib	2001-2500	1112-1389	Cold - Cool
Region II	2501-3000	1390-1667	Cool - Moderate
Region III	3001-3500	1668-1944	Moderate
Region IV	3501-4000	1945-2222	Warm - Hot
Region V+	≥ 4000	≥ 2223	Hot

Winkler Index

- A measure of **heat accumulation** over time in a region

- Based on Growing Degree Days
  - GDD calculator available at:
  - https://ipm.ucanr.edu/weather/degree-days/#gsc.tab=0
  - Fahrenheit | lower threshold = 50°F

- Can match it up with original location of each variety to see if it fits in **your climate**

Variety	Region	Climate	Vigor	Yields
Chardonnay	I, II	Cold	Moderate	Moderate
Sauvignon blanc	I, II, III	Cool	High	High
Riesling	I, II, III	Cool	Moderate	Moderate
Gewürztraminer	I, II	Cool	Moderate	Low
Sémillon	II, III	Warm Coasts	Moderate	High (clonal 8-10)
Melon	I, II	Cold	Moderate	Moderate
Pinot blanc/gris	I, II	Cool	Low	Low-Moderate
Viognier	III, IV	Warm-Hot	Moderate	Low
Colombard	II, III, IV	Warm	High	High
Chenin blanc	II, III	Cool-Warm	High	High
Emerald Riesling	II, III	Cool-Warm	High	High
Burger/Monbadon	III, IV, V	Warm-Hot	High	High
Palomino/Listan	IV, V	Hot	High	High
Muscat blanc	II, III, IV	Warm	Low-Moderate	Low-Moderate
Malvasia bianca	II, III, IV	Warm	Moderate	Moderate
Cabernet sauvignon	I, II, III	Cool	High	Moderate
Merlot	I, II, III	Cool	High	Moderate
Cabernet franc	I, II, IIi	Cool	High	Moderate
Malbec/Cot	II, III	Cool-Warm	High	Moderate
Petite Verdot	I, II, III	Cool	Moderate	Low
Zinfandel	II, III, IV, V	Cool-Hot	Moderate	High
Mourvedre	II, III, IV	Warm	High	Moderate
Pinot noir	I, II	Cool	Low	Low
Syrah/Shiraz	II, III, IV, V	Cool-Hot	High	Moderate
Sangiovese	III, IV, V	Warm-Hot	Moderate	High
Petite Sirah/Durif	II, III	Cool-Warm	Moderate	Moderate
Valdiguie/Napa Gamay	III	Warm	Low	High
Carignane	III, IV	Warm-Hot	High	High
Grenache	III, IV	Warm-Hot	High	High
Tempranillo	II, III, IV	Warm	High	High
Barbera	III, IV	Warm-Hot	Moderate	Moderate
Ruby Cabernet	III, IV	Warm-Hot	Moderate	Moderate
Carnelian	IV, V	Hot	High	High
Mission	IV, V	Hot	High	High
Rubired	IV, V	Hot	High	High
Alicante Bouschet	IV, V	Hot	High	High

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Extreme Weather Impacts

Must consider both **direct** and **indirect** impacts of changing and extreme weather

1. Change in growing season length

2. Earlier or later budbreak and ripening

3. Resource scarcity (i.e., water/fertilizer)

4. Increased soil salinity

5. More extreme weather events

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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)

Stressors

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

Insect responses to changing mesoclimates

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.

Insect/pathogen migration

A migration of insects and pathogens is expected to move northward if average temps continue to rise

- This is the case for more crops than grapevines

Temperatures and elevated CO_2 levels are essential components to estimate the potential for pest/disease migration [20]

20. Holly A. Ameden and David R. Just. Pests and agricultural production under climate change, 2001.

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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
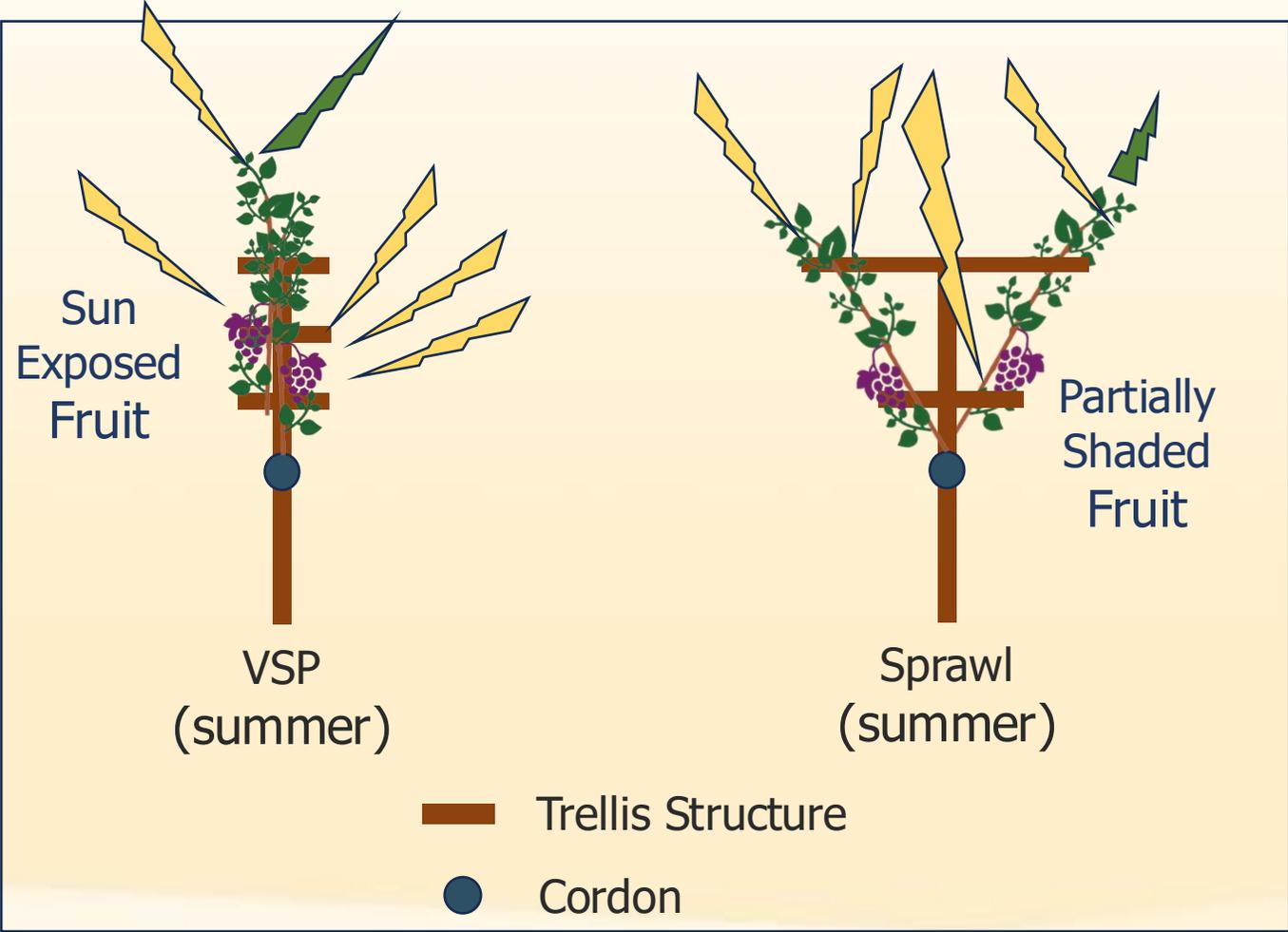
UC CE | **UNIVERSITY OF CALIFORNIA** Agriculture and Natural Resources | Cooperative Extension
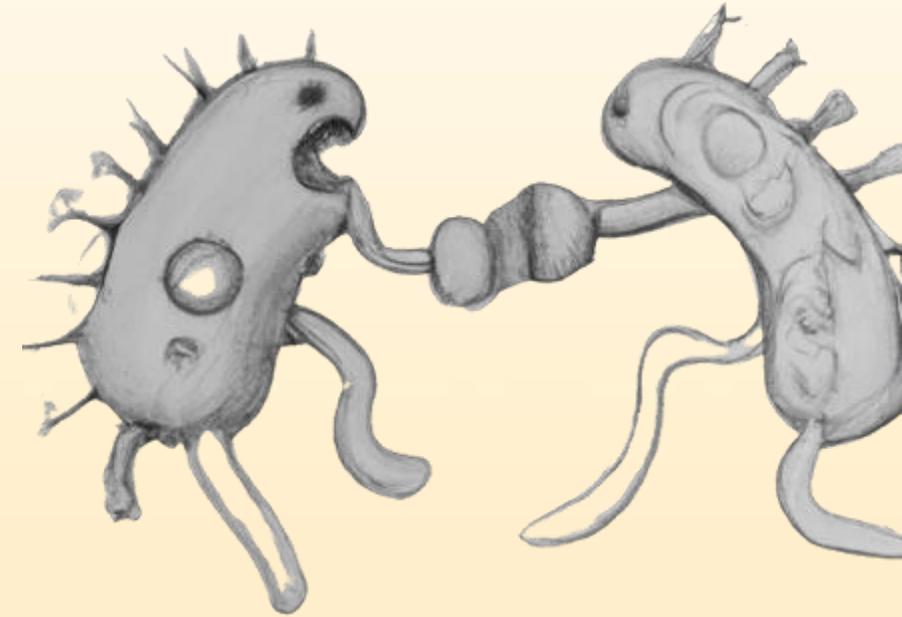
Protecting Vineyards from Extreme Heat

