Drought Tolerant Rootstocks for a Changing Climate

Christopher Chen
Ph.D. Horticulture and Agronomy
Specialization: Viticulture
University of California Davis

Extreme Heat - Trends

Extreme Heat

Extreme temperatures

↓

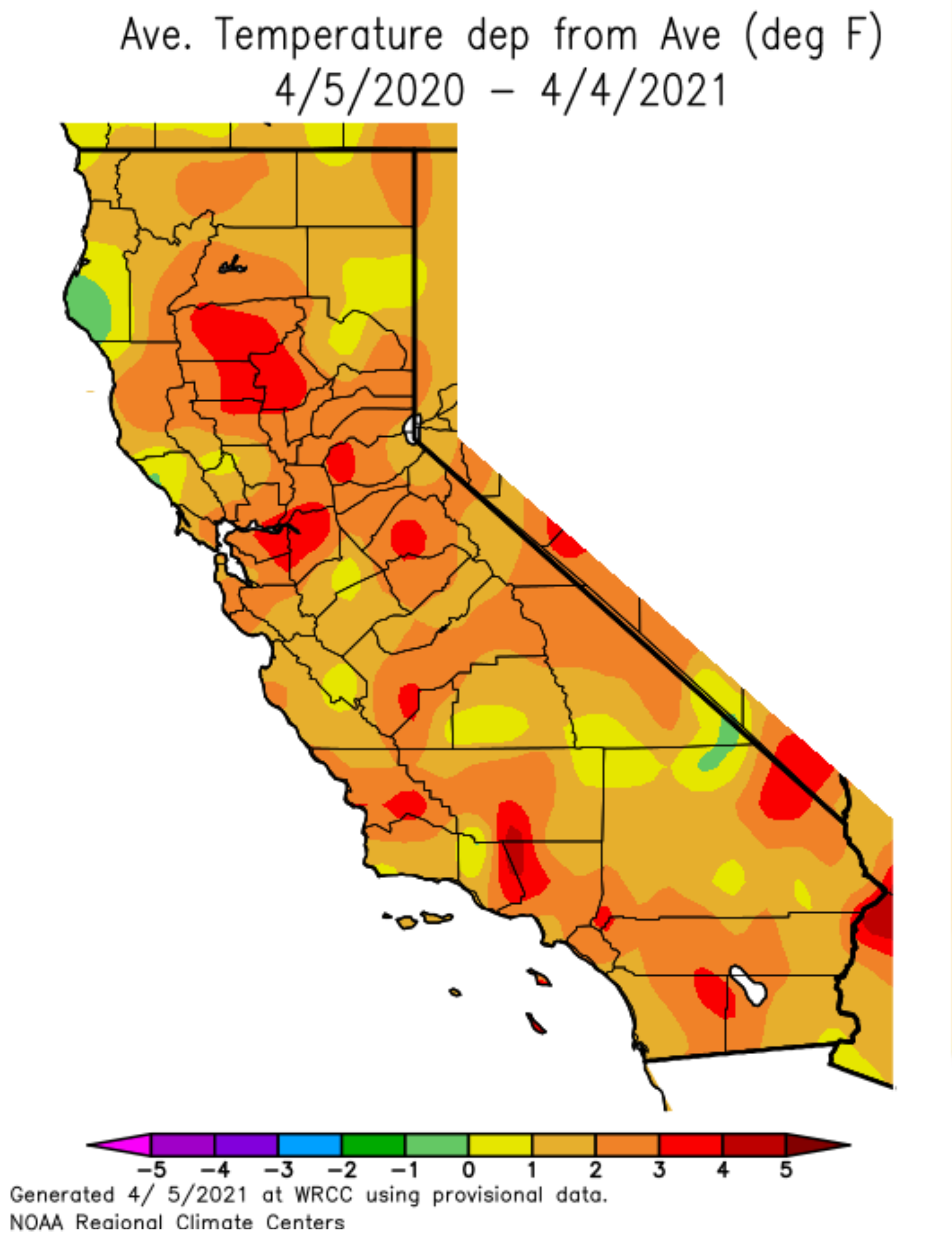
High evapotranspiration

↓

Greater water demand

↓

Damaged fruit



Credit: California Climate Data Archive (2021)

