Abiotic Stressors in Vineyards

UCCE North Cost Viticulture

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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








66.6
°F/°C

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

Extreme Heat - Trends

Extreme Heat

Extreme temperatures

↓

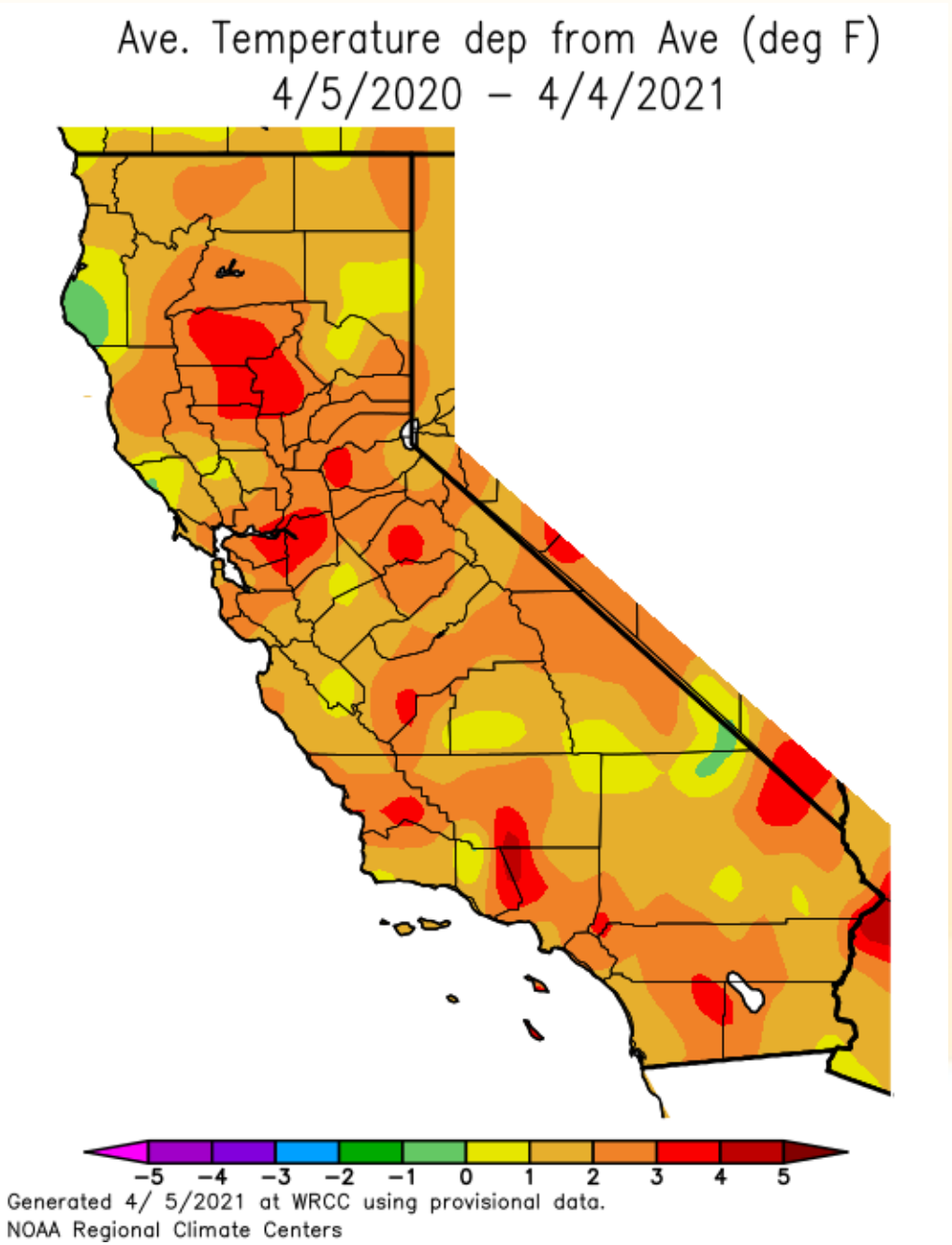
High evapotranspiration

↓

Greater water demand

↓

Damaged fruit



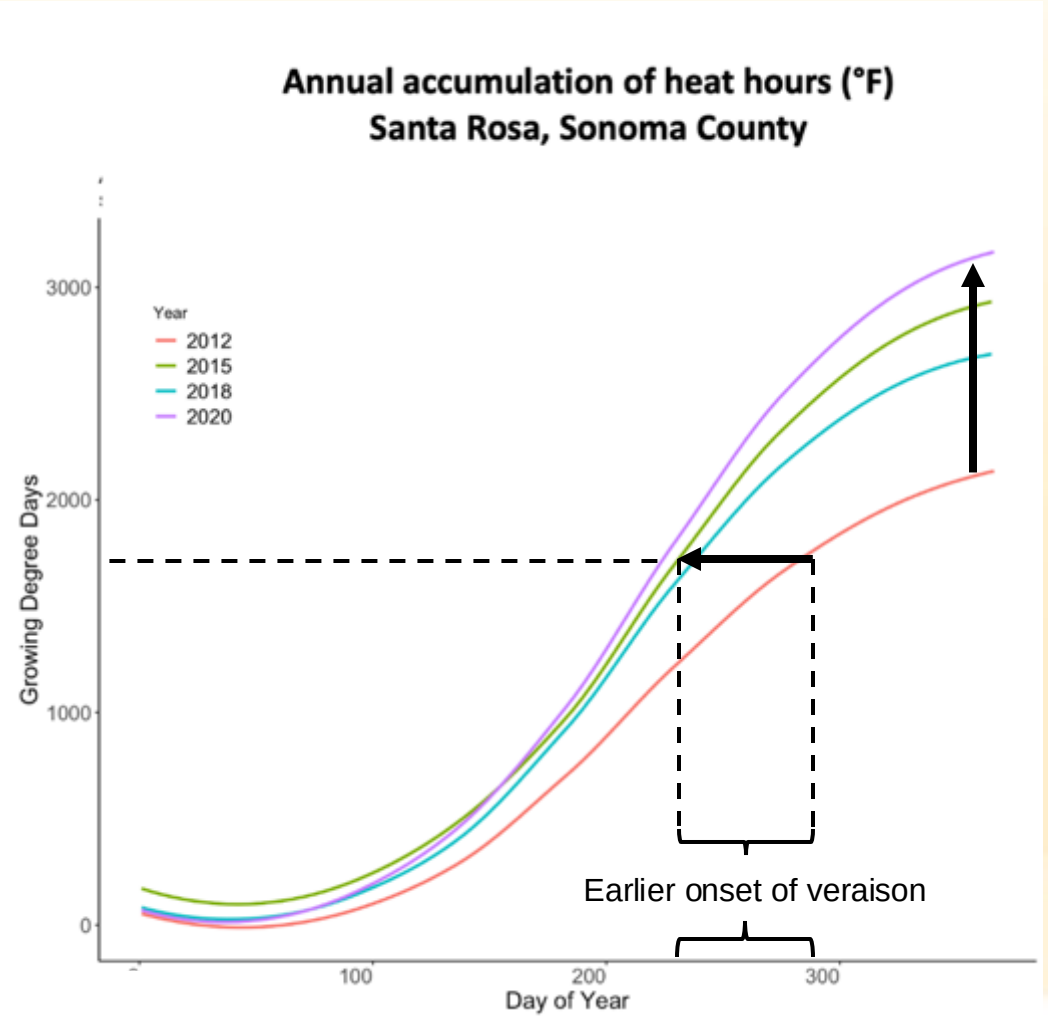
Credit: California Climate Data Archive (2021)