Provide Protection from Environmental Extremes

| Environmental Risk	Recommended Trellis	Effect
Fruit Sunburn and Dehydration	Weeping Trellis Types	Shoots shade the fruit
High Wind Conditions	Short Trellis Types	Less prone to wind damage
Unexpected Precipitation	Open Trellis Types (good airflow)	Allows water to dry rapidly

Sun Exposed Fruit

VSP (summer)

Partially Shaded Fruit

Sprawl (summer)

Trellis Structure

Cordon

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Increasing Temperatures

Row orientation

- Important for daily light and heat distribution on both sides of canopy

- Northeast - Southwest

More equal distribution of daily solar radiation
NE - SW

N
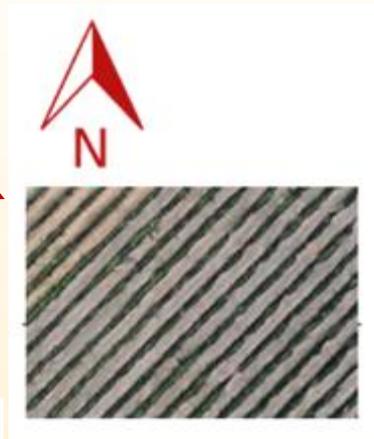
NE - Morning ⟵⟶ SW - Evening
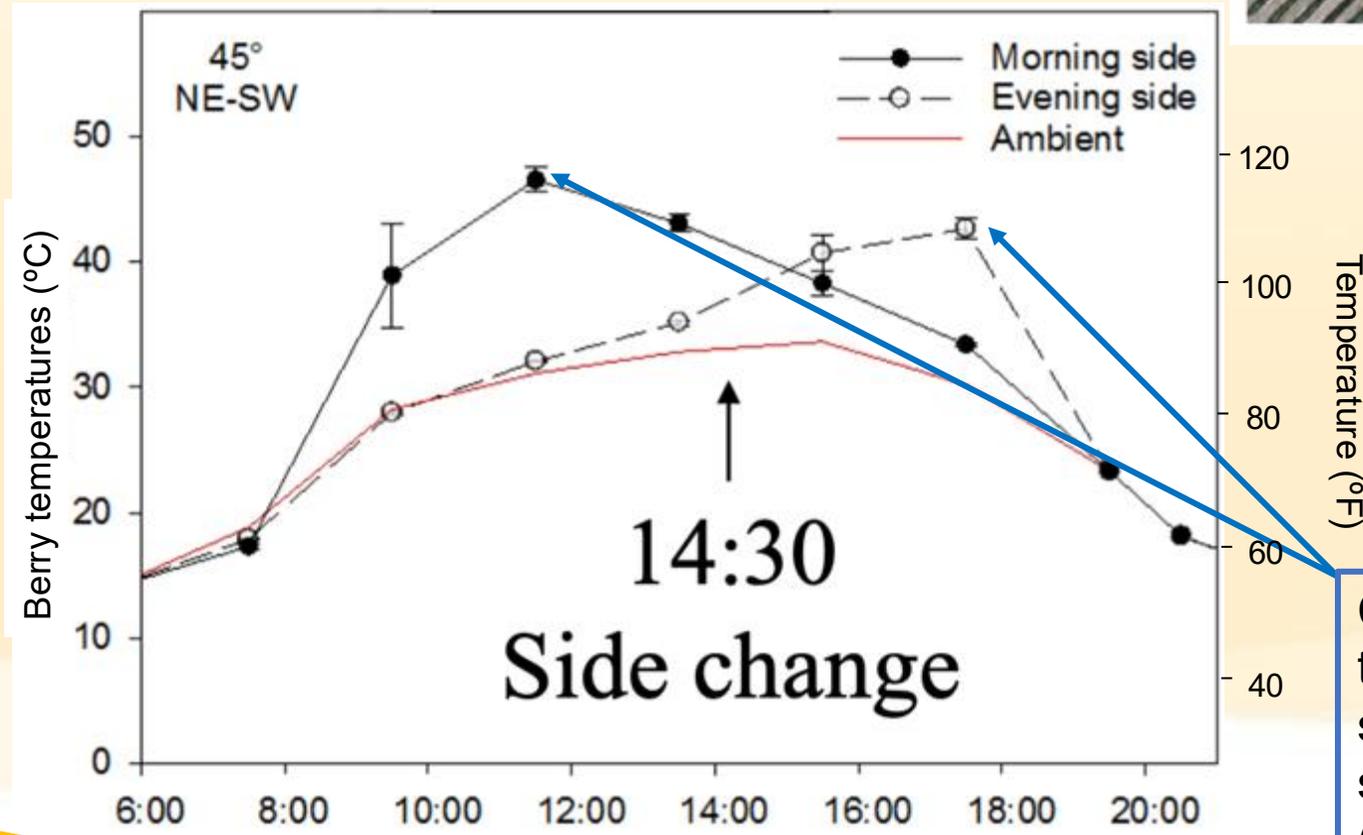
Both sides of canopy receive **similar hours of direct sunlight**

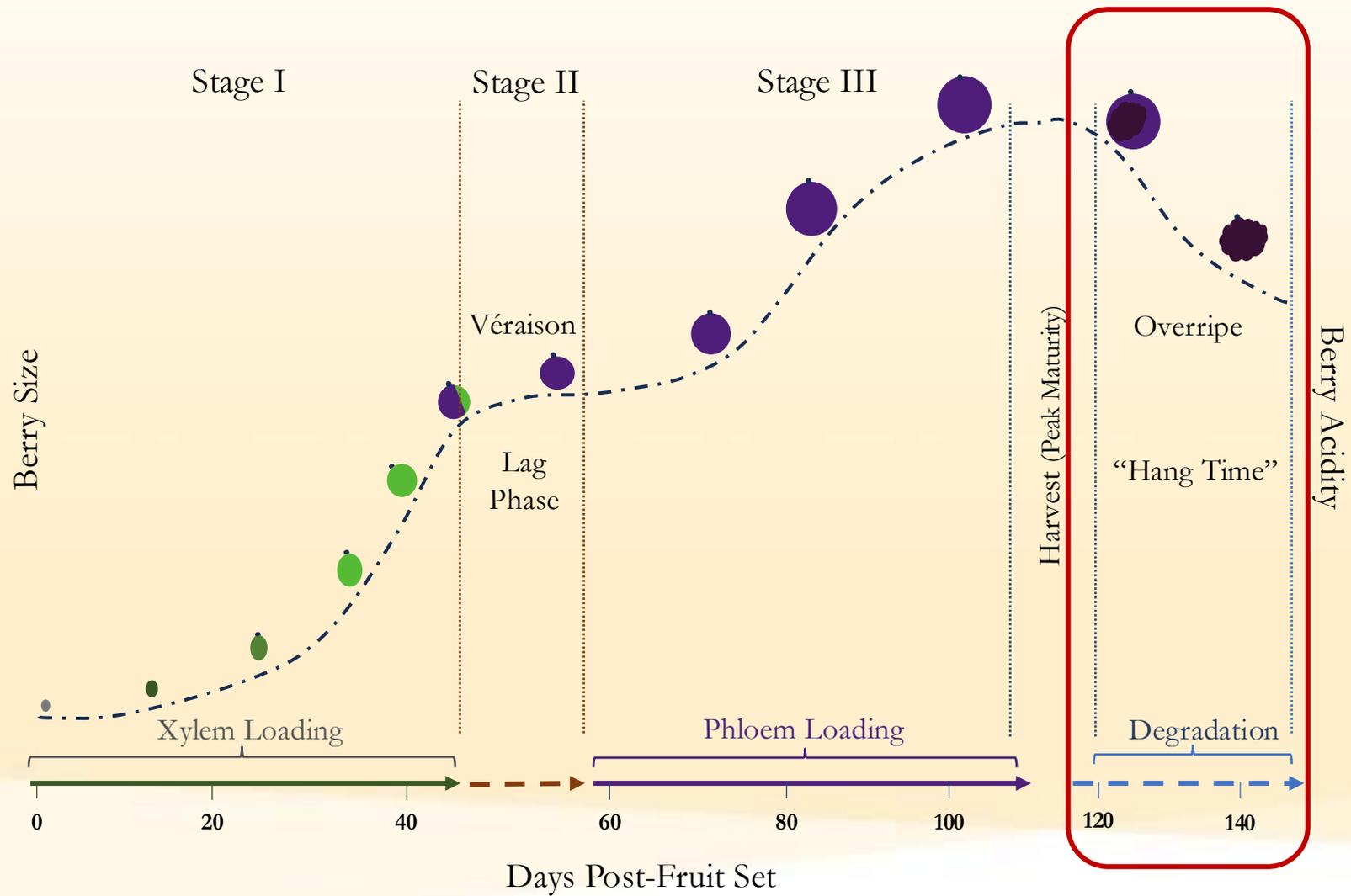Cluster temperatures similar on both sides of canopy (**110 to 120 °F**)

Image credit: "*Vineyard Design spacing and trellis selection*" – Johann Martinez (UC ANR presentation 2019)

