Viticulture Strategies for Extreme Weather Events & New Pest & Fungal Pressures

UCCE North Cost Viticulture

Christopher Chen, Ph.D.

UCCE – Integrated Vineyard Systems Advisor

North Coast

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

Climate Impacts

Must consider both **direct** and **indirect** impacts of changing climates

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
6. Changes in pest development and behavior


66.6

Climate Concerns with Agriculture

- Climate conditions impact many aspects of agriculture

    1. Resource availability
    2. Extreme and sudden weather events
    3. Biotic and Abiotic stressors
    4. Pest/disease success and survival
    5. Phenological timing of crops
    6. Yields
    7. Plant health

Changing Climates

- Climates are changing and impacting the factors that affect vine health.

  i. Temperatures
     - Affects all aspects of vine health

  ii. Precipitation
     - Affects all aspects of vine health

  iii. Extreme weather events
     - Heatwaves, fire, and late frost events
     - Impacts photosynthesis and reproduction

Changing Climates

Temperatures

- Impact all living things
- Alter physiology
- Ideal range differs by species
- Range differs by cultivar too
- Winter & summer temperatures

Changing Climates

Precipitation

- Mediterranean climates with unique precipitation patterns
- Changing with the climate
- Shifting precipitation patterns
- Impacts crops and diseases

Changing Climates

Extreme weather events

- Impacts dependent on microclimates
- Existing infrastructure matters
  - Heatwaves
    - More damaging in coastal regions
  - Spring Frosts
    - More damaging inland
  - Wildfires
    - More damaging where not prepared

What are Abiotic Stressors?

- Abiotic stressors are any environmental condition that causes stress to the grapevine which limits growth and reproductive capacity of that vine
- Any source of stress that is not a living organism
- Often, there are multiple abiotic stresses on the grapevine at any given time

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)

Vine Abiotic Stress

- In grapevines, abiotic stress can be persistent or additive with other stressors
- Plants do not have an 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
- Vine pest susceptibility ~ abiotic stress
- More abiotic stress = more biotic stress

Extreme Heat - Trends

Extreme Heat

Extreme temperatures

↓

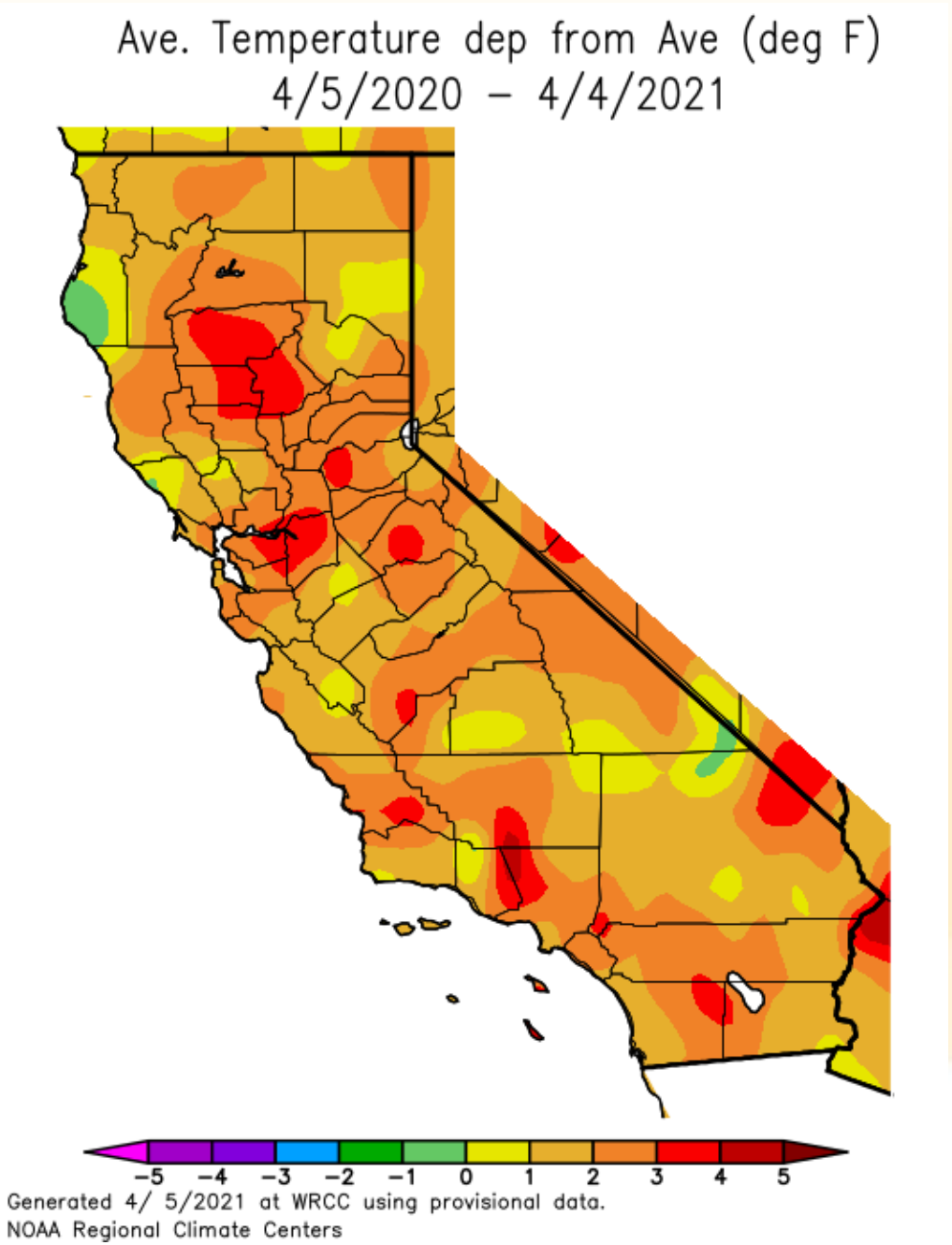
High evapotranspiration

↓

Greater water demand

↓

Damaged fruit



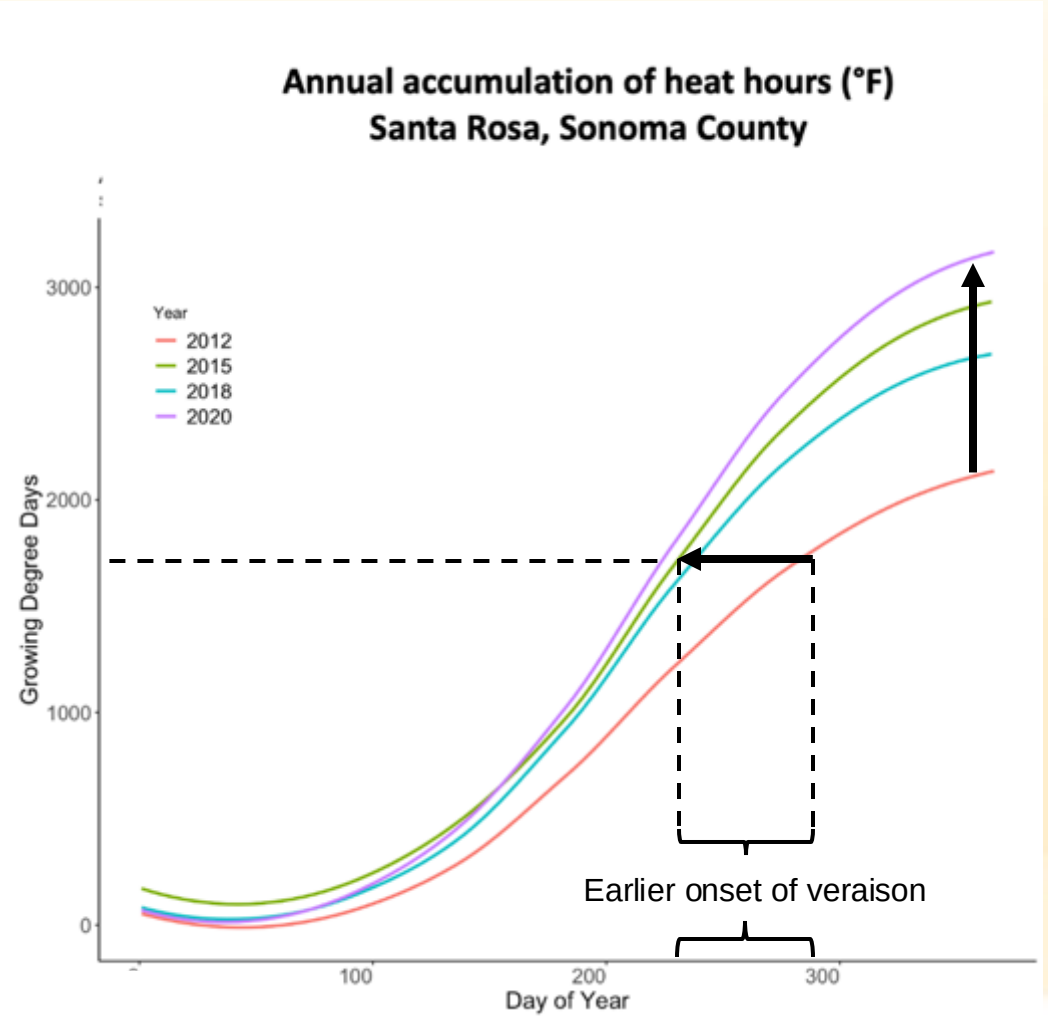
Credit: California Climate Data Archive (2021)