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



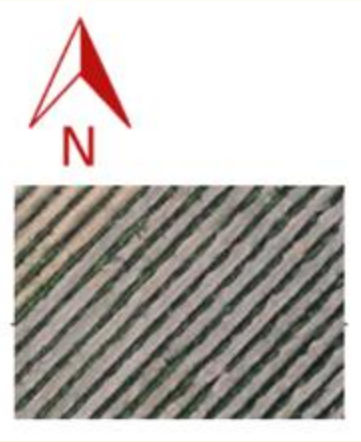
Cumulative heat accumulation in Santa Rosa, California in 2012, 2015, 2018, and 2020. (Data from https://cimis.water.ca.gov)

Increasing Temperatures

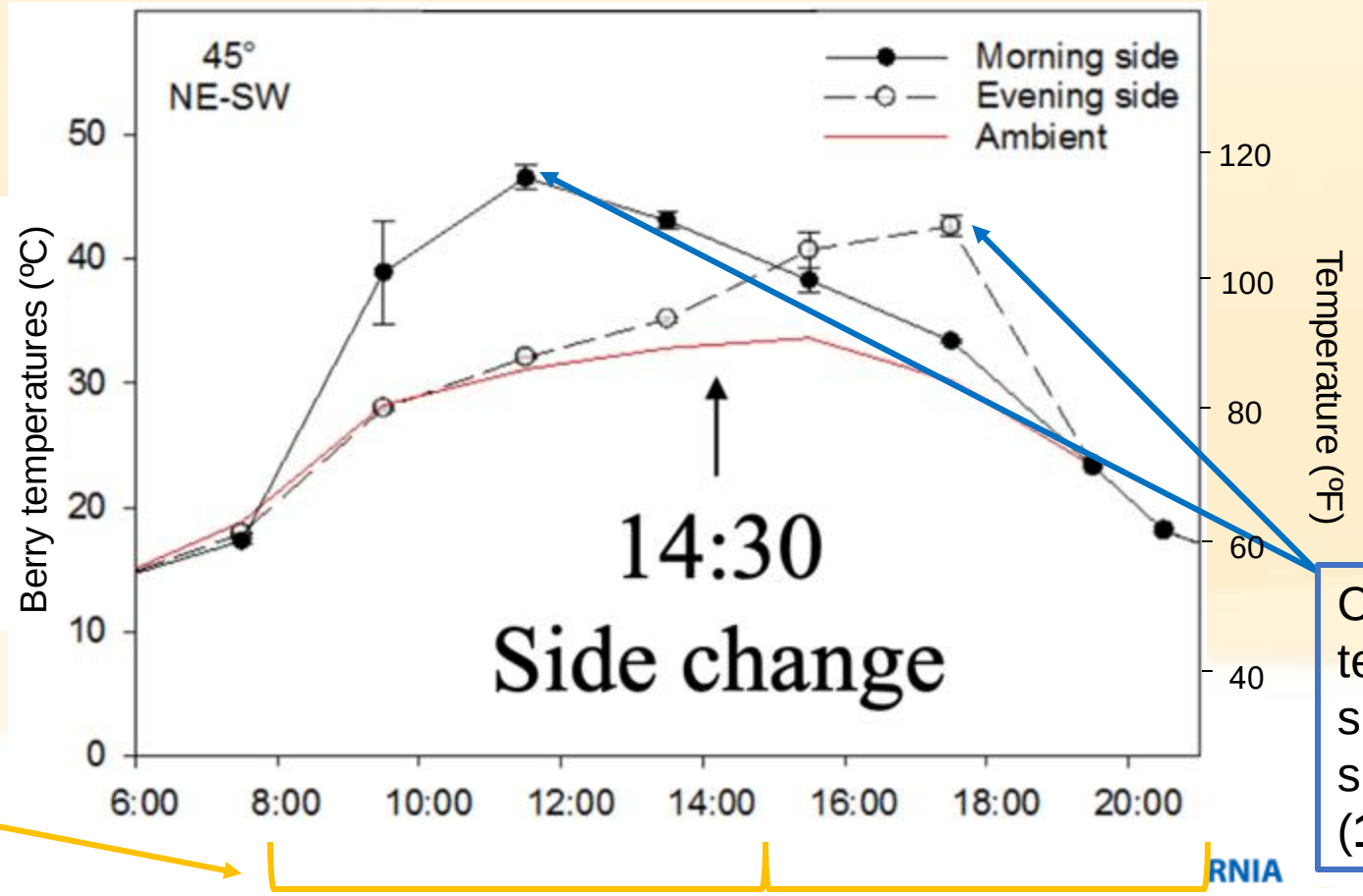
Row orientation

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