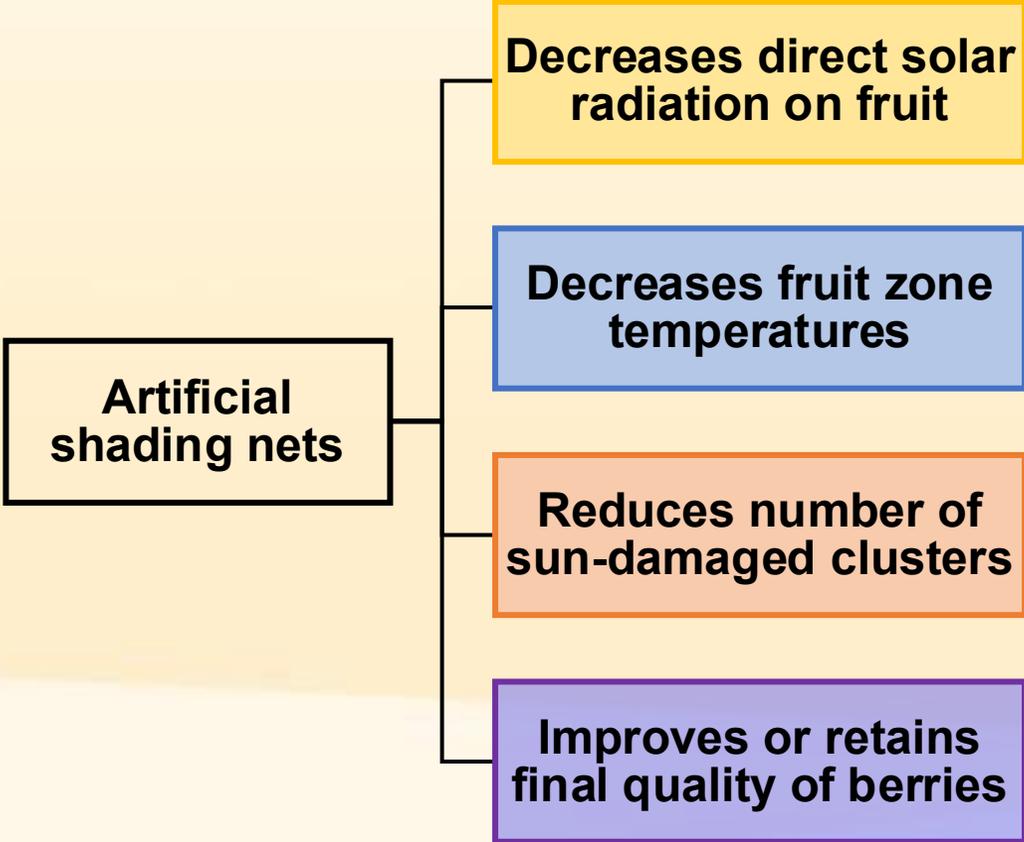UC CE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

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!

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Stage I   Stage II   Stage III

Berry Size

Véraison

Lag Phase

Harvest (Peak Maturity)

Overripe

"Hang Time"

Berry Acidity

Xylem Loading   Phloem Loading   Degradation

0   20   40   60   80   100   120   140

Days Post-Fruit Set

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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.

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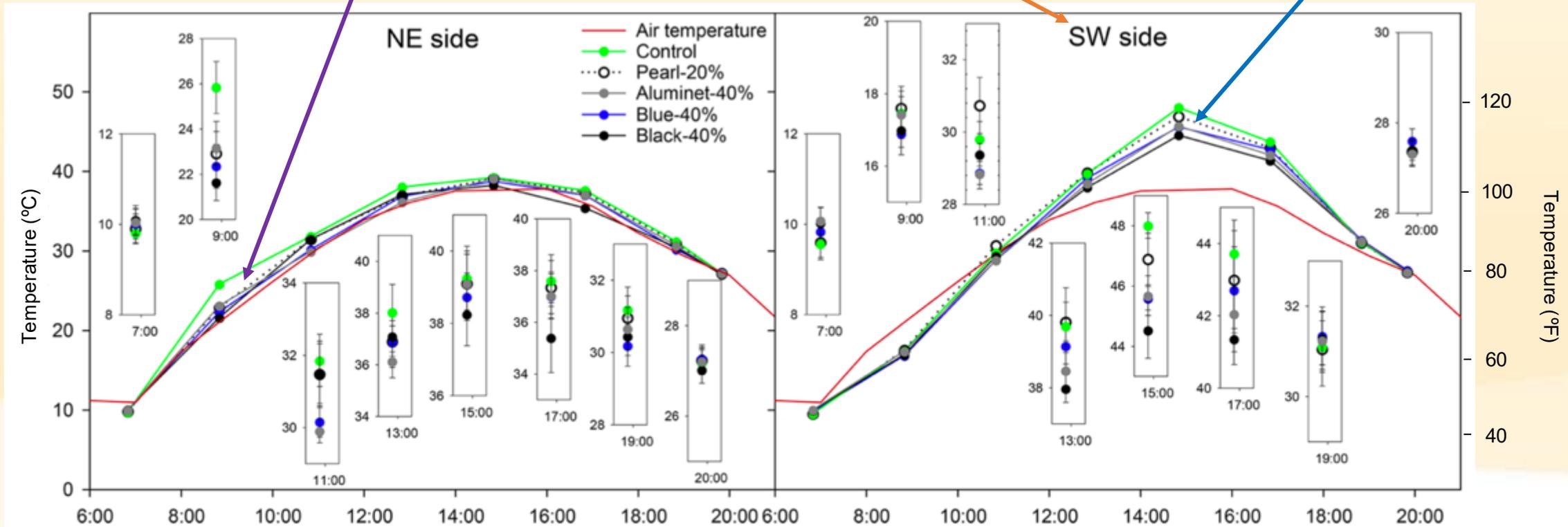
Cabernet Sauvignon fruit zone air temperatures measured under different colored shade nets in Oakville, CA in July 2016 (figure from Martínez-Lüscher et al. 2017)
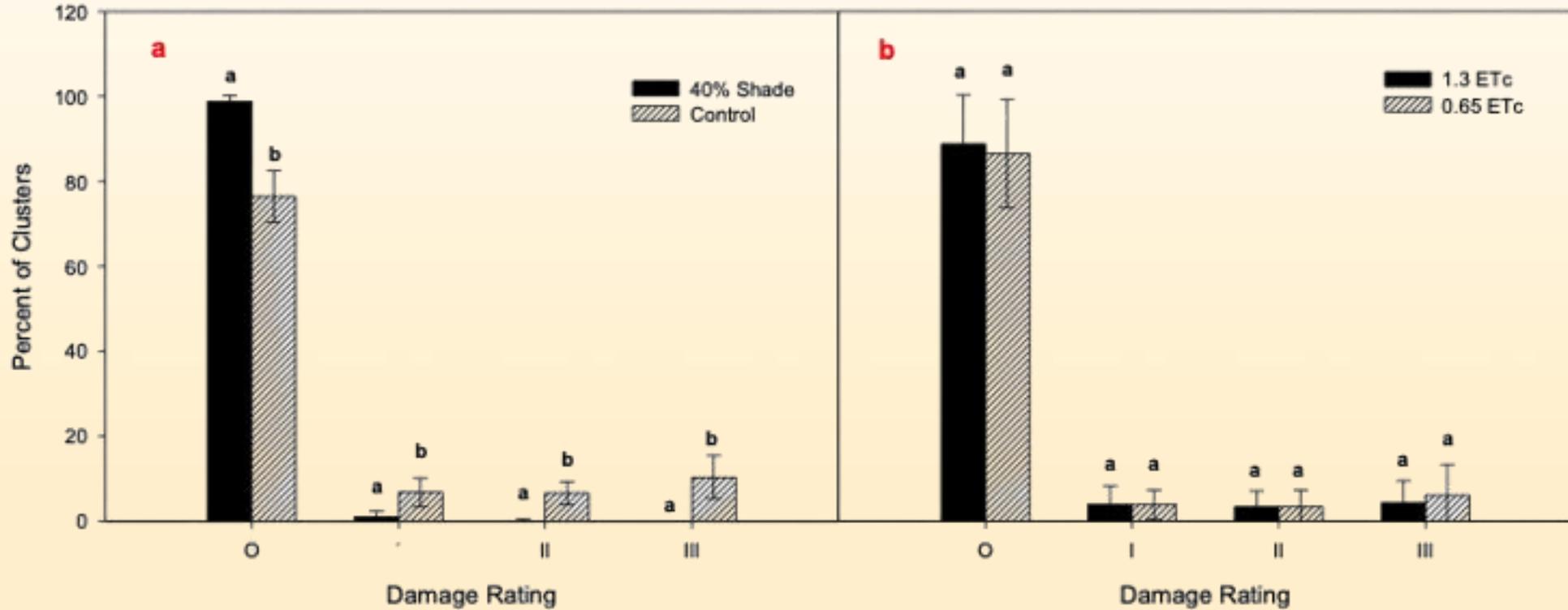
Increasing Temperatures

No shade netting

Shade netting

a

b

c
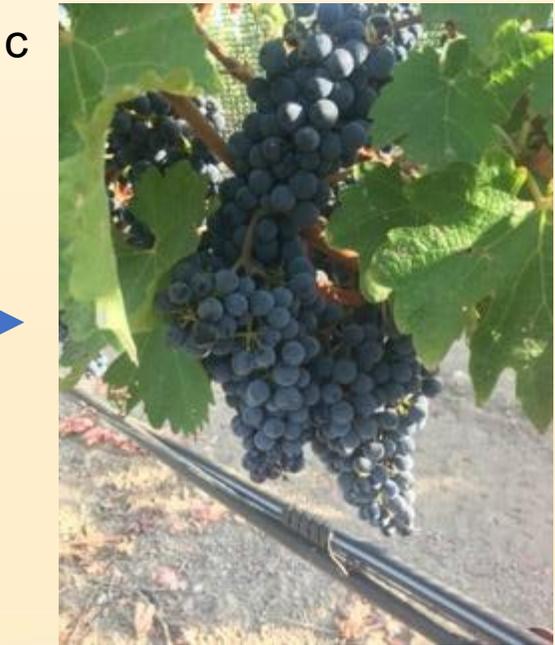
Left to Right: (a) no shade net applied; (b) example of black shade net applied following fruit set; (c) resulting cluster protected by shade net; all images were taken on the same day in Oakville, CA in August 2017.