Increasing Temperatures

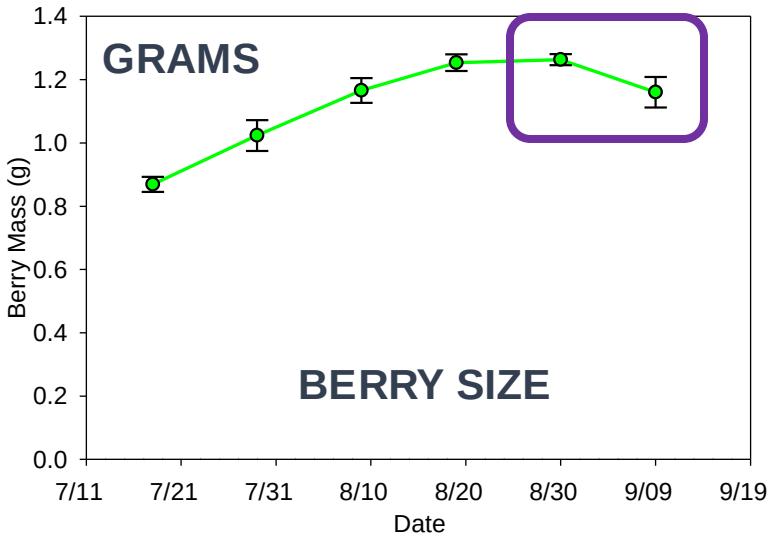
In Central Europe the impact of warming climates has been documented in Bernáth et al. 2021

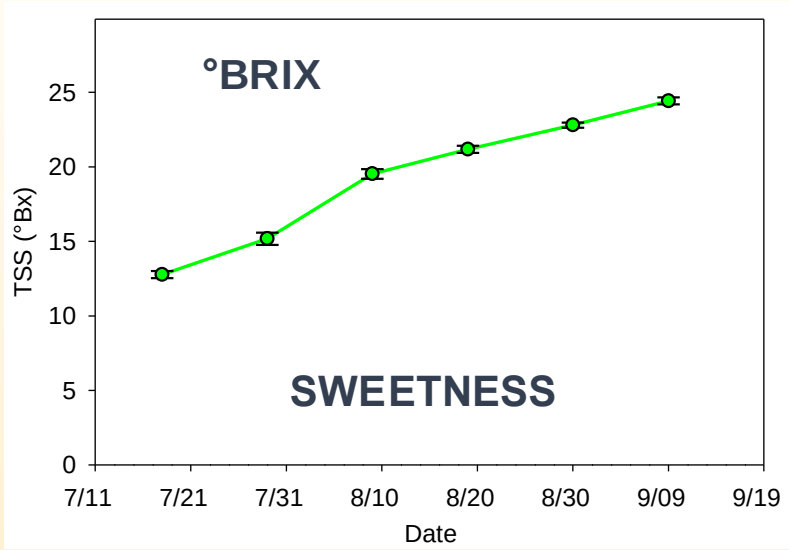
Between 1985 and 2018

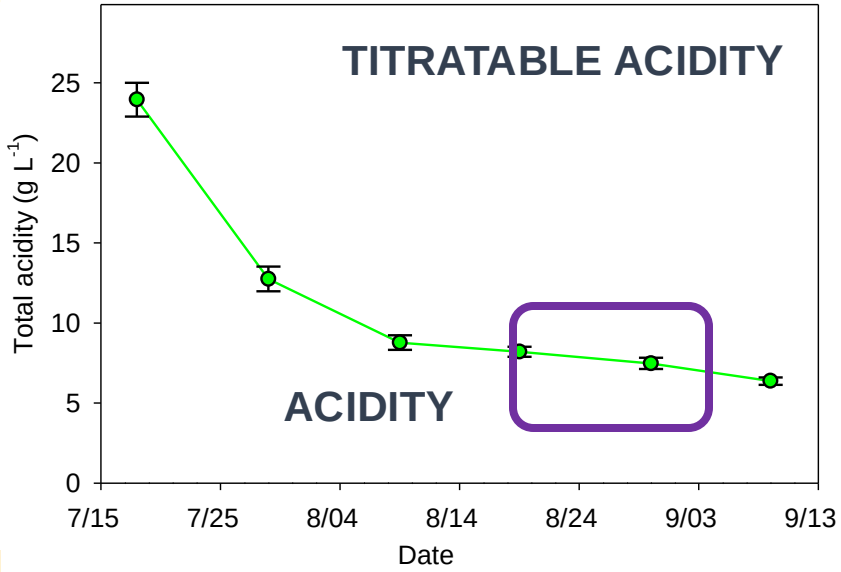
- Budbreak: 5-7 days earlier
- Flowering: 7-10 days earlier
- Berry maturity: 18 days earlier
- Harvest: 8-10 days earlier