More equal distribution of daily solar radiation
NE - SW



NE - Morning ⟵ ⟶ **SW - Evening**



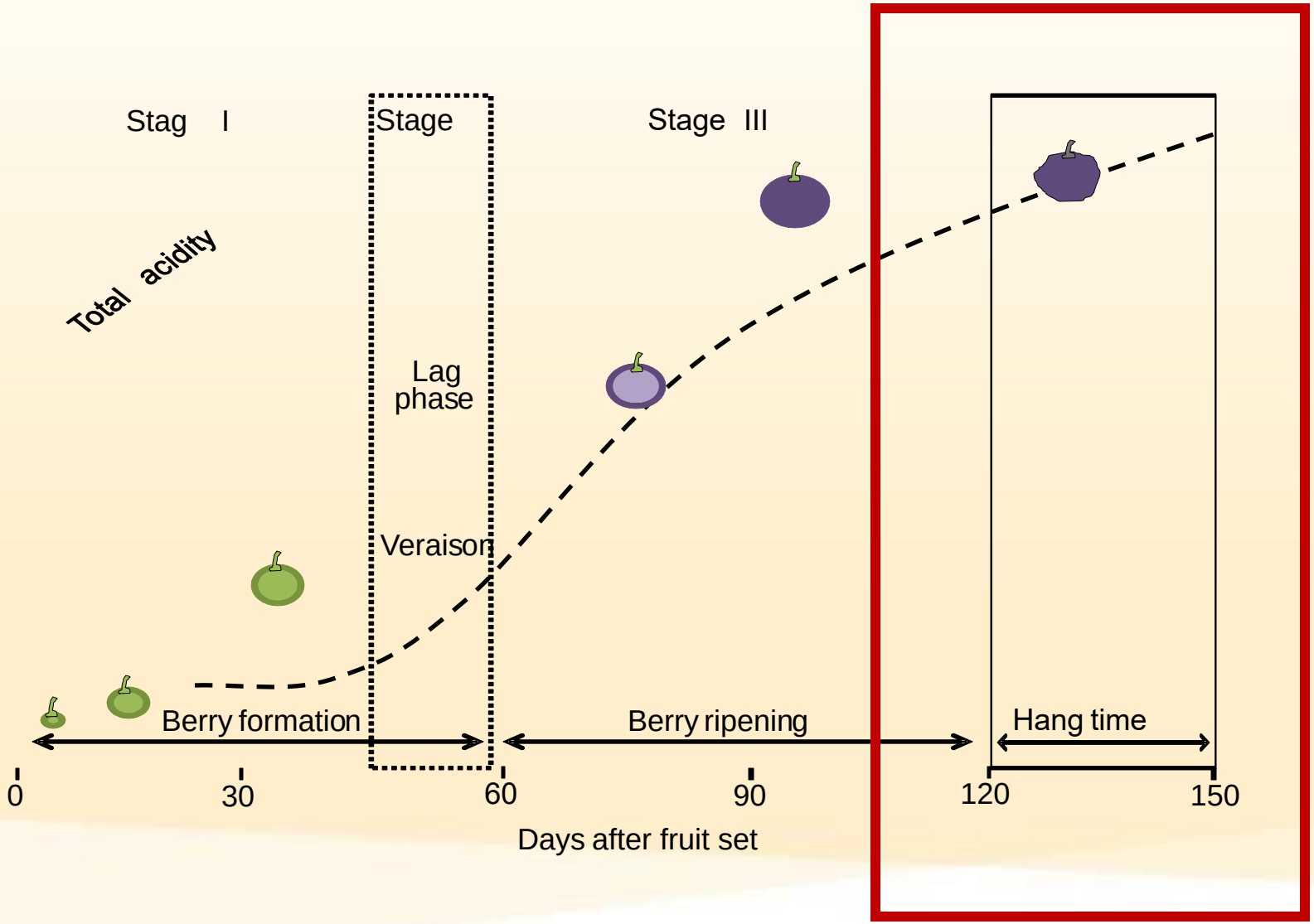
Both sides of canopy receive **similar hours of direct sunlight**

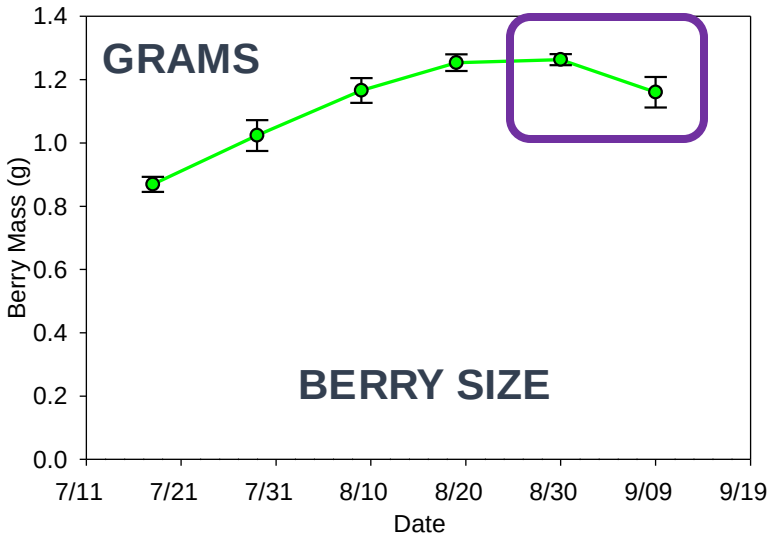
Cluster temperatures similar on both sides of canopy (**110 to 120 ºF**)