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Black shade net applied   Modified Irrigation

Visible Damage

Using a rating system we visually assessed damage to whole clusters attributed to excess exposure:

- 0 = No damage
- 1 = Minor damage
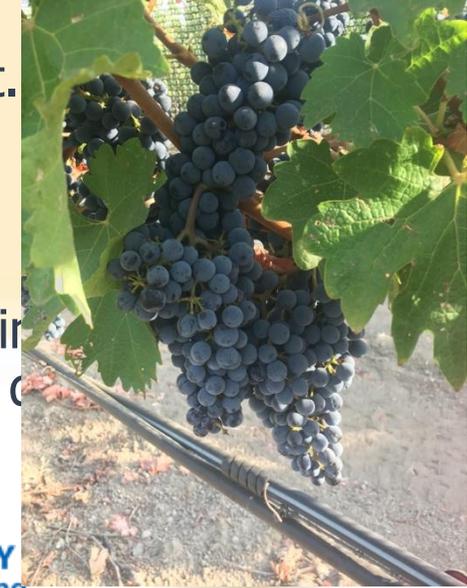- 2 = Moderate damage
- 3 = Extreme damage
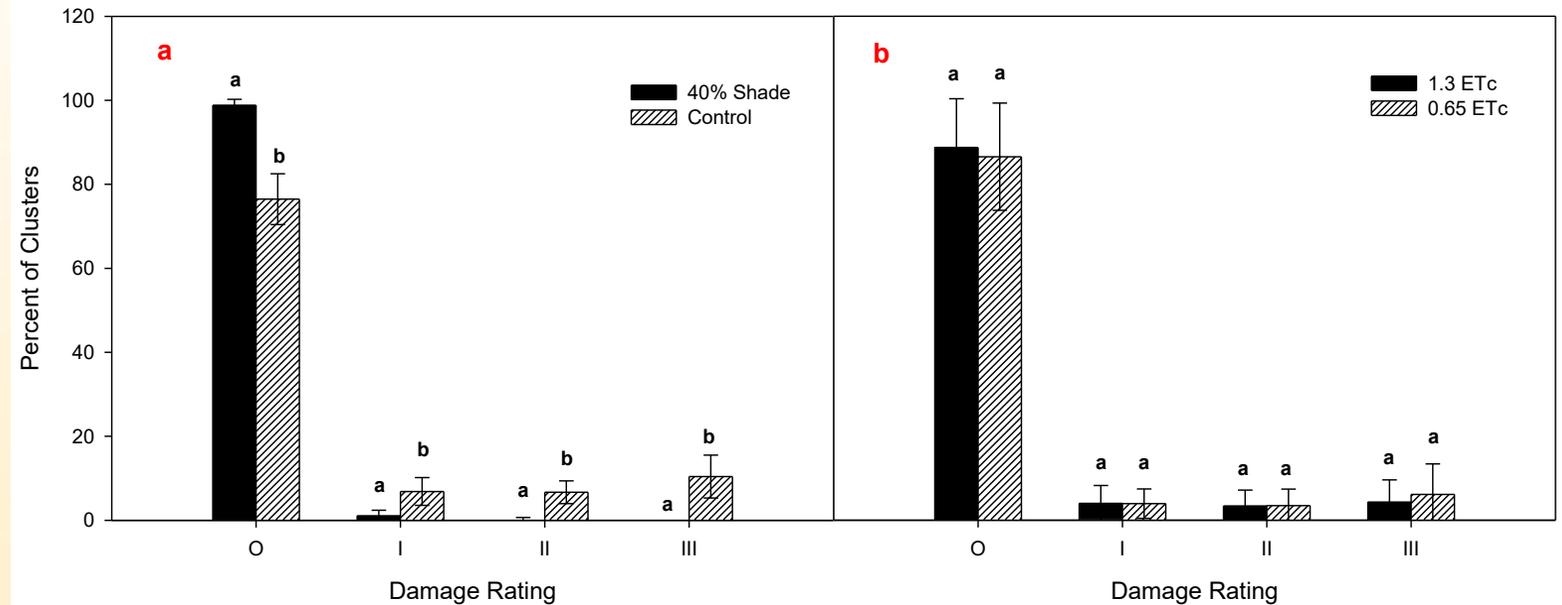
The[...]rded[...]damag[...]vest.

- S[...]redu[...]isible[...]s
- A[...]unts[...]isible[...]s
- V[...]spon[...]rtial[...]ns i[...]e[...]s tha[...]e be[...]ing [...]
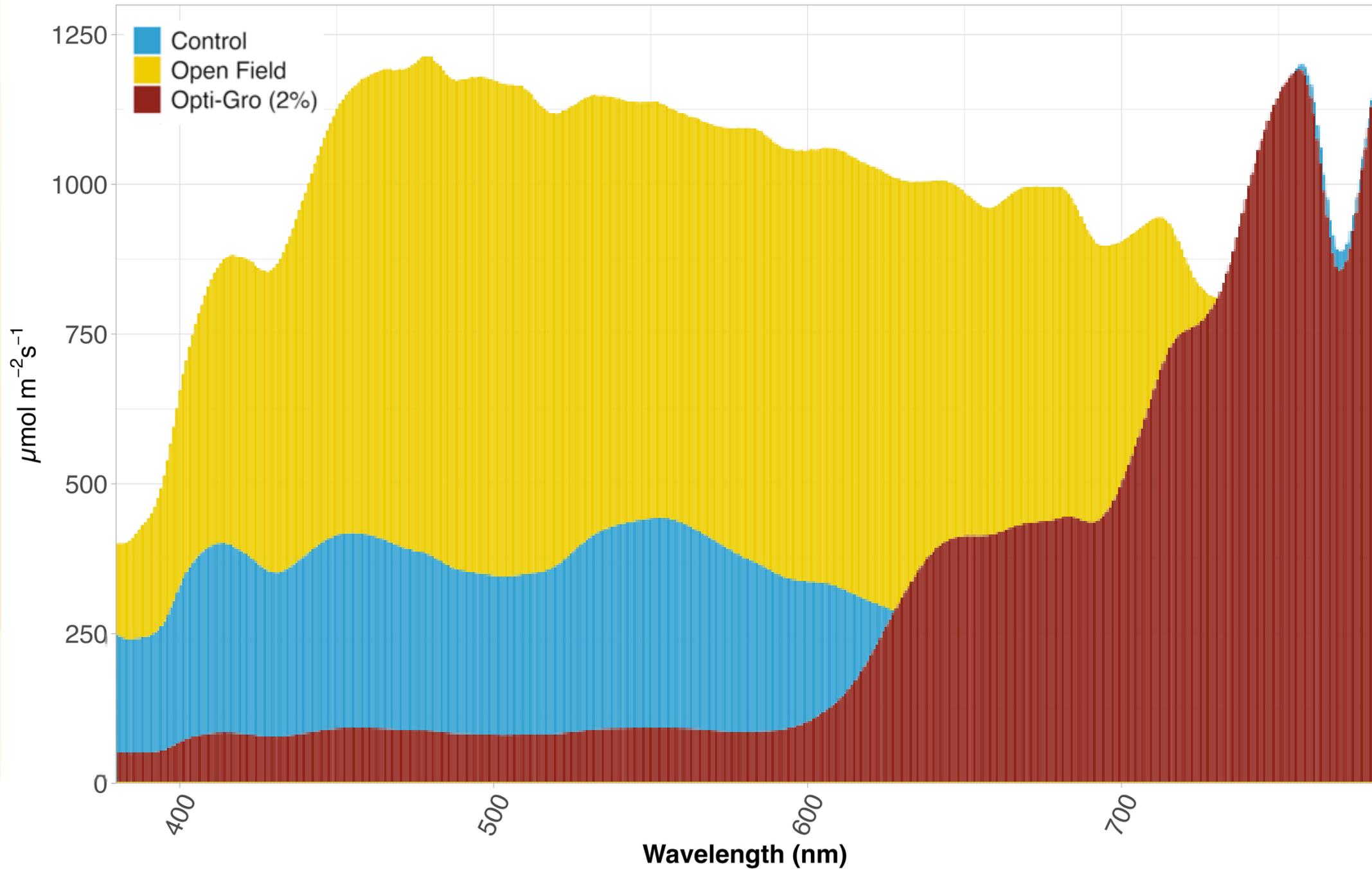
Light Modification in Other Forms
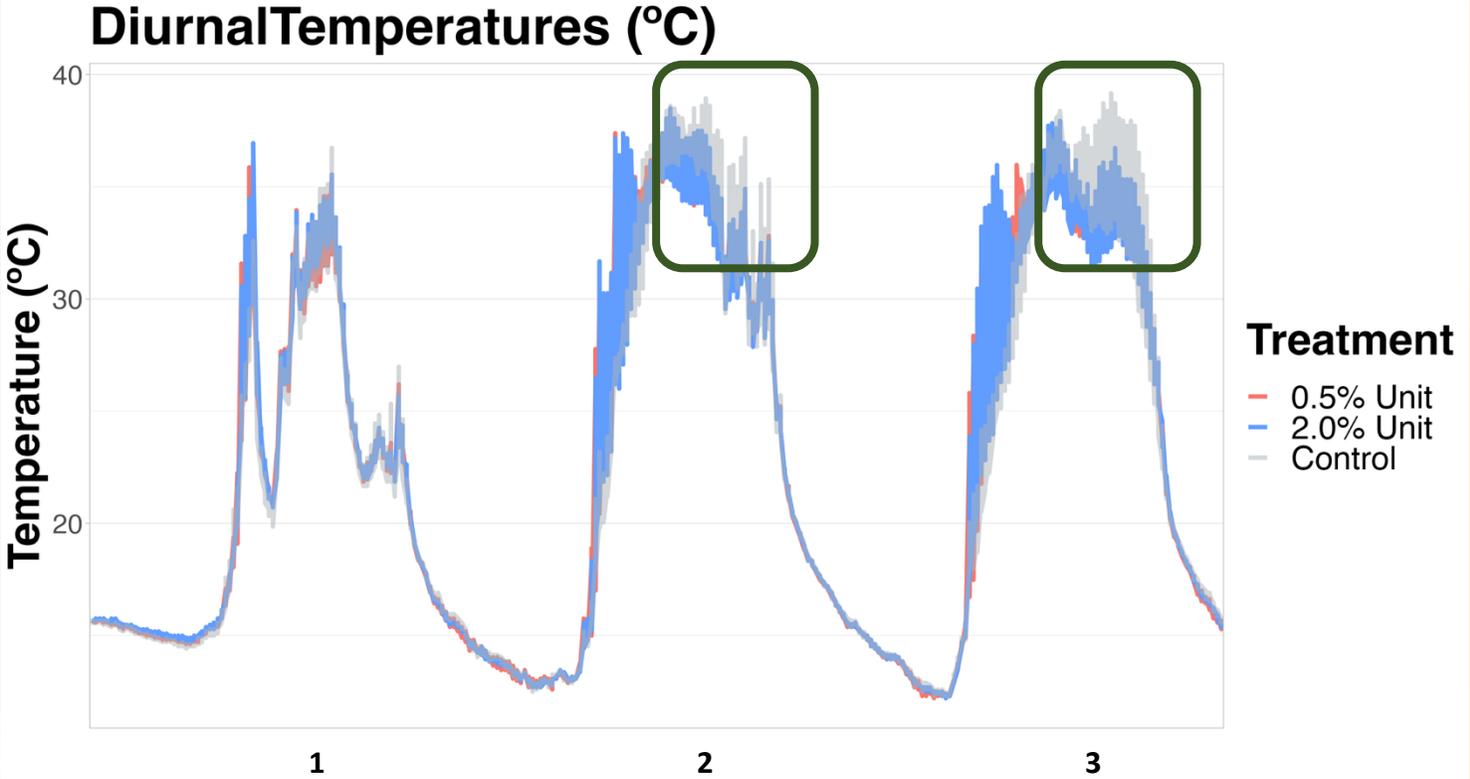
Study – Light Modification Cones (Opti-Gro)