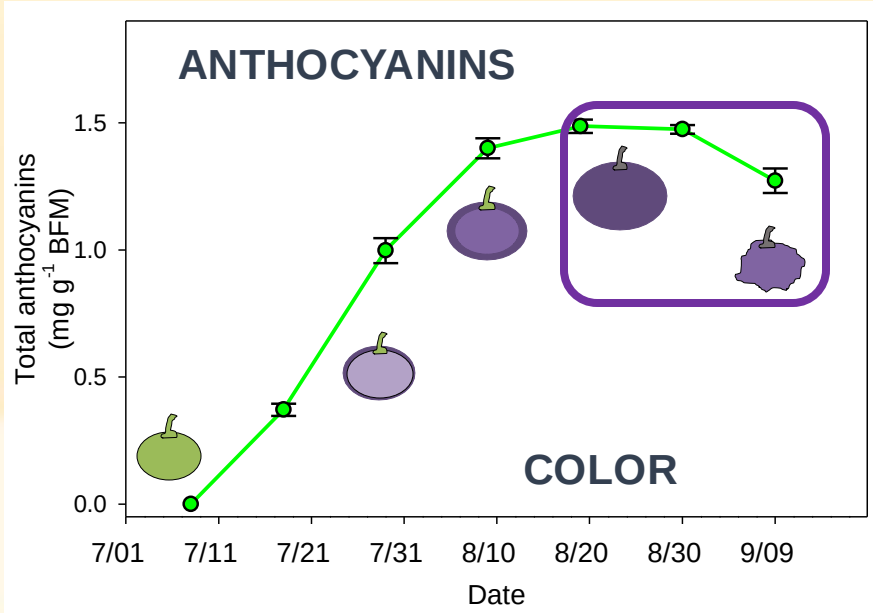


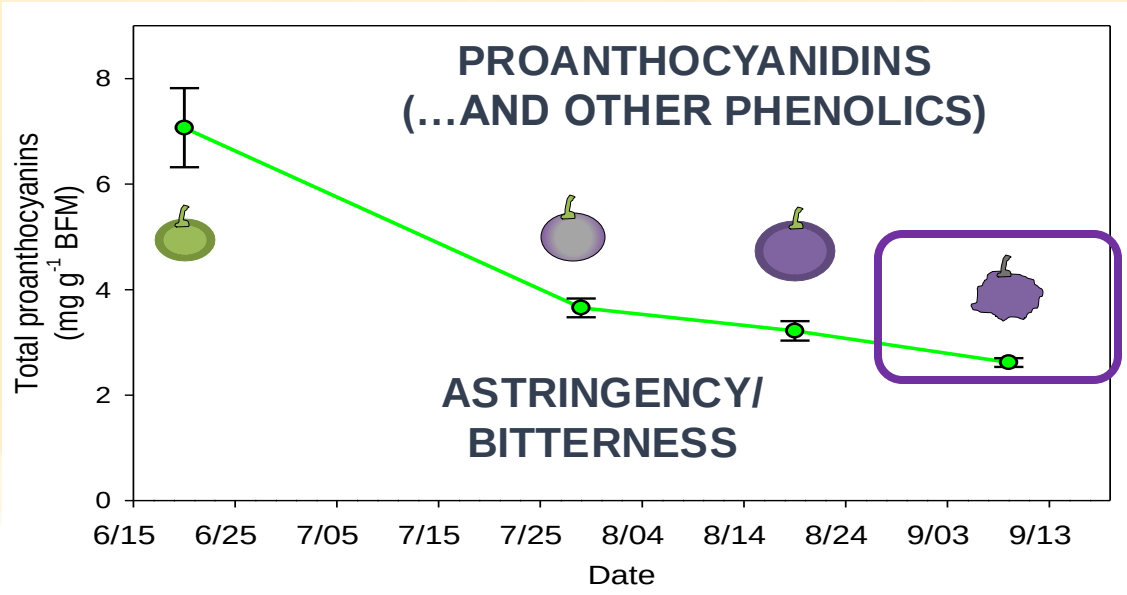
Cumulative heat accumulation in Santa Rosa, California in 2012, 2015, 2018, and 2020. (Data from https://cimis.water.ca.gov)











Credit: S.K. Kurtural

UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources Cooperative Extension

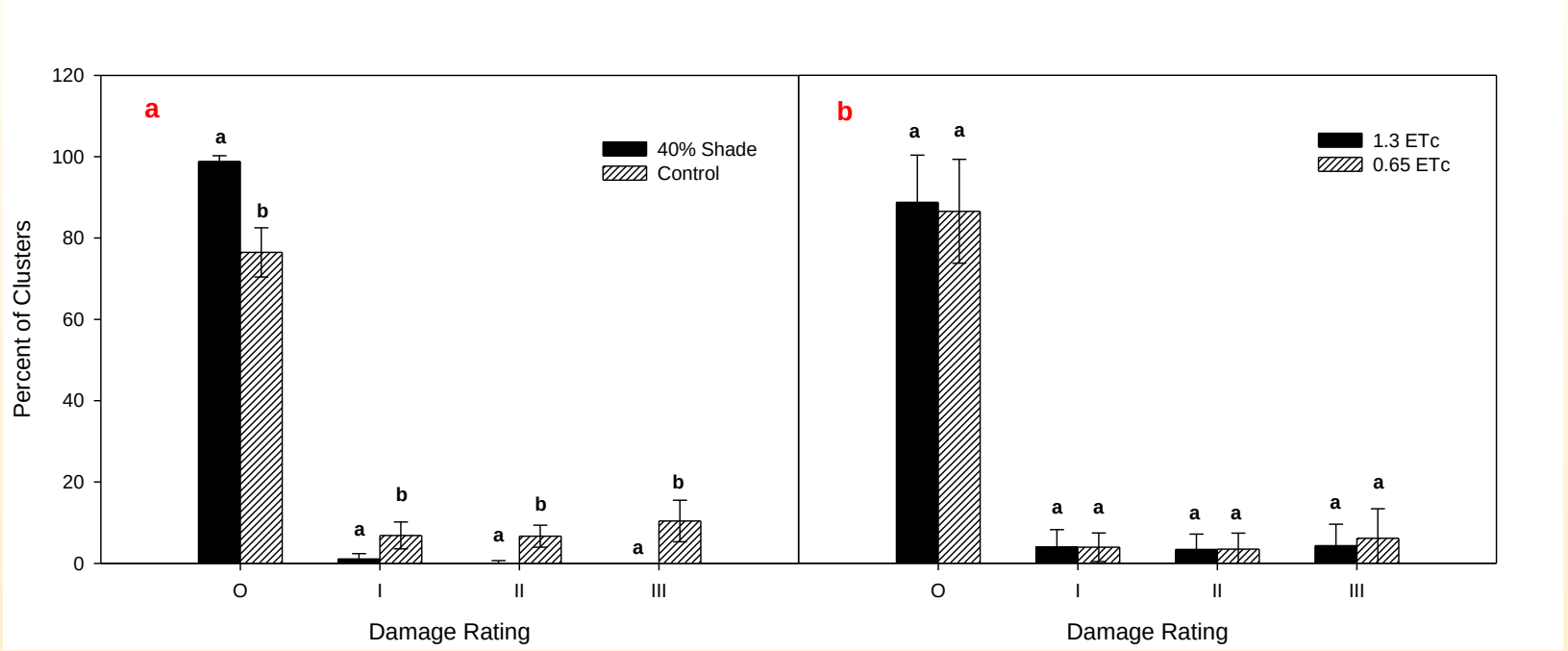
Short-Term Solutions Exist – Shade Nets

- 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!

Shade Nets

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 amag vest.