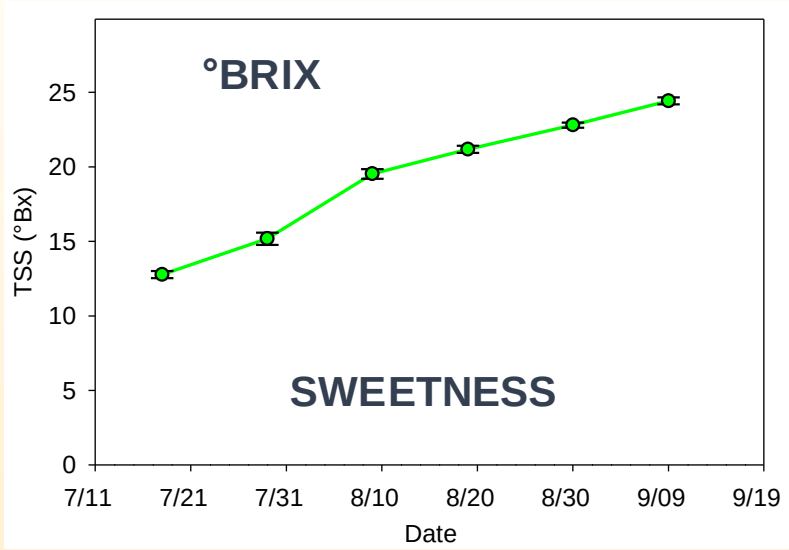
Image credit: "*Vineyard Design spacing and trellis selection*" – Johann Martinez (UC ANR presentation 2019)

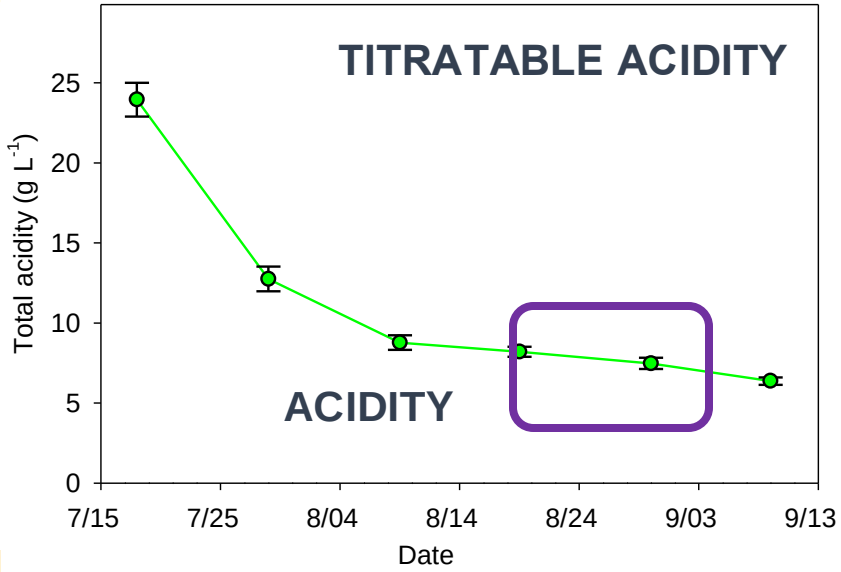
Research – Shade nets for sun mitigation

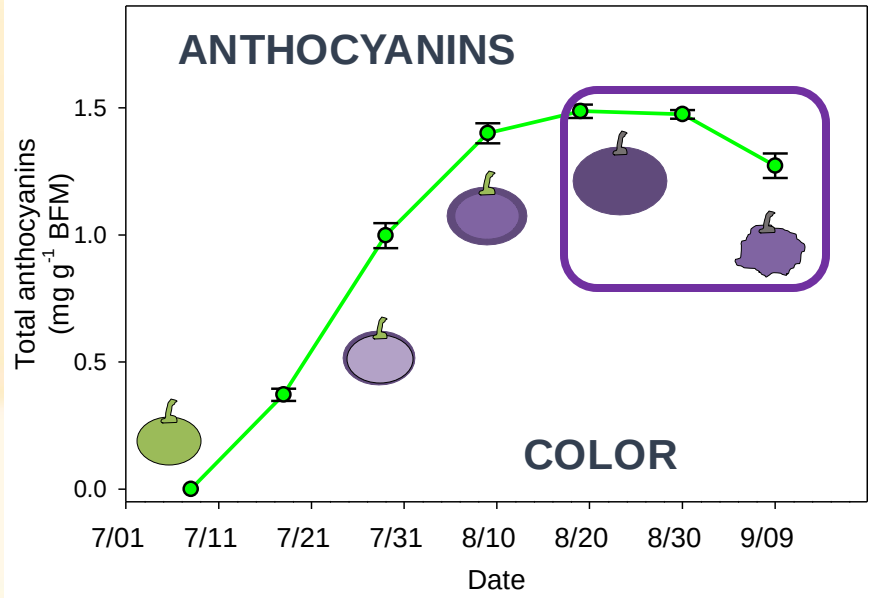
- Sun and heat damage are major concerns
- Often canopy is enough to limit damage
- In cooler climates, leaf removal might be necessary to ensure proper ripening
- Leaf removal + heatwave = berry damage
- Artificial Shading!

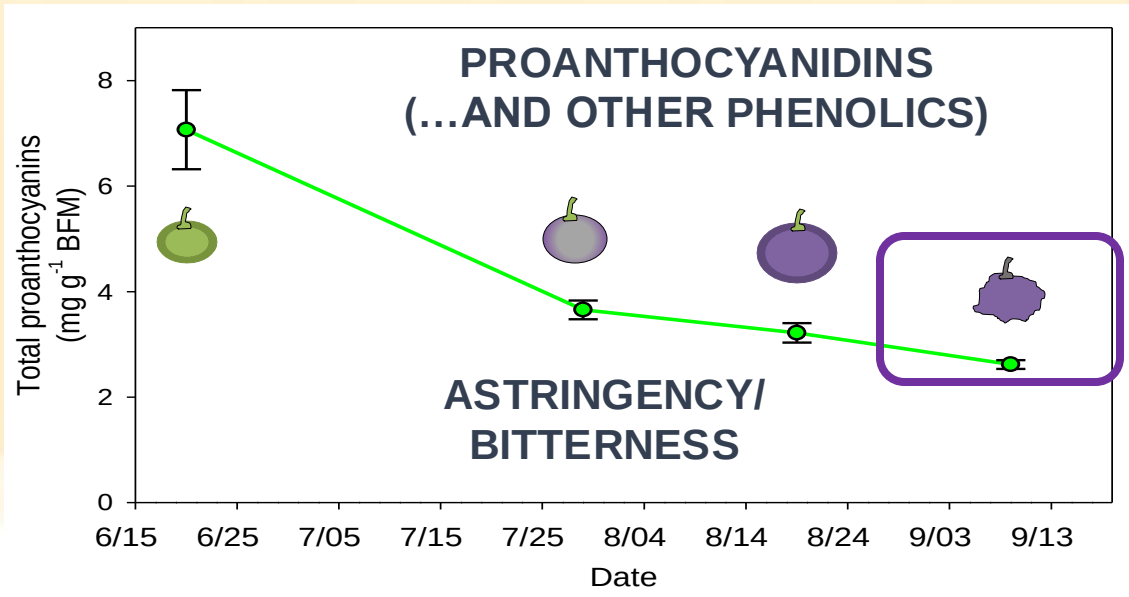

Stag I
Stage
Stage III
Total acidity
Lag phase
Veraison
Berry formation
Berry ripening
Hang time
0
30
60
90
120
150
Days after fruit set