- 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
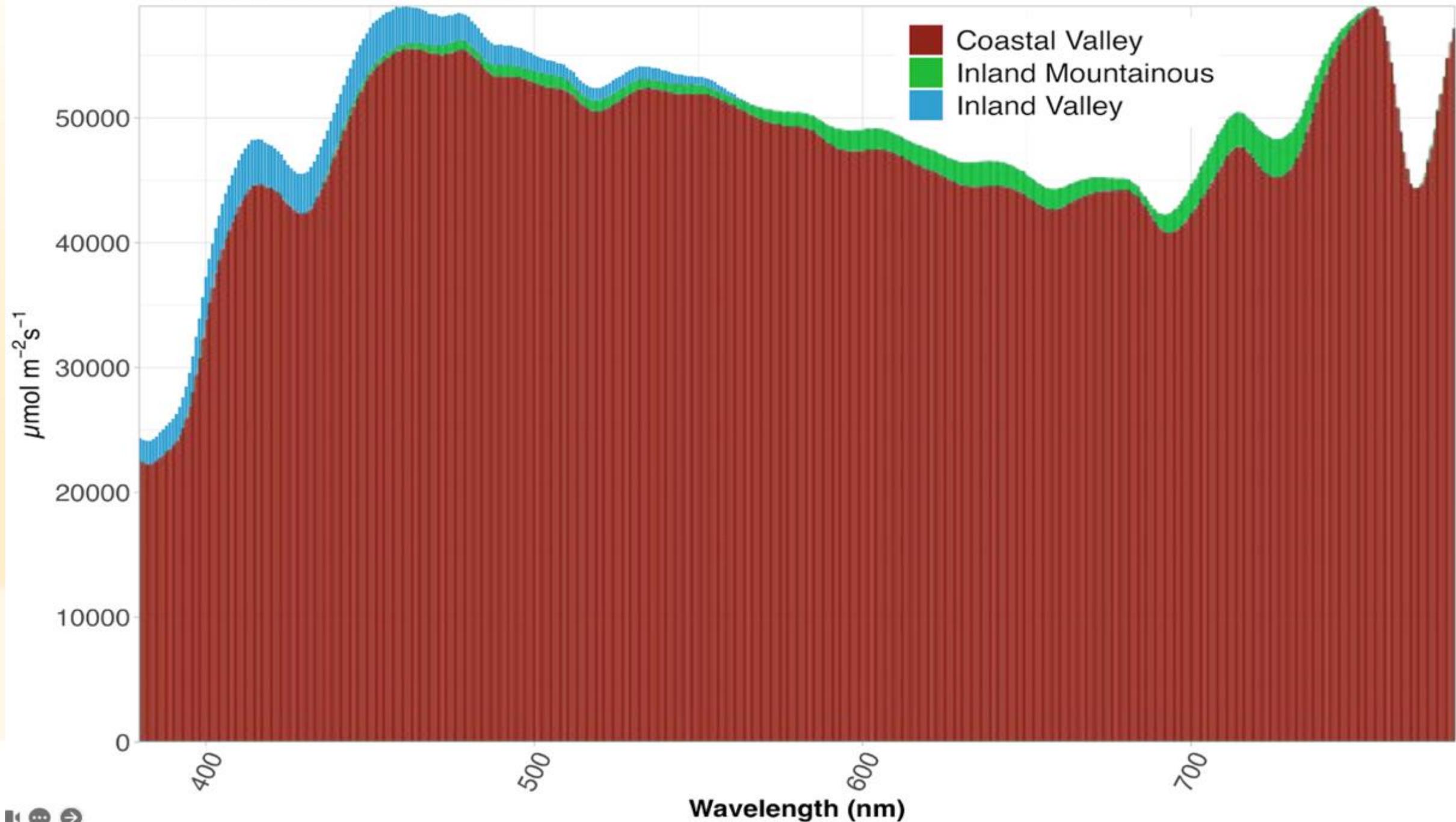
- Mitigates the impacts of extreme weather events

	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

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Light Spectrum Intensity

Light Spectrum Intensity

Scion Variety Bottleneck

- Market limitations on profitable cultivars

- Bottleneck down to a few scions

- Wide range of climate adaptation in scions

Examples of desirable characteristics:
  i. Weeping canopies (self shading)
  ii. Moderate vigor (less water demand)
  iii. High production of polymeric phenolics
    - More stable under high temperatures

Other Whites 17%

Other Reds 43%

Chardonnay 20%

Cabernet Sauvignon 20%
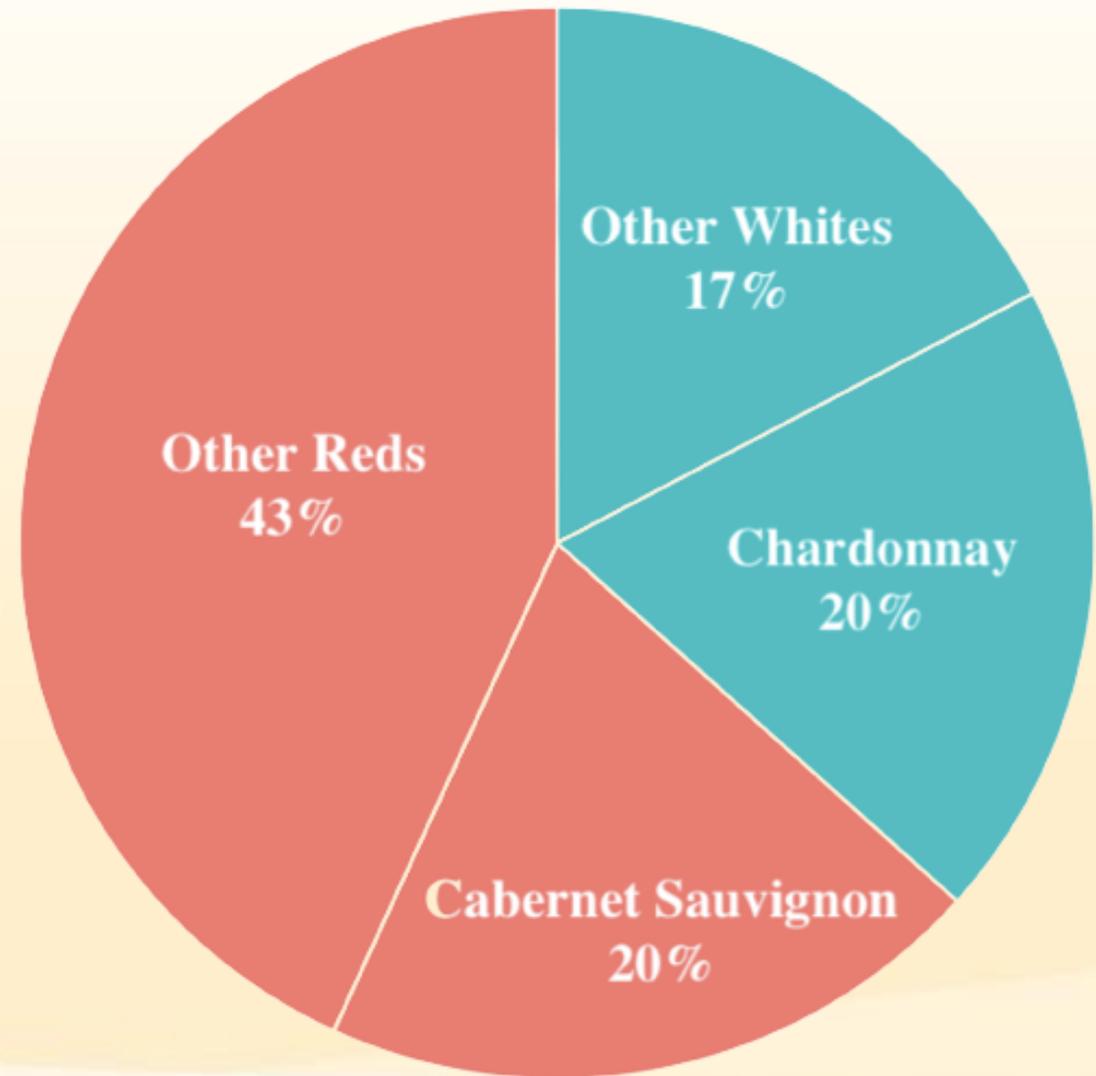
CA Grape Acreage Report (2020)