- S redu isible s
- A unts isible s
- W spon rtial ns in
  e s tha e be ing c

SITY
Agriculture and Natural Resources ■ Cooperative Extension

California drought conditions through the years

April 12,
2016

April 11,
2017

April 10,
2018

April 9,
2019

April 14,
2020

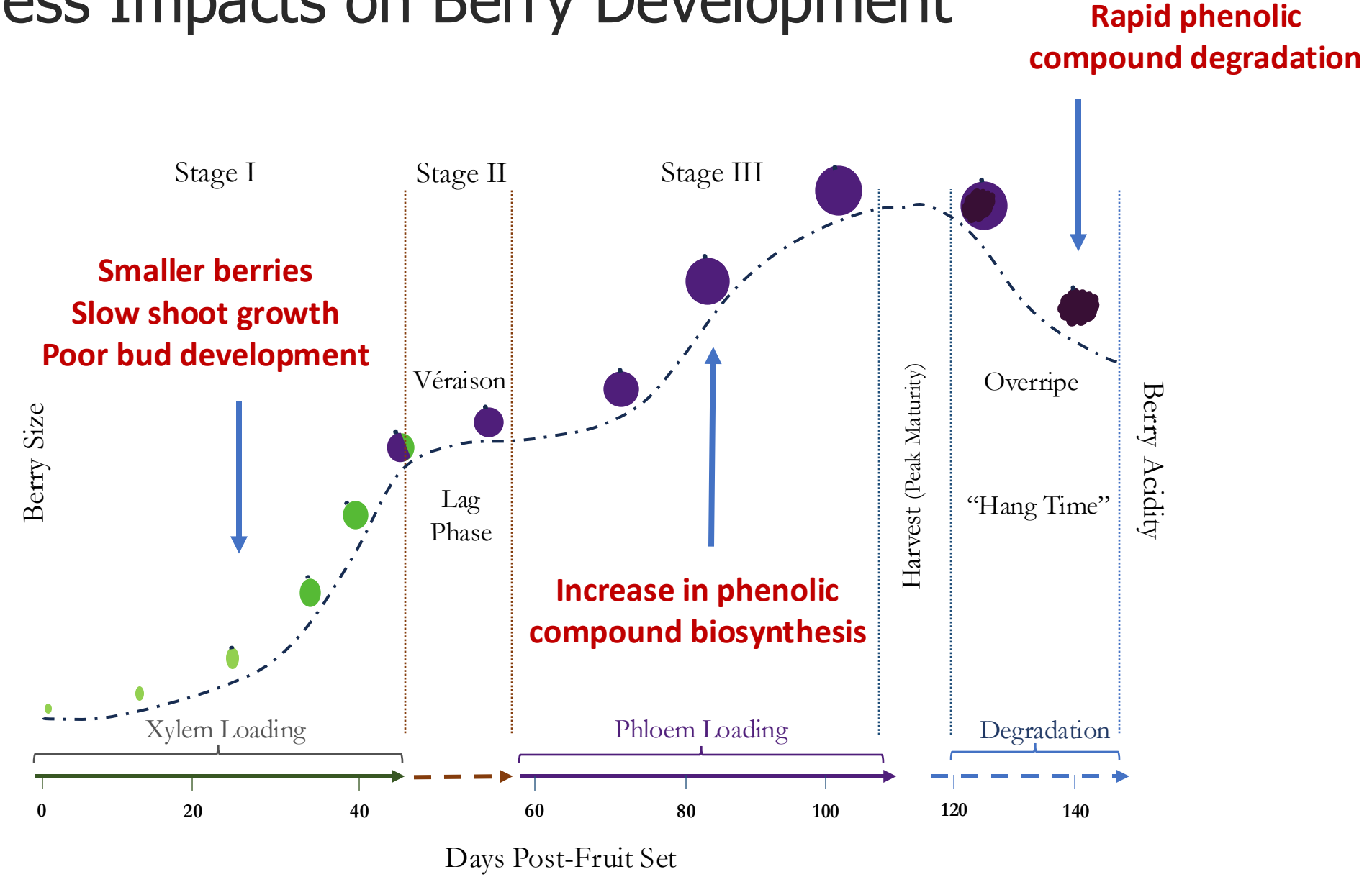
April 13,
2021

Impacts of Water Stress on Grapevines

- Insufficient water availability impacts grapevines differently based on timing

    1. Early Spring – Poor shoot growth & bud development
    2. Late Spring – Poor fruit set and slow berry growth
    3. Early Summer – Smaller berries and lower crop loads
    4. Mid – Summer – Poor development of fruit phenolics
    5. Late Summer – Low yields and degraded fruit

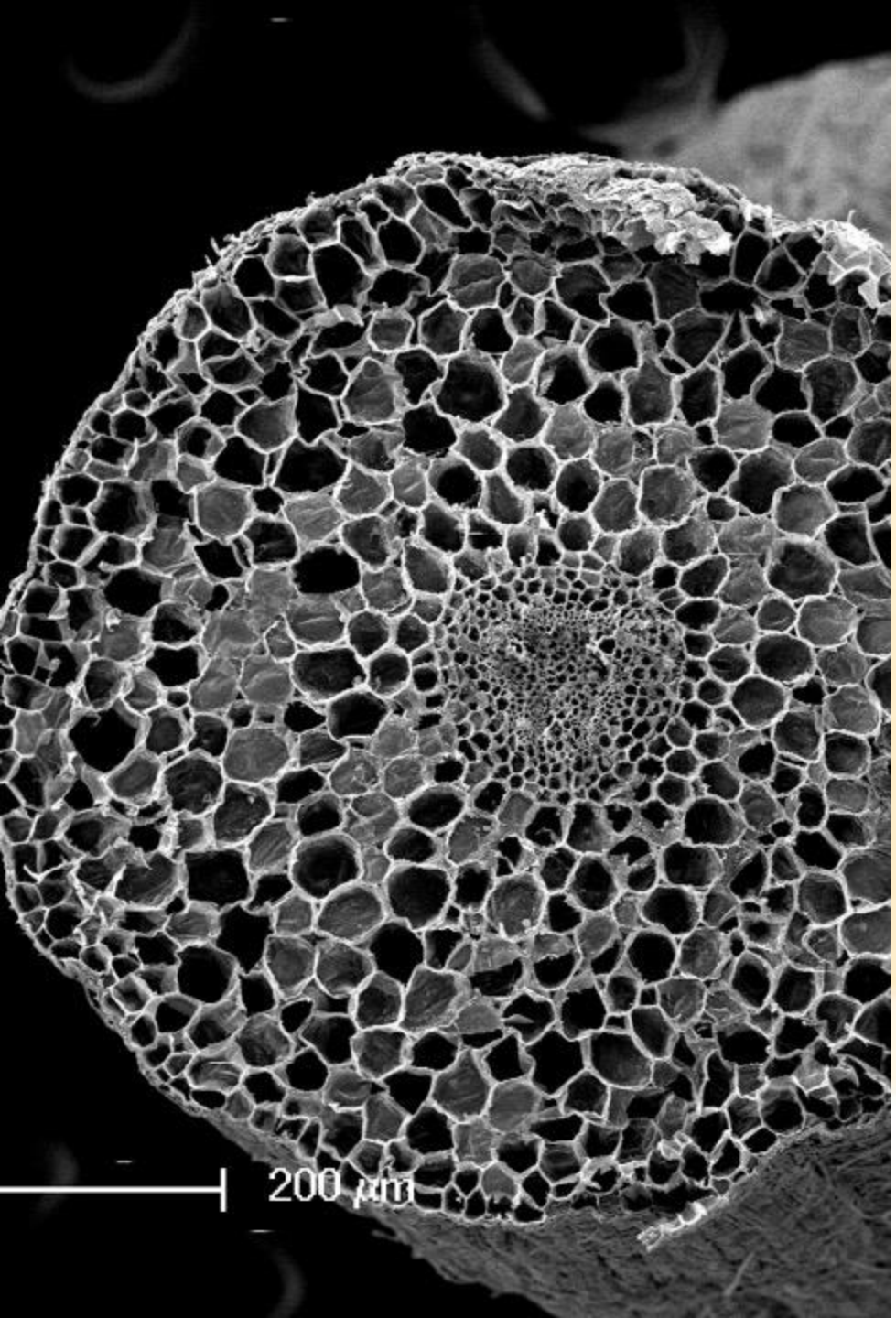
Water Stress Impacts on Berry Development



Abiotic Stressors Impact Vine Susceptibility

- A lot of the previous slides focused on how these abiotic stressors directly impact vine growth and yield

- But those direct impacts can improve the conditions for biotic pathogens and pests within the vineyard system



Physiological impact of abiotic stressors

1. Heat stress:
   - Increases vine water demand
   - Increases vine respiration
   - Timing of heat stress can increase foliar growth
     i. Resulting in more sugars for phytophagous insect pests
2. Drought stress:
   - Can result in whole-vine oxidative stress
   - Polyphenol synthesis increases (abiotic stress response)
   - Modified morphological and phenological characteristics
     i. e.g., xylem vessel size and hydraulic conductivity [4]
     ii. Improved conditions for *X. fastidiosa*

4. Claudio Lovisolo and Andrea Schubert. Effects of water stress on vessel size and xylem hydraulic conductivity in Vitis vinifera L. Journal of Experimental Botany, 49(321):693–700, 04 1998. ISSN 0022-0957. doi: 10.1093/jxb/49.321.693.

Vineyard Pests and Pathogens

– *Biotic Responses to Extreme Weather* –

Pest and disease responses to climate change

As a result of the indirect impacts of:

1. Increased average temperatures
2. Abiotic stress demands on plant resources
3. Temperature-driven lifecycle development
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

Invertebrate responses to climate change

Invertebrates 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 in response to changing climates

A migration of insects and pathogens is expected to move northward as climates change. (15)

- 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.

Increased functional ranges

- Changes in temperature, CO2 levels, water availability, and frequency of extreme weather events are likely to expand the range of existing insect pests in the vineyard [16].
- Preference for a given climate can help predict the spread of pathogens like GTDs using weather data and on-the-ground observations [17]
- Some pests/pathogens be more generalized than others and have higher potential to spread [10]

16. Tomasz Jaworski and Jacek Hilszczan´ski. The effect of temperature and hu- midity changes on insects development their impact on forest ecosystems in the expected climate change. Forest Research Papers, 74, 12 2013. doi: 10.2478/frp-2013-0033.
17. Y Qiu, C C Steel, G J Ash, and S Savocchia. Effects of temperature and water stress on the virulence of botryosphaeriaceae spp. causing dieback of grapevines and their predicted distribution using climex in australia. pages 171–182. International Society for Horticultural Science (ISHS), Leuven, Bel- gium, 3 2016. ISBN 2406-6168. doi: 10.17660/ActaHortic.2016.1115.26.

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

- Multiple years of extreme drought followed by late spring frost and summer rains = Vine abiotic stress
- Pests are living organisms affected by climate conditions too; sometimes positively

10. A Songy, O Fernandez, C Cl′ement, 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.

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.