Credit: S.K. Kurtural

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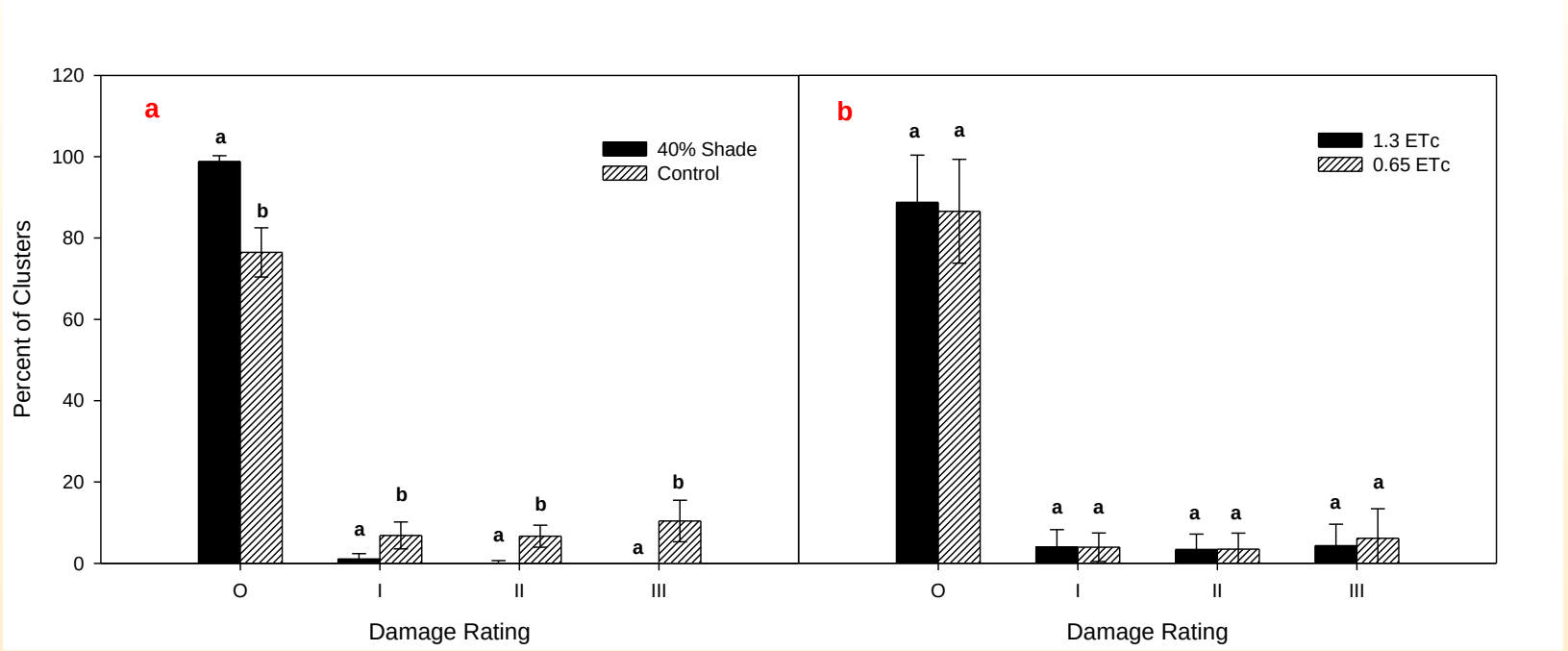
Visible Damage