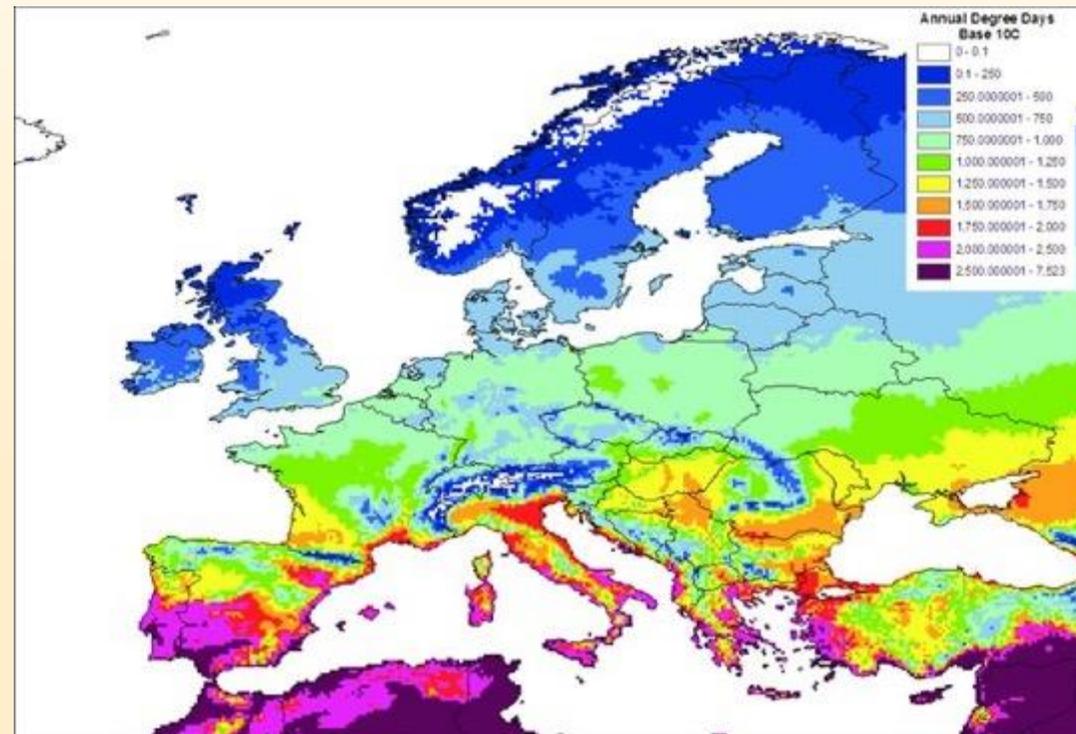# Wine Grape Acreage by Cultivar (CA. 2024.)
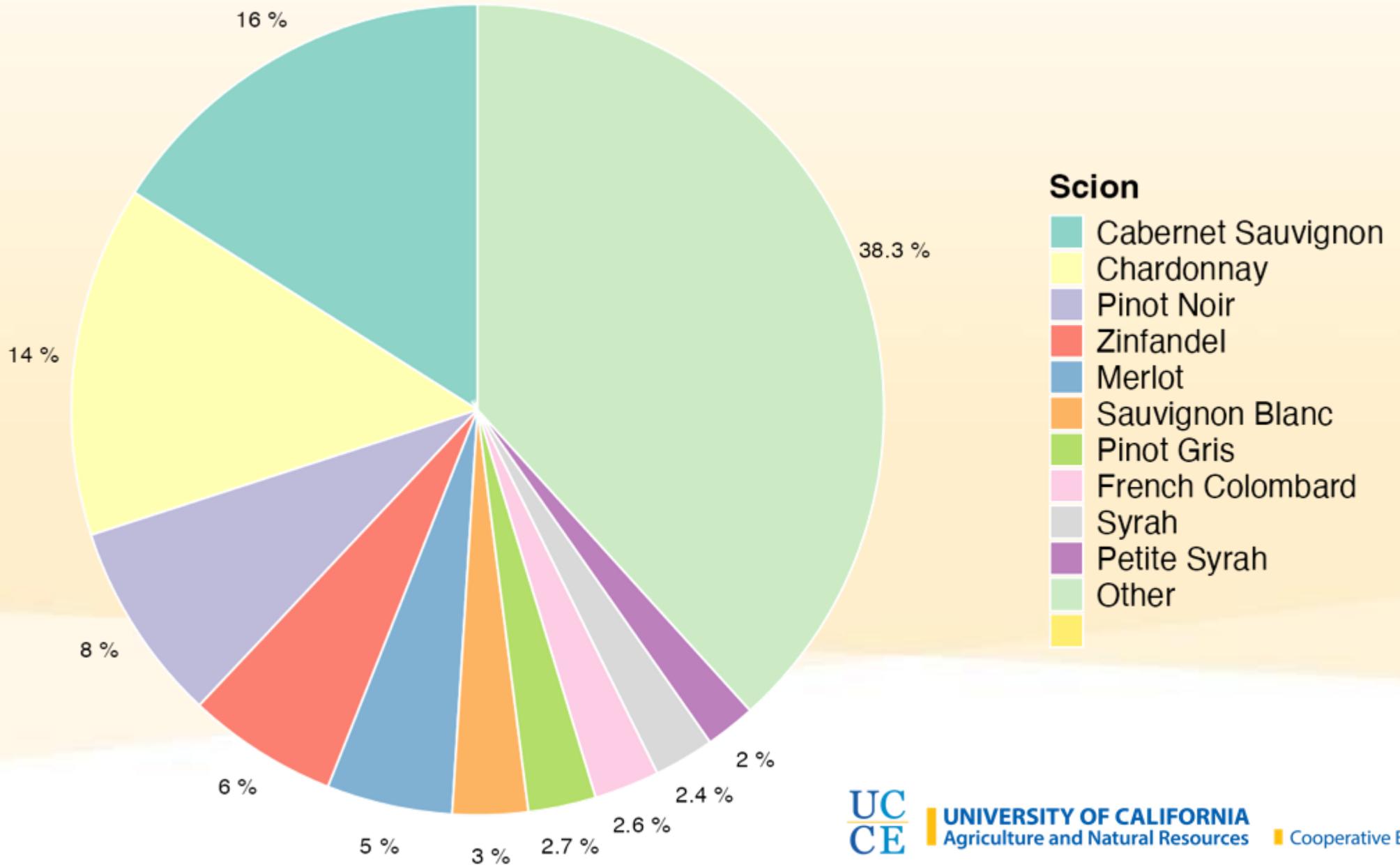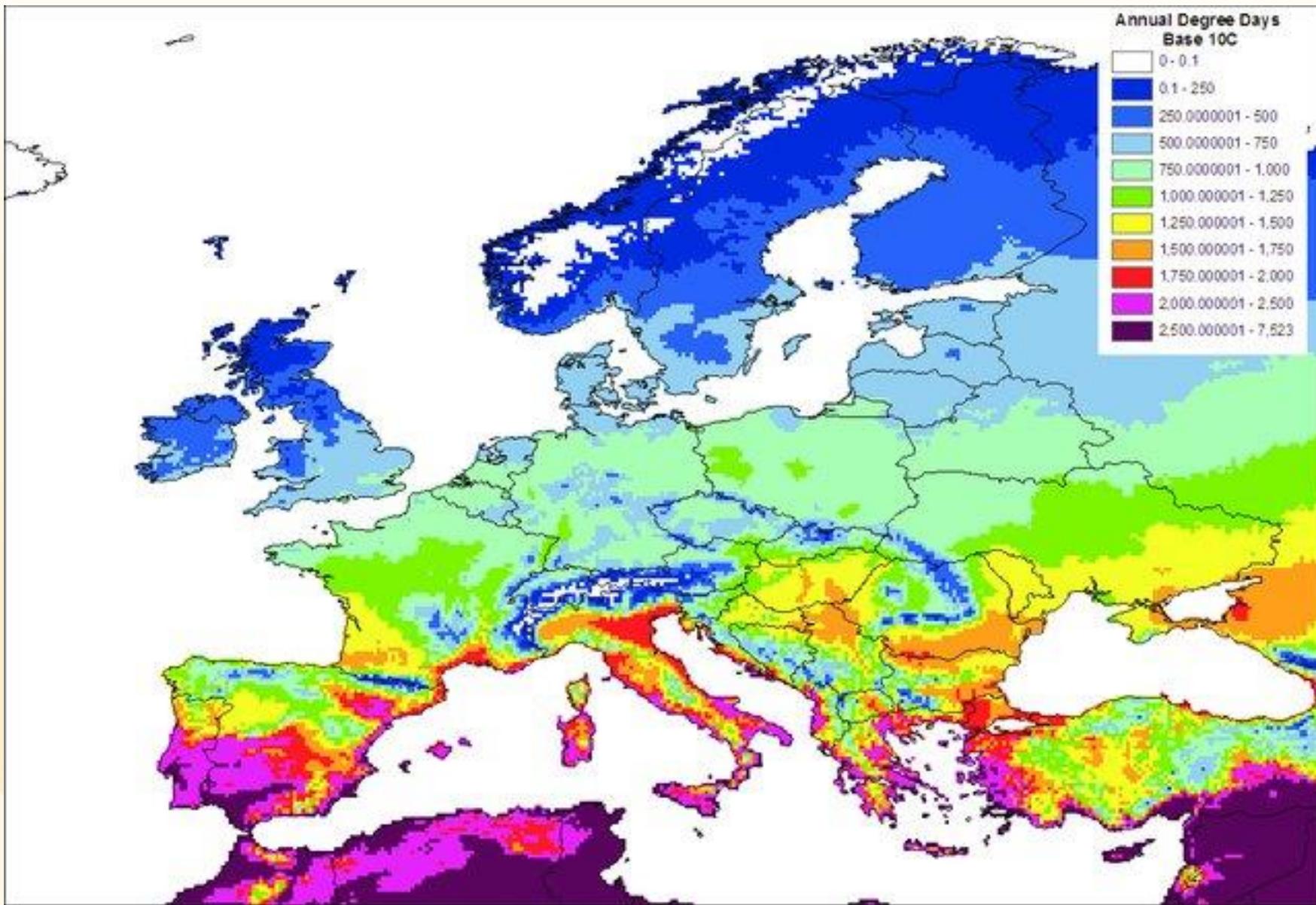
Climatic Origins