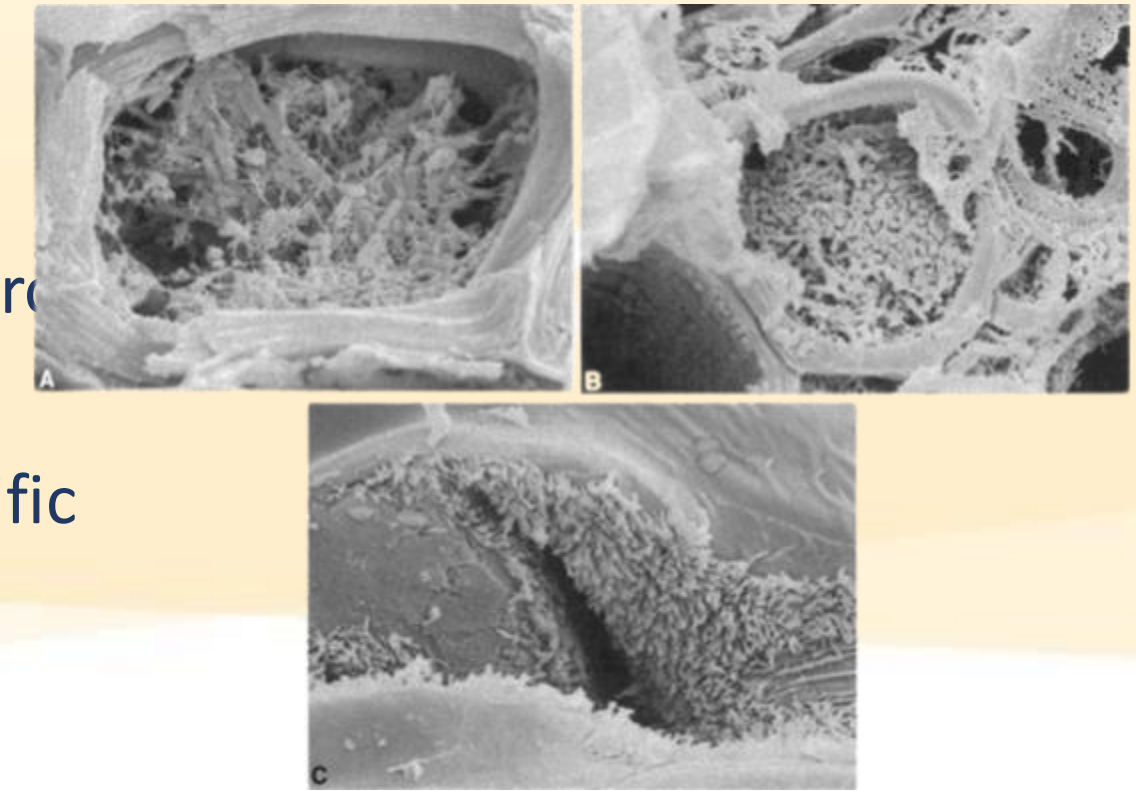
11. Helene Feil and Alexander H. Purcell. Temperature-dependent growth and sur- vival of xylella fastidiosa in vitro and in potted grapevines. Plant Disease, 85 (12):1230–1234, 2001. doi: 10.1094/PDIS.2001.85.12.1230
12. Tapan B Pathak, Mahesh L Maskey, Jeffery A Dahlberg, Faith Kearns, Khaled M Bali, and Daniele Zaccaria. Climate change trends and impacts on california agriculture: A detailed review. Agronomy, 8, 2018. ISSN 2073-4395. doi: 10.3390/agronomy8030025.

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 numer signaling pathways

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



Combined stressors: heat and drought

Changes in morphology and physiology are greater with combined stressors:

- Heat and drought in combination decrease plant growth and yields more so that each stressor individually. (10, 18)

Responses include ROS production and/or hormonal signaling (10)

Grapevine Trunk Diseases and fungi in general tend to increase growth rates at higher temperatures (25-40 ºC) (10)

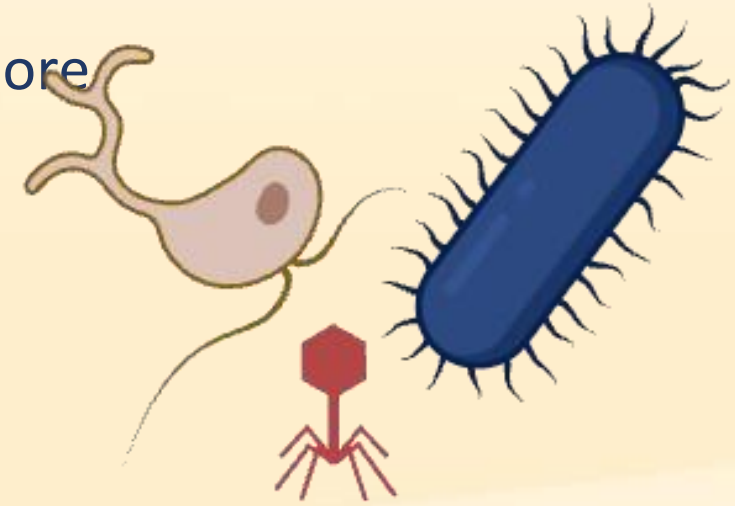
- However, they also might have an unexpected, combined-stress response(19)

Microbial Adaptation

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 adapted to higher temperatures



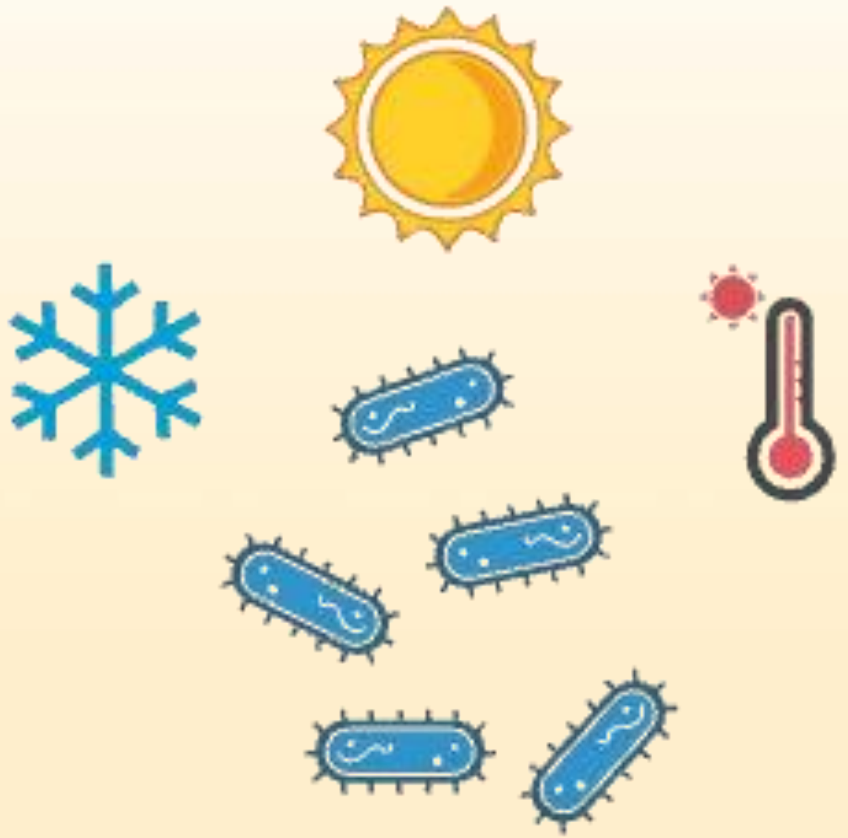
Viral temperature ranges are similarly problematic

- Viruses can adapt rapidly to new conditions
- Fever – mechanism to expose viruses to higher than tolerable temps

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

‘New’ diseases in vineyards

Often can be difficult to identify:

- Lime disease on the West Coast or GRBV in vineyards

Grapevine Red-Blotch Associated Viruses

- Flagship example for grapevines
- Not known until 2008 (Oakville, CA)

Case Study: GRBV

Red blotch was an unknown disease in grapevines for decades and likely was already present in the north coast during the 20th century.

Large, clean-material vineyards used to source pathogen-free material did not know it existed and thus, did not know what to test for.