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



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- S redu isible s
- A unts isible s
- V spon rtial ns in
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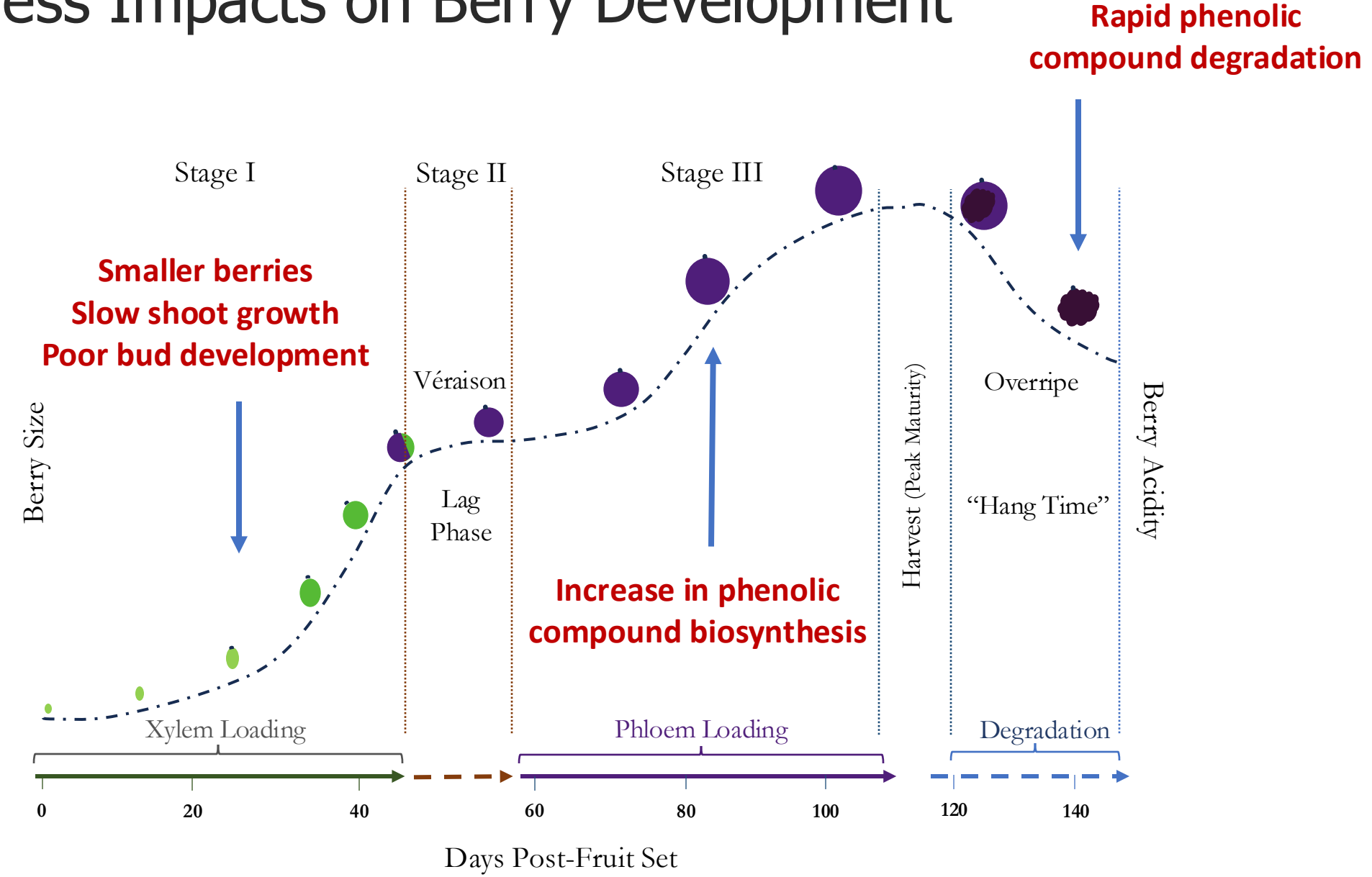
Impacts of Water Stress on Grapevines

- 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

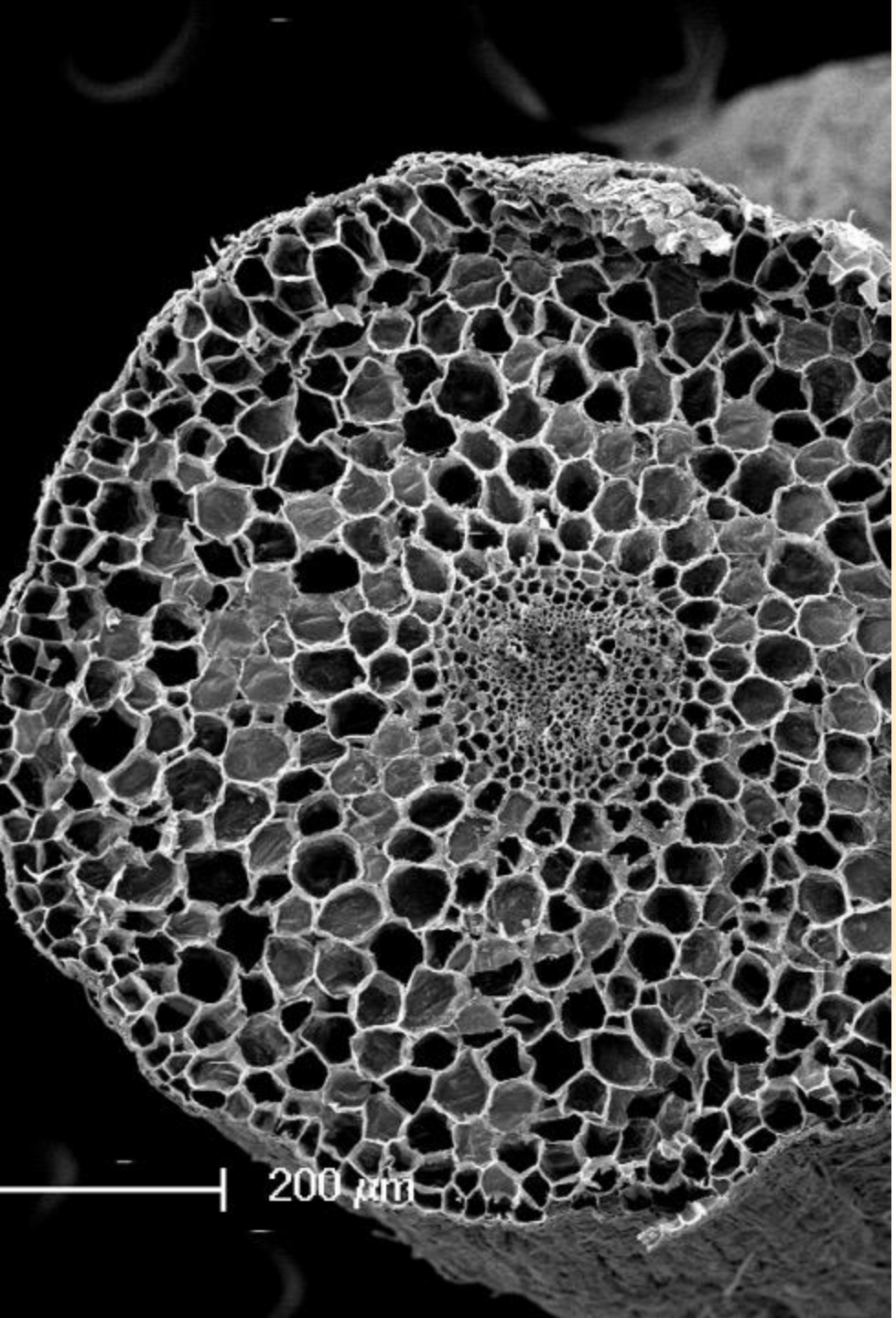
Water Stress Impacts on Berry Development



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.

Abiotic Stressor impacts on Biotic Stressors

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

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.