Where did the scions originate from?

This impacts their tolerance for heat (and other stressors)

Think about how your climate matches up with the original climate of the scion

- Or how future climate predictions match up with cultivar preferences

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

Smoke and Fire – Temperature and Light Impacts

Effects of smoke on gas-exchange & photosynthesis

Three parameters of photosynthesis affected by smoke exposure

1. Stomatal Conductance (g_s)
2. CO_2 assimilation rates
3. Intercellular CO_2 levels
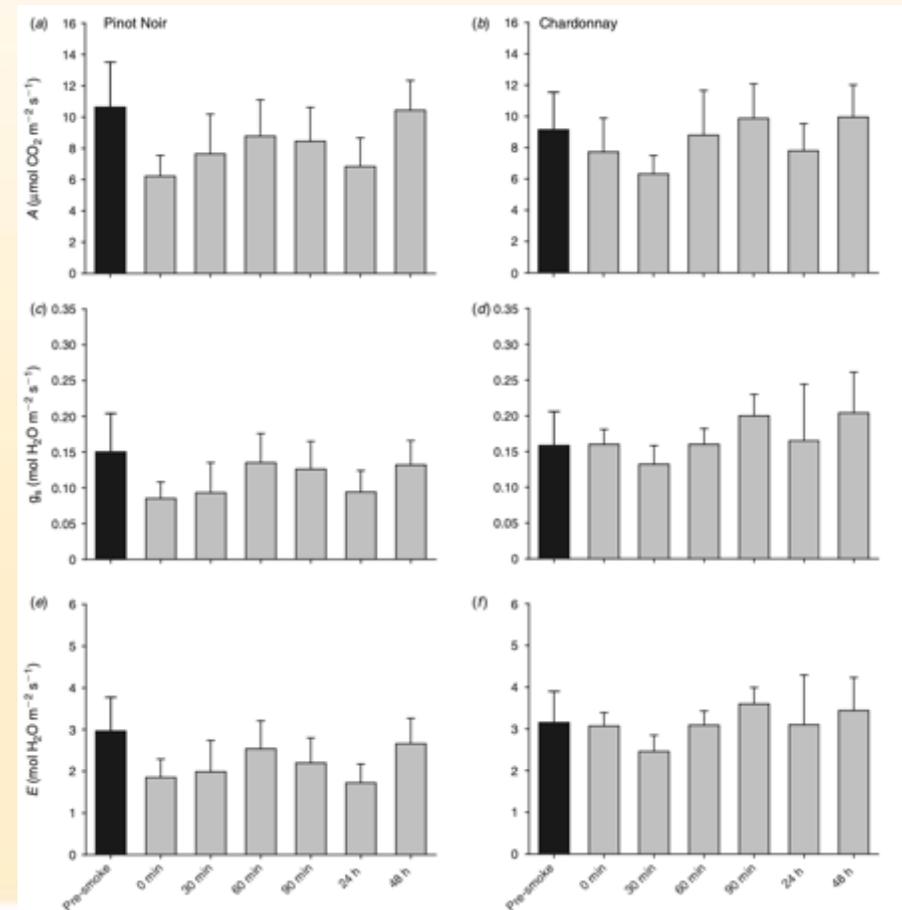
However, reductions in these functions are short term

Plants can acclimate to the smoke-exposure within 24 - 48 hours

Gilbert and Ripley 2022

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Effects of smoke on gas-exchange & photosynthesis

Fuel type matters for the short-term responses observed in gas exchange

- Research has observed a difference in grapevine stomatal conductance impacts depending if smoke comes from Coast Live Oak or Eucalyptus species (Bell et al. 2013)

Overall, the impacts of smoke *by itself* on gas exchange and photosynthesis are transitory and can be self-corrected by the vine

Bell et al. 2013

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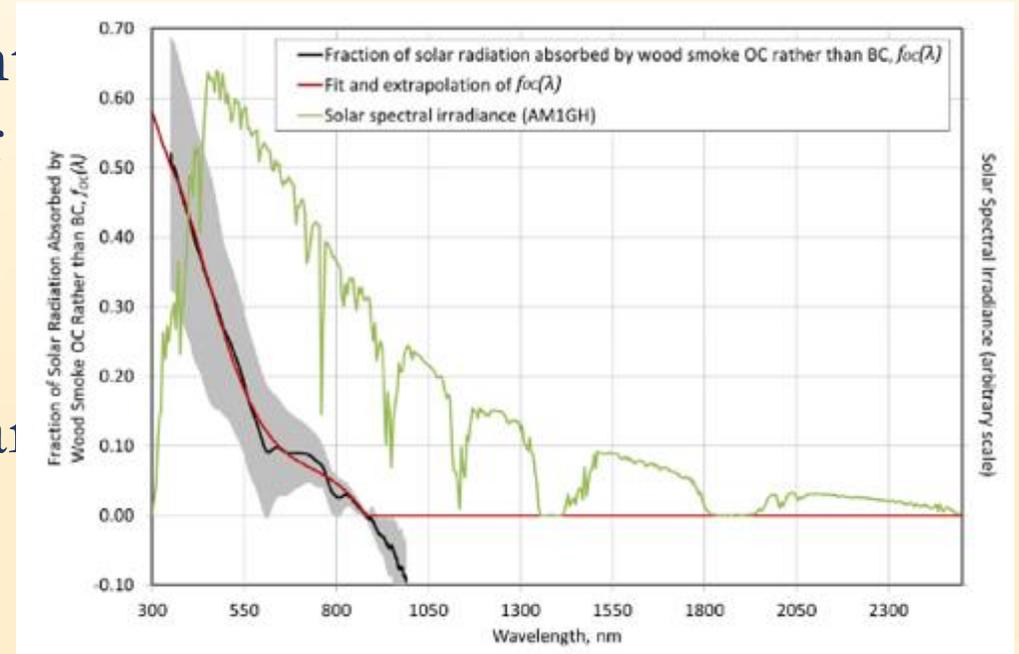**Agriculture and Natural Resources** Cooperative Extension

Effect of smoke on light-availability

While smoke itself may not have a significant impact on photosynthesis, particulate matter from smoke can

Wood smoke has been shown to absorb solar radiation with specific spectral selectivity
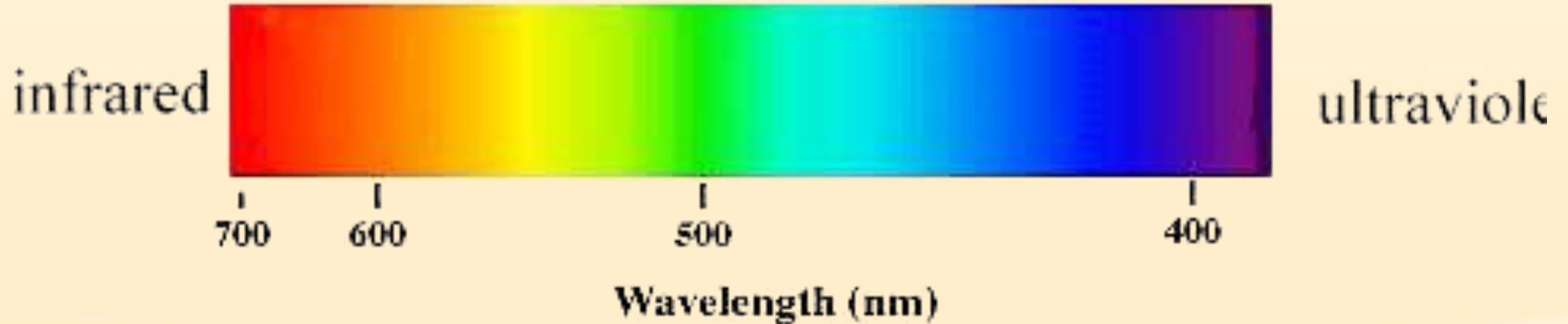(Kirchstetter and Thatcher 2012)