The future of our climate may increase the likelihood of new diseases we cannot test for or expression of existing pathogens becoming more problematic

The Climate-Adaptive Vineyard

1. Resource Use Efficiency
   - Water use efficiency
   - Appropriate nutrient inputs
   - Resource alternatives
2. Extreme Weather Resilience
   - Resilient infrastructure
   - Future-climate adapted cultivars
3. Effective Management Practices
   - Precision vineyard practices
   - Optimized vineyard design
   - Consistent and reliable monitoring
   - Exploring alternate strategies

The Climate-Adaptive Vineyard

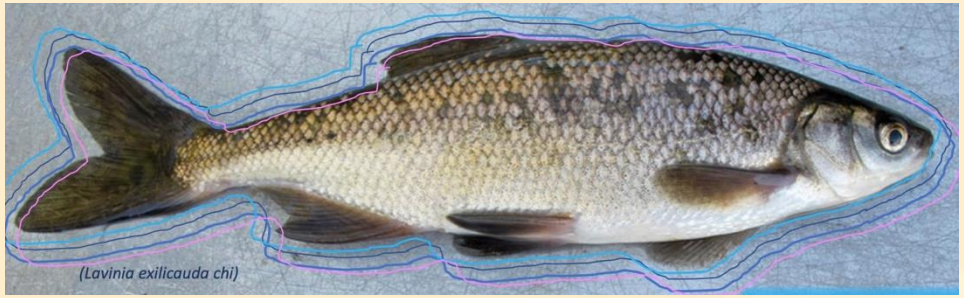
4. Prioritizing Vine and Site Health
    - Soil health properties
    - Vine longevity and productivity
5. Monitoring Pest Behavior
    - Pests may adapt to changing climate
    - Predators and parasitoids may not
    - “New” pests may move to new areas
6. Community Cooperation
    - Make jobs desirable
    - Improve employee retention and well-being
    - Work with neighbors to improve positive impacts of viticulture

Case Study: Frost Protection and Water Conservation

- Inversion Tower Project
  - Lake County, CA (2023 – 2025)
  - Bella Vista Vineyard Management
  - Over 25 different contributors
- Objective
  - Identify climate subregions where frost fans could replace overhead frost irrigation effectively
- Contributing Factors and Need for Information
  - Culturally important fish may be impacted by frost protection water usage in spring
  - Scarcity of water resources
  - Late spring frost events increased frequency

Clearlake Hitch

- Fish species in Lake County, CA
  - Large species of Minnow
  - Uses tributaries of Clearlake to reproduce
- Importance to Pomo Tribes of Clearlake
  - Known as the **Chi** to local Pomo Tribes
  - Staple food for generations
  - Culturally Symbolic
- Impacts of Viticulture on Clearlake Hitch
  - Spring frost irrigation may lower water levels in the Clearlake tributaries used by the Hitch
  - Disagreements on water priority
  - Preserve viticulture at the cost of a culturally important species?
  - Legal actions and regulations on the table



Temperature Inversion Towers

- Concept based on work by Mark Battany
- Required conditions for frost fan effectiveness:
  - Freeze type = Radiative Freeze
  - Temperature inversions
    - ➢ Higher elevation air is warmer
  - Area within fan coverage
  - Mixed air temperature > 32 ºF

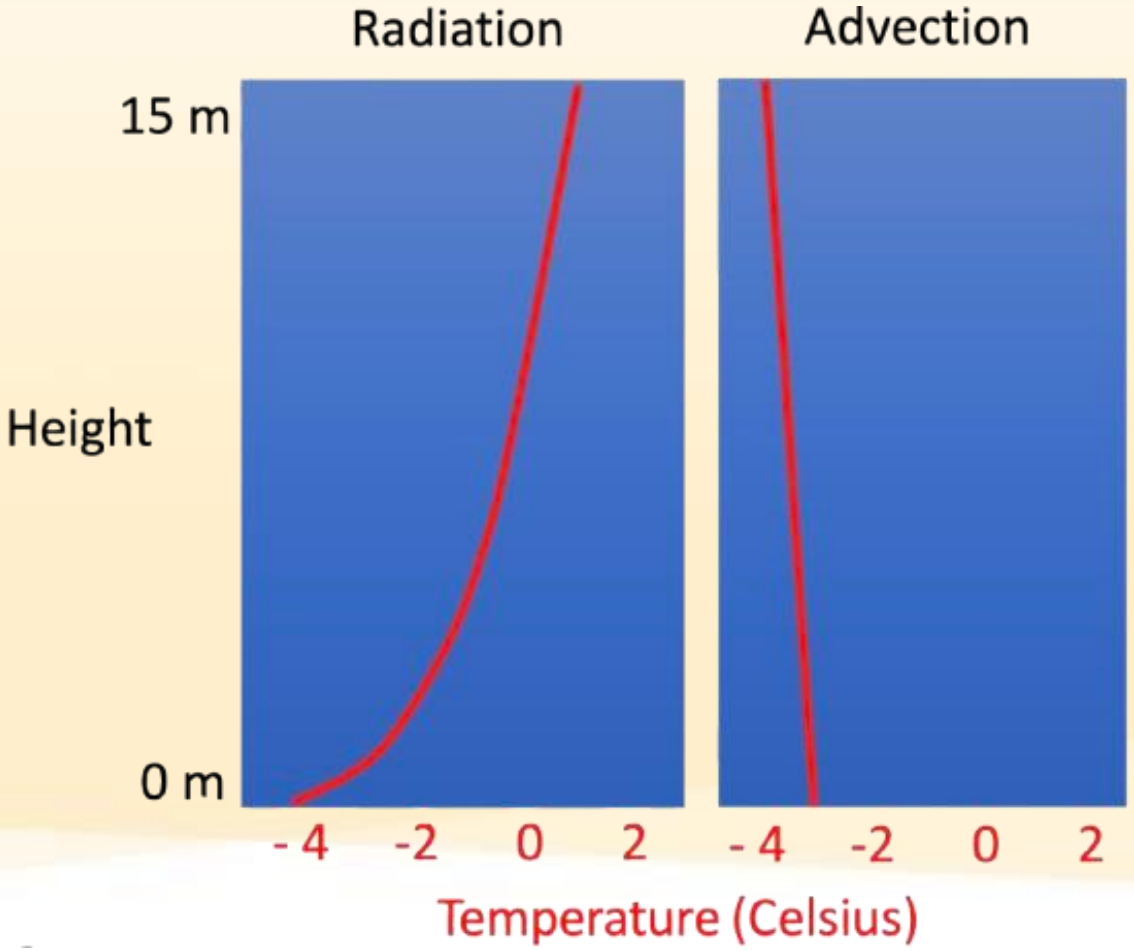


Image Credit: Mark Battany

Overhead Frost Irrigation

- Freezing water = Exothermic reaction
  - Small amount of heat released
- Water must freeze continuously to maintain above freezing temperatures
- Must add more heat from freezing than lost to evaporation
- Can increase total vineyard water demand per acre per year by 20-30%
- Equipment failure common and will result in severe frost damage

Image Credit: Mark Battany

Wind Machines for Frost Protection

- Wind machines mix warmer air at elevation with colder air at ground level
- Require no water and low energy
- High up-front costs
- Coverage requires 10-25 hp/acre
- Only beneficial during **radiative freezes**
  - Must be reliable and predictable
  - Limits areas where fans are useful