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
- Pests are living organisms affected by climate conditions too

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 numerous signaling pathways

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

Impacts of high temperatures on fungal and viral population and reproduction

Worldwide Temperature Increases

Heatwaves have increased in frequency and severity [3]

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

CRISPR – CAS9

Makes use of *Agrobacterium spp.* ability to sequester genetic sequences from other organisms and incorporate them as part of their own genome

This is why we can make glowing fish using snippets of jellyfish genomes

This may also contribute to the rapid pace of bacterial adaptation in new conditions

‘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

Changes in pathogen virulence in vineyards

Temperatures can directly affect the biosynthesis of 2º metabolites and enzymes in GTDs and other pathogens (10)

Pest and disease pressure is likely to increase over time with invasive species benefiting from increased CO_2, higher temperatures, and better overwintering success. (15)

15. 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 farm- ers. Mitigation and Adaptation Strategies for Global Change, 13:555– 575, 2008. ISSN 1573-1596. doi: 10.1007/s11027-007-9125-2.

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.

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.

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, their intracellular morphology may be modified too (19)

The unpredictable nature of climate change

We know what to expect, but not when and where to expect it

- e.g., Snow in Paso Robles | Heatwave in Humboldt

Extreme events are occurring more frequently and unexpectedly; often in regions unprepared for them

Impact of such events like heatwaves are more noticeable in regions unaccustomed to them (i.e., coastal heatwave impacts > inland heatwaves)

Tools for tolerance

1. Breeding and genetic solutions (GRN rootstocks; PD-resistant scions)

2. New monitoring techniques/Proximal sensing (LiDAR sensing; non-invasive disease ID)

3. Promotion and development of new and existing beneficial species

4. Research on combined-stress responses in grapevines

Resistant Cultivars

Rootstocks have long been used as a method of tolerance to both biotic and abiotic stressors. (22)

- GRN rootstocks for nematode tolerance

Scions are also being developed to help impart tolerance to specific pests and/or diseases (23)

- Pierce's Disease resistant scions

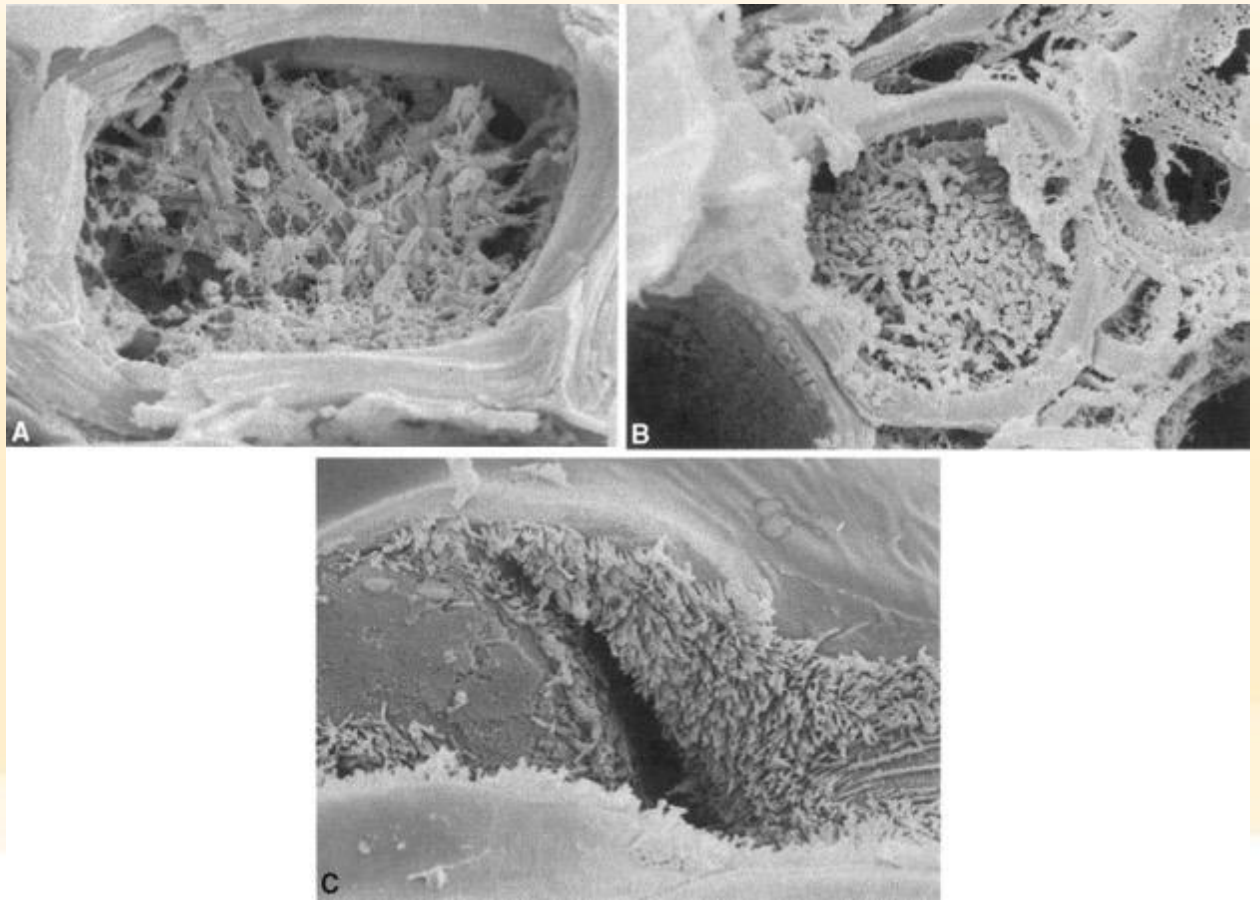
22. M. Mumtaz Khan, Muhammad Tahir Akram, Rashad Waseem Khan zQadri, and Rashid Al-Yahyai. Role of grapevine rootstocks in mitigating environmental stresses: A review. Journal of Agricul- tural and Marine Sciences [JAMS], 25(2):1–12, Sep. 2020.

23. A. F. Krivanek and M. A. Walker. ¡i¿vitis¡/i¿ resistance to pierce's disease is characterized by differential ¡i¿xylella fastidiosa¡/i¿ populations in stems and leaves. Phytopathologyà, 95:44–52, 1 2005. ISSN 0031-949X. doi: 10.1094/PHYTO-95-0044.