- Ultraviolet to visible spectrum absorption
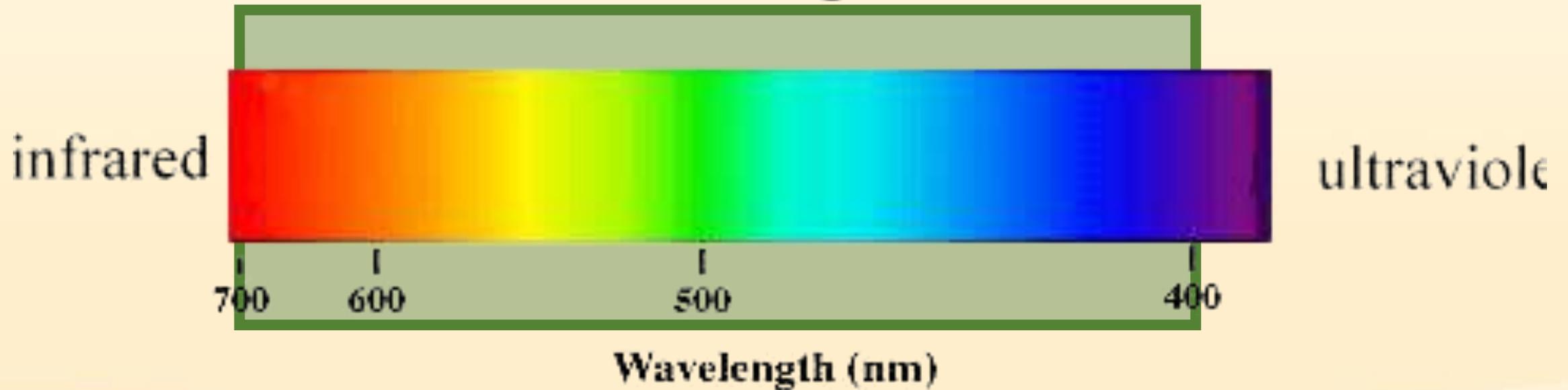
Up to a 50% reduction in UV-light and Visible-light

Kirchstetter and Thatcher 2012

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The visible spectrum

infrared — ultraviolet

Wavelength (nm)

The visible spectrum

infrared   ultraviole

700   600   500   400

Wavelength (nm)

Photosynthesis

Wavelengths reduced from wildfire smoke

The visible spectrum

infrared

ultraviole

700   600   500   400

Wavelength (nm)

Photosynthesis

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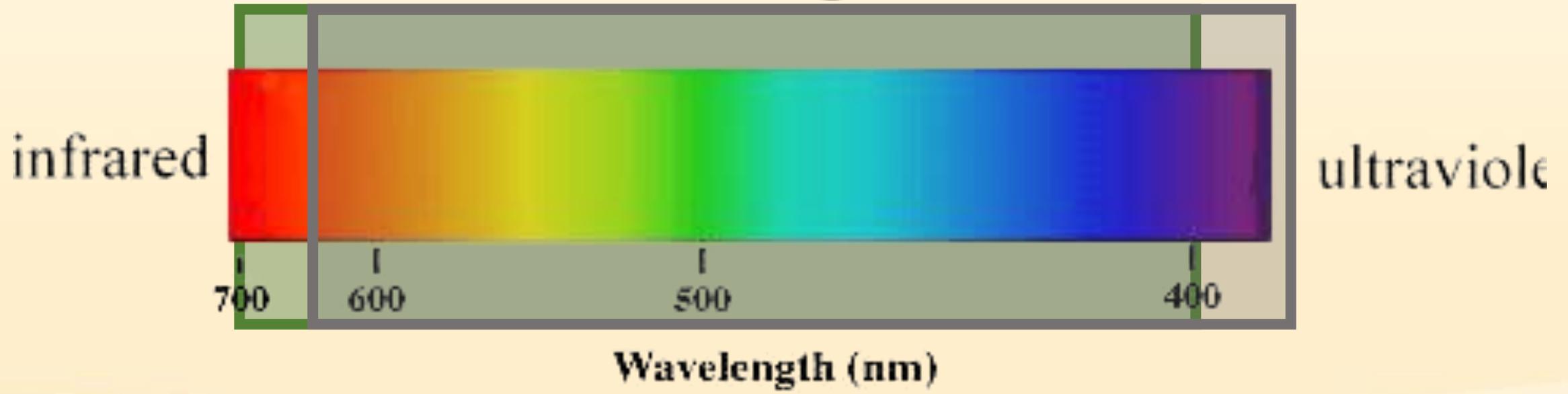
Effect of smoke on surface temperatures

Because wood smoke preferentially filters light in the UV and Visible spectrums

- **Most Infrared light makes it down to the surface**

Most of the heat-imparting effects of solar radiation come from the Infrared spectrum

There is **little to no decrease in surface temperatures** under high-instances of smoke particulate matter


Tarasova et al. 1999

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Effects of Smoke on Fruit

Volatile phenols

– Smoke derived compounds associated with burning vegetation.

– Absorbed through the skin of ripening grapes and accumulate by binding to sugars

– Bound by a native grape enzyme: glycosyltransferase

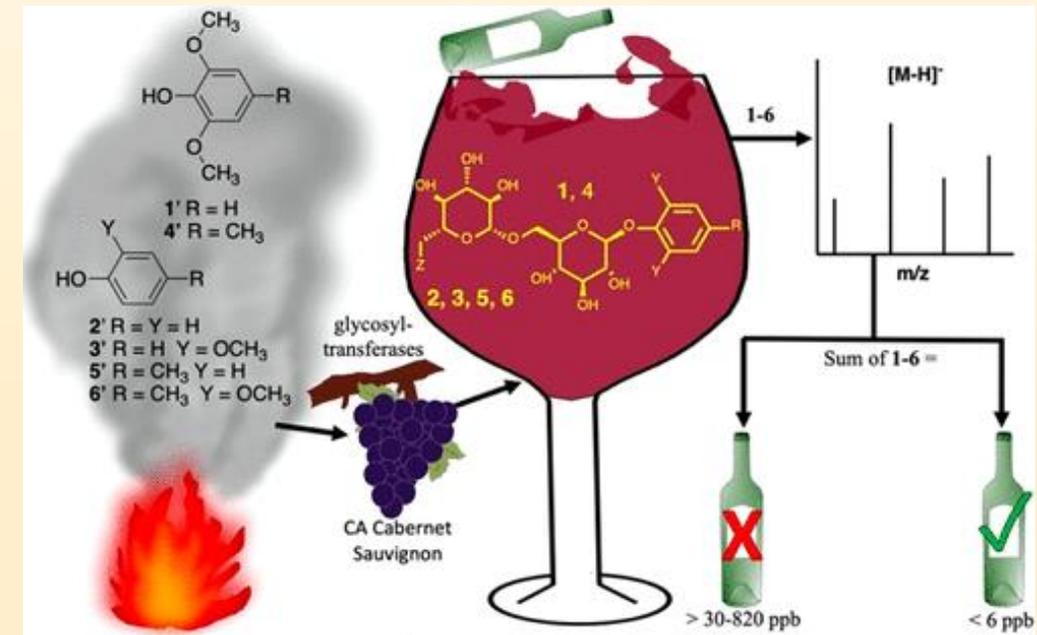– Results in Phenolic Diglycosides

forest fire
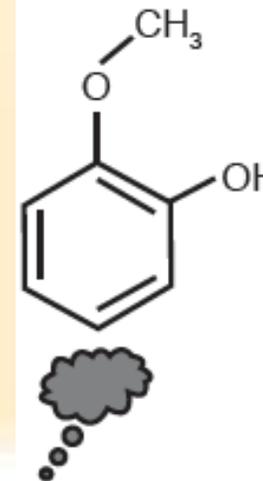
Härtl and Schwab 2018 (Article)

Effects of Smoke on Fruit

Phenolic Diglycosides

- A **nonvolatile compound** (volatile phenols bound to sugars)

- Stable compound while bottle aging (sticks around)

- Cannot be smelled or tasted while still in bound form

- Can be **released by enzymes during fermentation or in the mouth**

Crews et al. 2022

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Summary

- While average temps are getting warmer, it is not uniform increases everywhere; Mediterranean climates are at higher risk

- Some regions will be more affected by warmer night temperatures than by warmer/hotter day temperatures

- Protecting vineyards from extreme heat conditions can be achieved through:
  1. Proper cultivar selection for current and future conditions
  2. Protective trellising designs that encourage self shading of fruit zones
  3. Planned row orientation when planting to allow equal light distribution
  4. Artificial shading (e.g., Shade netting and light modification technologies)

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Sources

You can find this presentation at:

1. https://ucanr.edu/sites/chenlab

2. Speaker Presentations

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Thank You