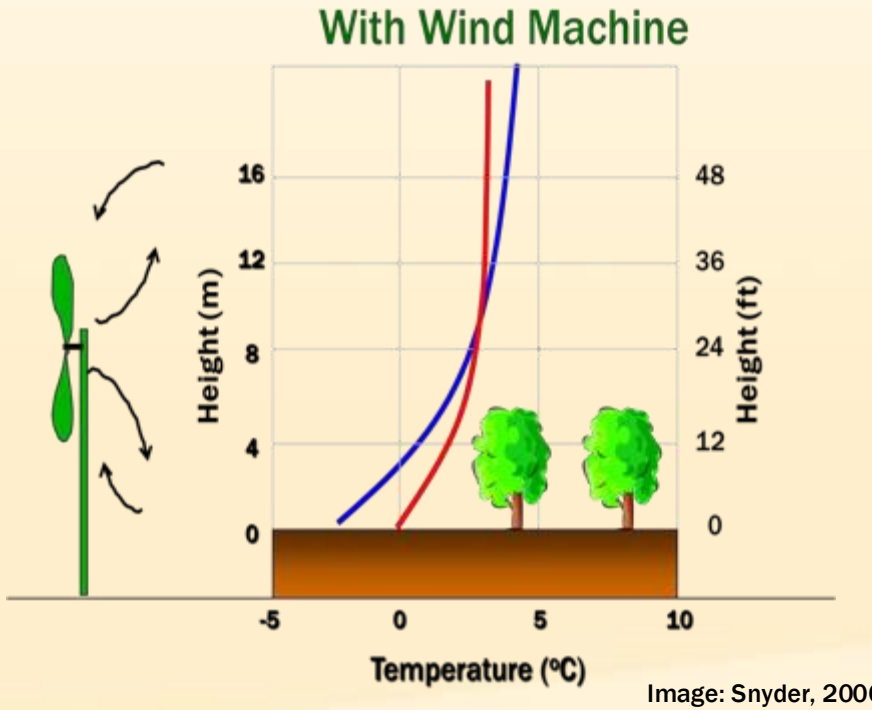


Image: Snyder, 2000

Measuring Inversions

- Based on Mark Battany's designs
- Two temperature and humidity data loggers
  - 1x at 5ft elevation
  - 1x at 30 ft elevation
- 30 ft tower with optional, additional measurement instruments

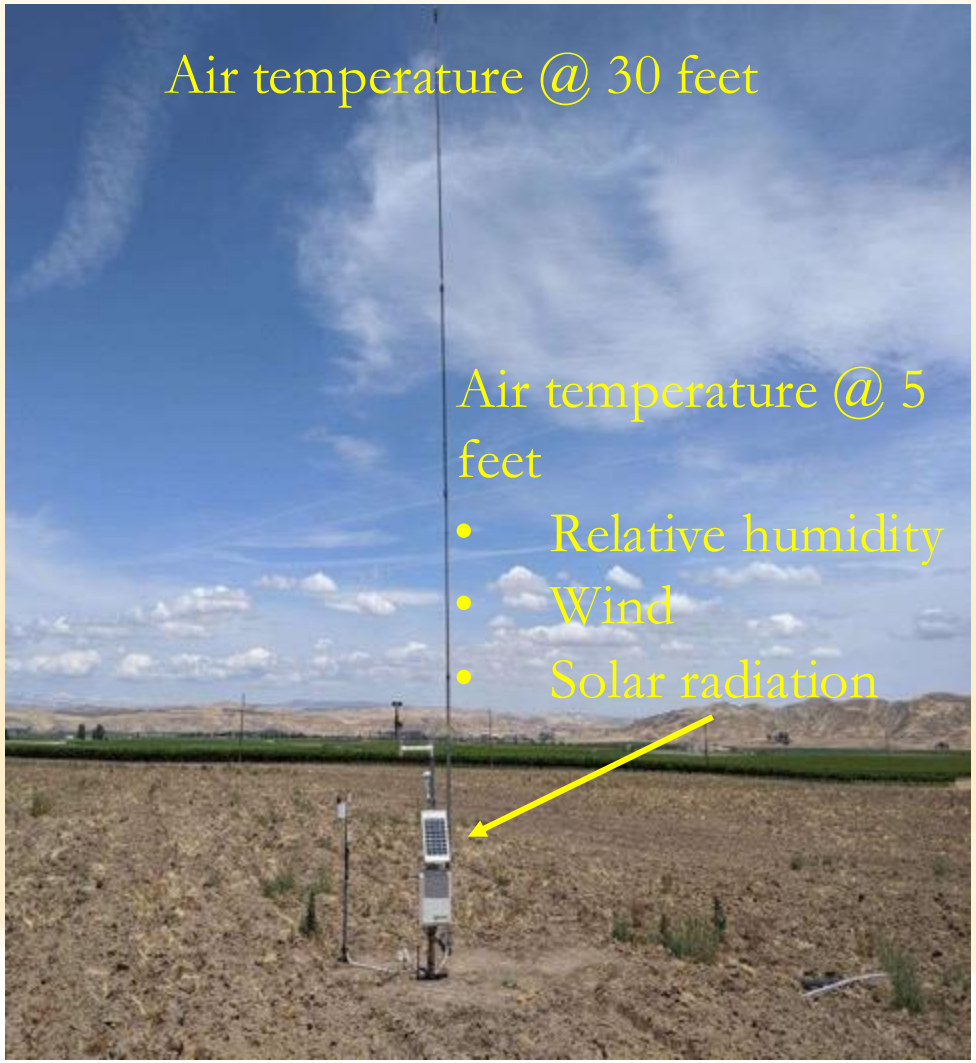
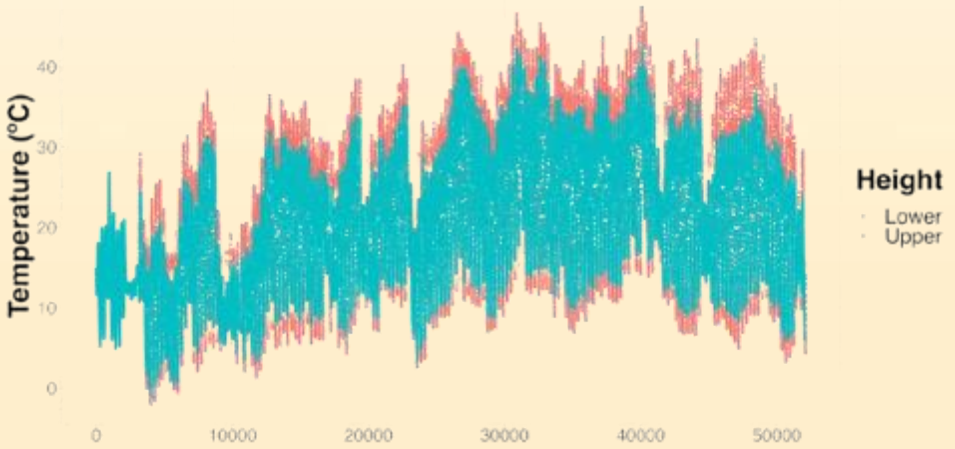


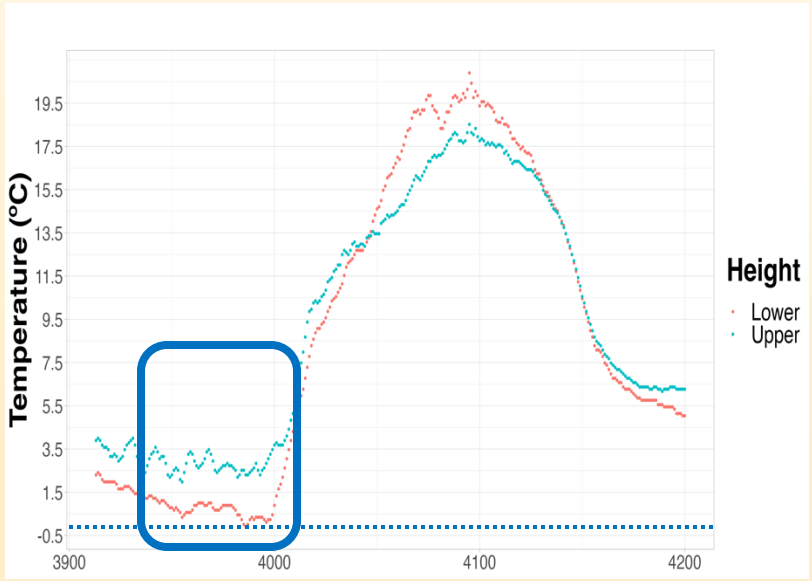
Image Credit: Mark Battany

Results – Replacing Frost Irrigation with Fans

- Lake County is shaped like a bowl
  - Lower elevations are prone to frost
  - These were the target locations of this study
- Not many locations fit the requirements
  - Only a handful of locations had temperature inversions during frost events
  - We are not sure if these are reliable and common enough to rely only on fans