Finding a PD-resistant Scion

Xylella fastidiosa clogs the xylem vessels in grapevines by colonizing the vessels

To find a ‘resistant cultivar’ would be to find one where vascular hydraulic conductivity does not fail under *X. fastidiosa* infections



New Monitoring Solutions

Remote sensing for pest and disease monitoring in vineyards

Examples

1. LiDAR sensing and modeling to identify flying insects on site
2. Radio Wave surveys of internal biological components of a living vine
3. Drone-based NDVI for disease impacted vines

Promotion of Beneficials

New phenological cycles of phytophagous insect pests may require a ‘reworking’ of our understanding of efficacy of certain beneficial species.

An asynchronous hatching of pest and beneficial may lead to a decline in their effectiveness

New distribution methods may increase survival rate of introduced beneficials in vineyards

- e.g., Drone-distributed beneficial mites

Research into combined stress responses

Plant responses to combined stressors may be unique to the specific combination of stressors.

- e.g., drought and *Xylella fastidiosa*

Research on phytotoxic metabolite biosynthesis in response to changing environmental conditions (10)

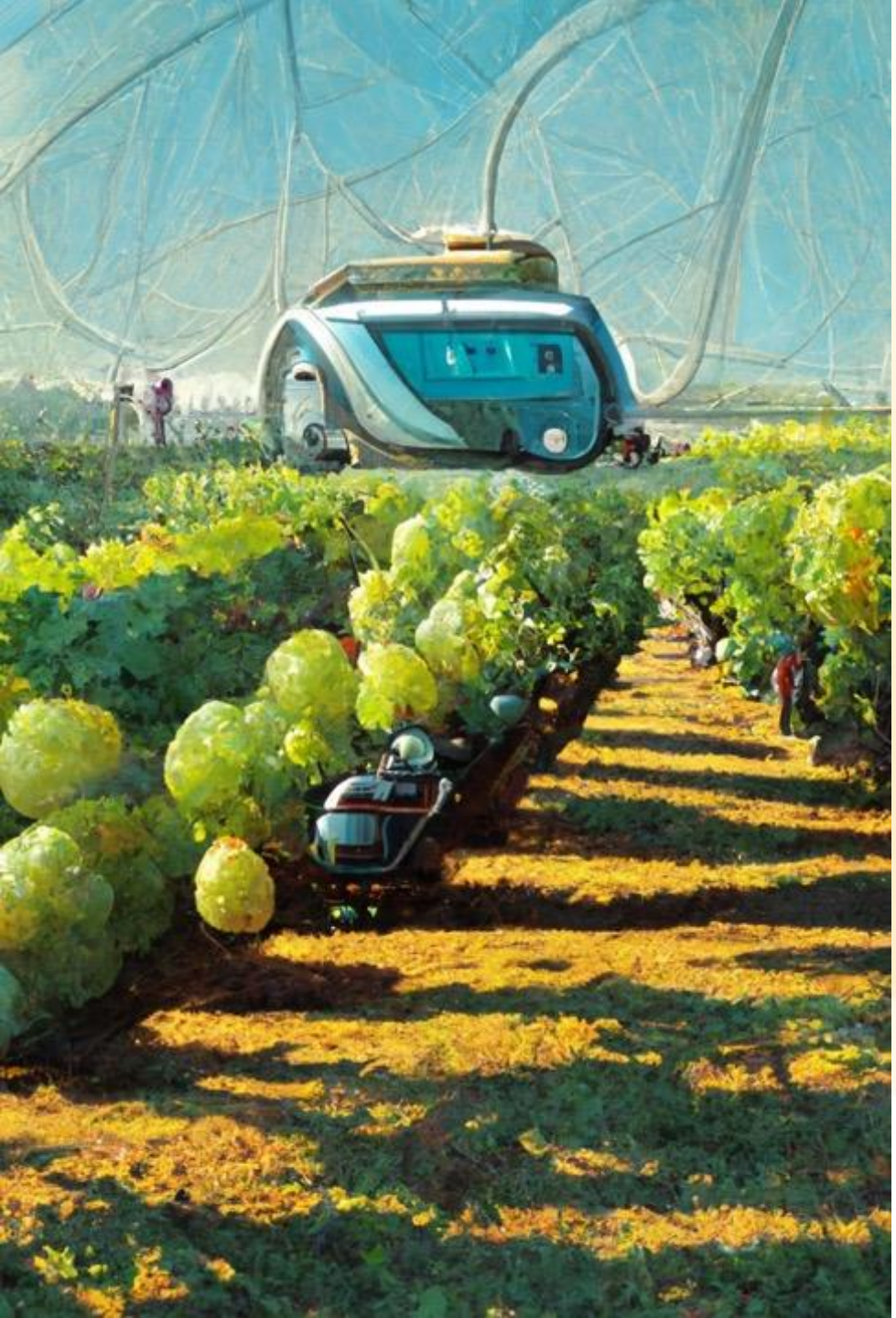
Combined stressors may be thought of as a third-type of stress beyond biotic and abiotic (14)

Other Promising Research

Biostimulants [24]

- Formulations of natural substances and/or microorganisms used to improve vine health and efficiency or tolerance from abiotic or biotic stressors.
- Currently show promise as a buffer against stress damage in grapevines
- But much more research is needed
    i. What mechanisms does each biostimulant act on to induce the observed results?
    ii. What are safe levels of application?
    iii. What phenological stage should they be applied at?
    iv. How and how often should they be applied?

24. Eliana Monteiro, Berta Gonçalves, Isabel Cortez, and Isaura Castro. The role of biostimulants as alleviators of biotic and abiotic stresses in grapevine: A review. Plants, 11(3), 2022. ISSN 2223-7747. doi: 10.3390/plants11030396.



Summary

1. Abiotic Stressors ~ Pest and Disease Impacts

2. The impact on both host and pathogen must be accounted for when designing any IPM strategy for changing climates

3. Existing solutions are in development to address larger functional ranges for pests and diseases

4. Research is still needed in most cases for grapevine responses to combined stressors and potential methods of stress alleviation

Downloadable Presentation

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

- Accompanying article published in Wine Business Monthly Online

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

Thanks for Listening

Contact me: codchen@ucanr.edu

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