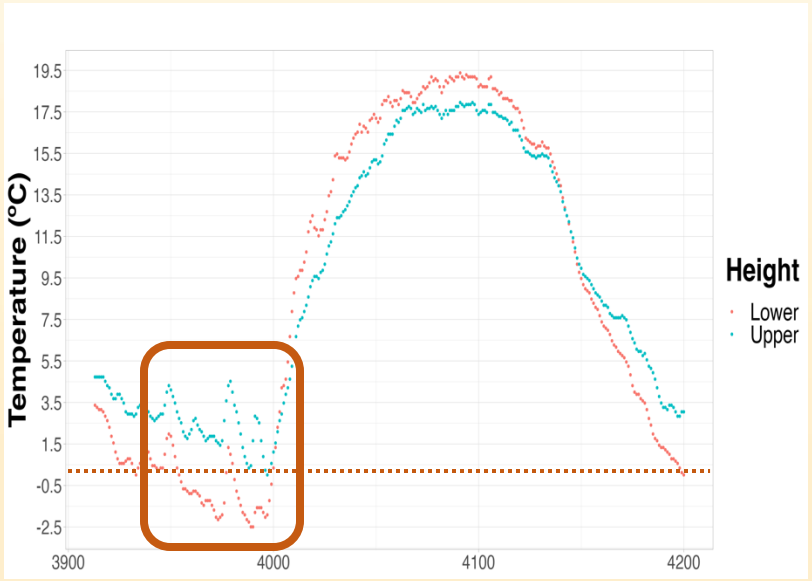


Reliable Temperature Inversion
Occurred at ≈ 11% of sites



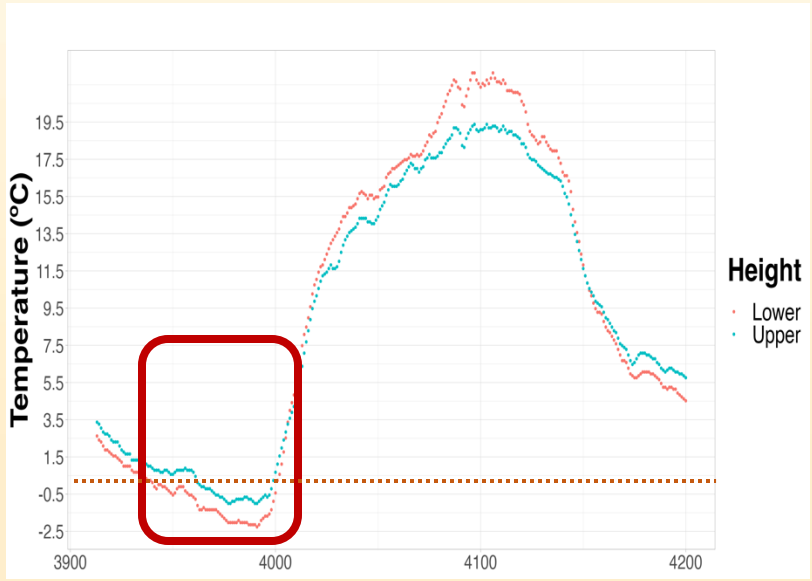
- Majority of locations with frost fan conditions were located in either:
  - Kelsey Bench
  - Scott's Valley
- Both are areas at higher elevation with regular elevation changes

Unreliable Temperature Inversion
Occurred at ≈ 27% of sites



- Majority of locations with frost fan conditions were located in either:
  - Kelseyville
  - Kelsey Bench
- These sites varied in topography and elevation

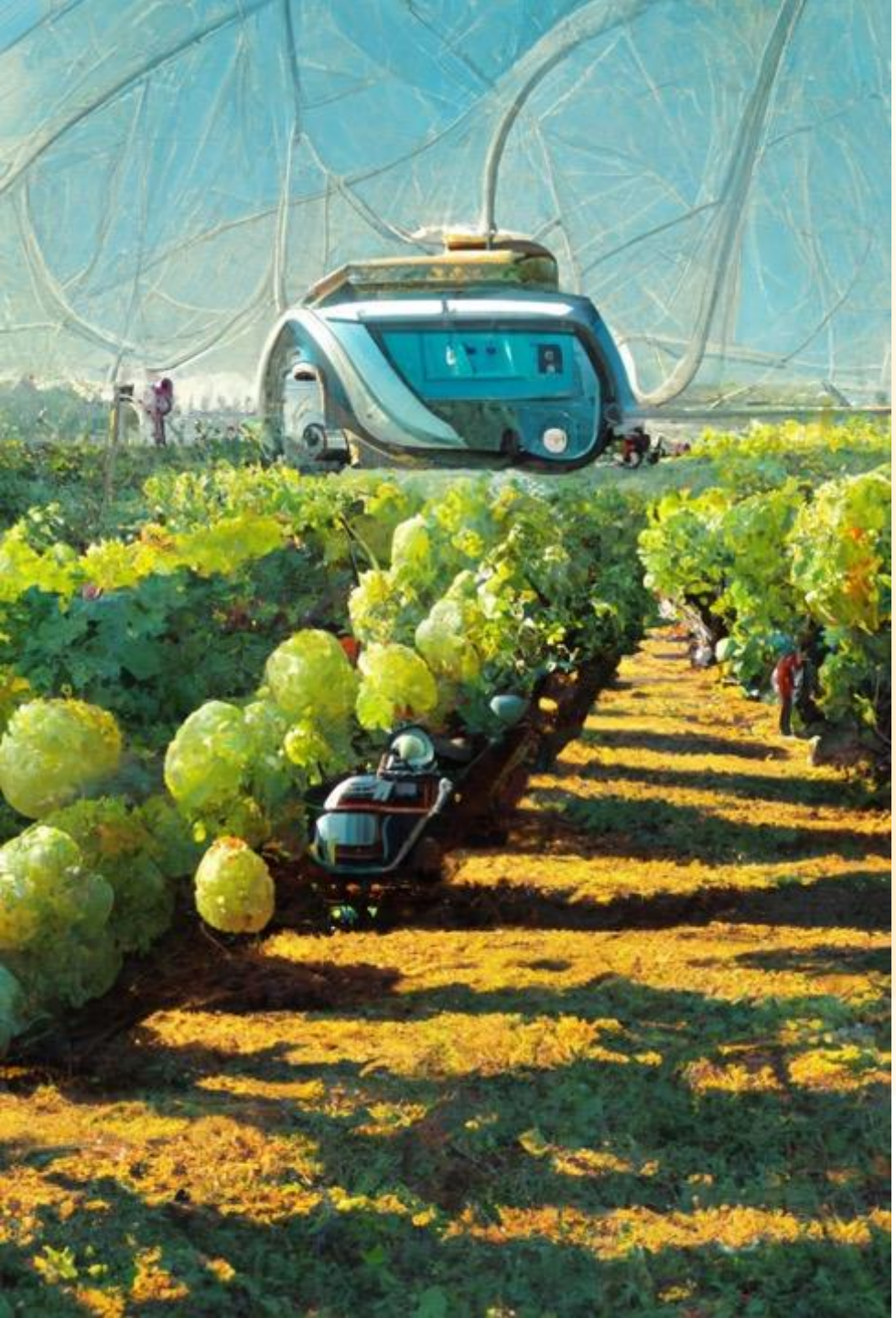
No Temperature Inversion
Occurred at ≈ 62% of sites



- Majority of locations with frost fan conditions were located in:
  - Big Valley
- This is a flat, low-lying area and is nearest to Clearlake

Takeaway – Replacing Frost Irrigation with Fans

- Effective use of frost fans is limited by weather and geography
  - Flat, low elevation – no fans
  - Hillsides might be the target use case for frost fans
- This is the kind of work that can help us adapt to changing weather
  - Initial motivation for this work was preservation of the Clearlake Hitch
  - Can be a model for increasing water use efficiency for vineyards regardless



Summary

1. Pest and Disease Impacts ~ Abiotic Stressors

2. Any stressor ties-up grapevine resources and limits its ability to defend against new stressors

3. Climate adaptive vineyards will be heavily impacted by resource use efficiency and effective management practices

4. Development and testing of alternate solutions to changing climate challenges is needed
   - -Resource allocation - Infrastructure designs
   - -Vine and soil health - Limiting controllable stress

Downloadable Presentation

- You can find this presentation at:
  1. https://ucanr.edu/sites/chenlab
  2. Speaker Presentations

Some original images created by OpenAI Labs Dall-E 3 Program and in https://BioRender.com

Thanks for Listening

Contact me: codchen@ucanr.edu

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