Drought - Trends

Drought

Declining precipitation

↓

Reservoirs not replenished

↓

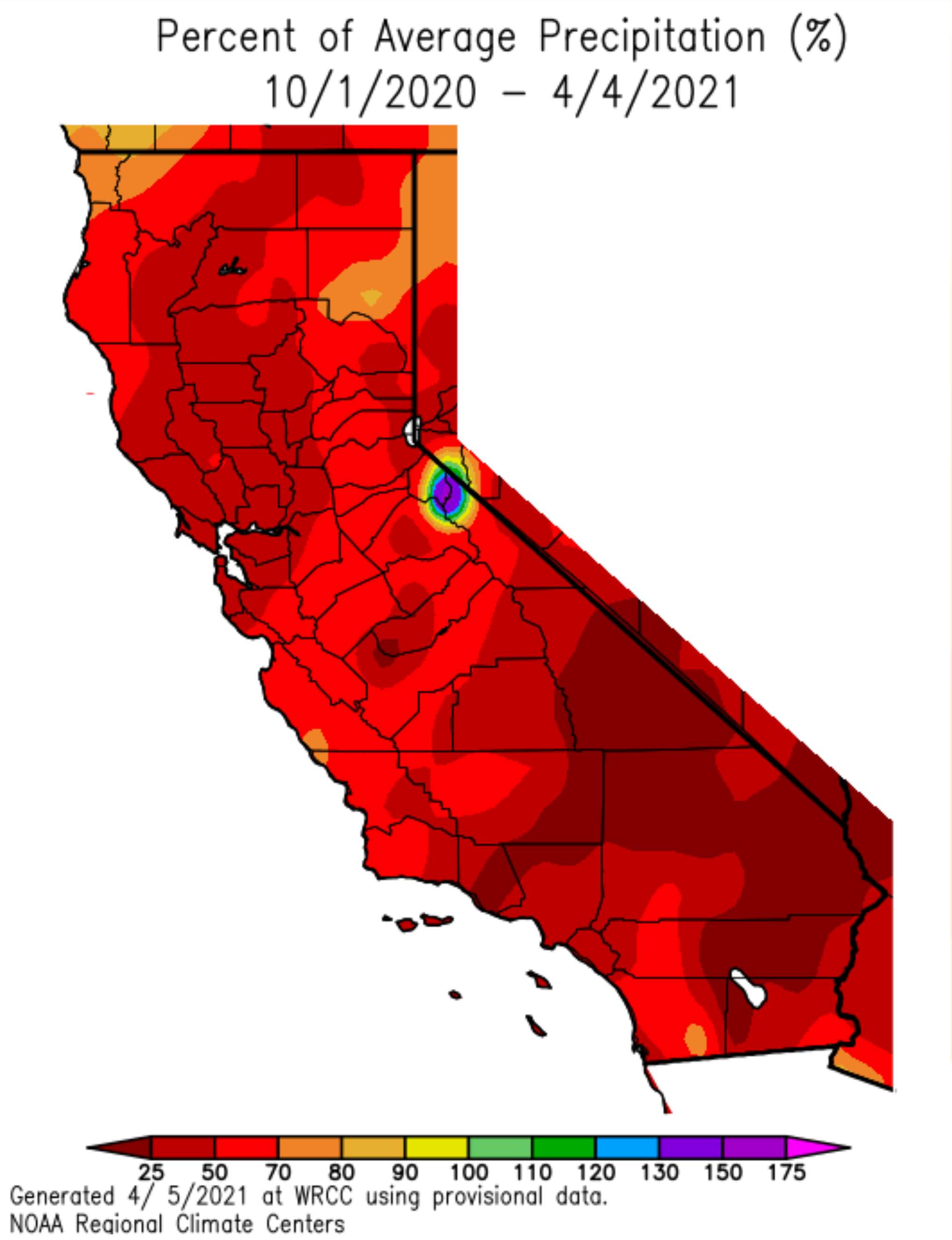
Water scarcity for agriculture

↓

Long term damage to grapevines

↓

Decreases in yield



Credit: California Climate Data Archive (2021)[3]

Increasing Temperatures

Increasing Temperatures

Temperatures rising

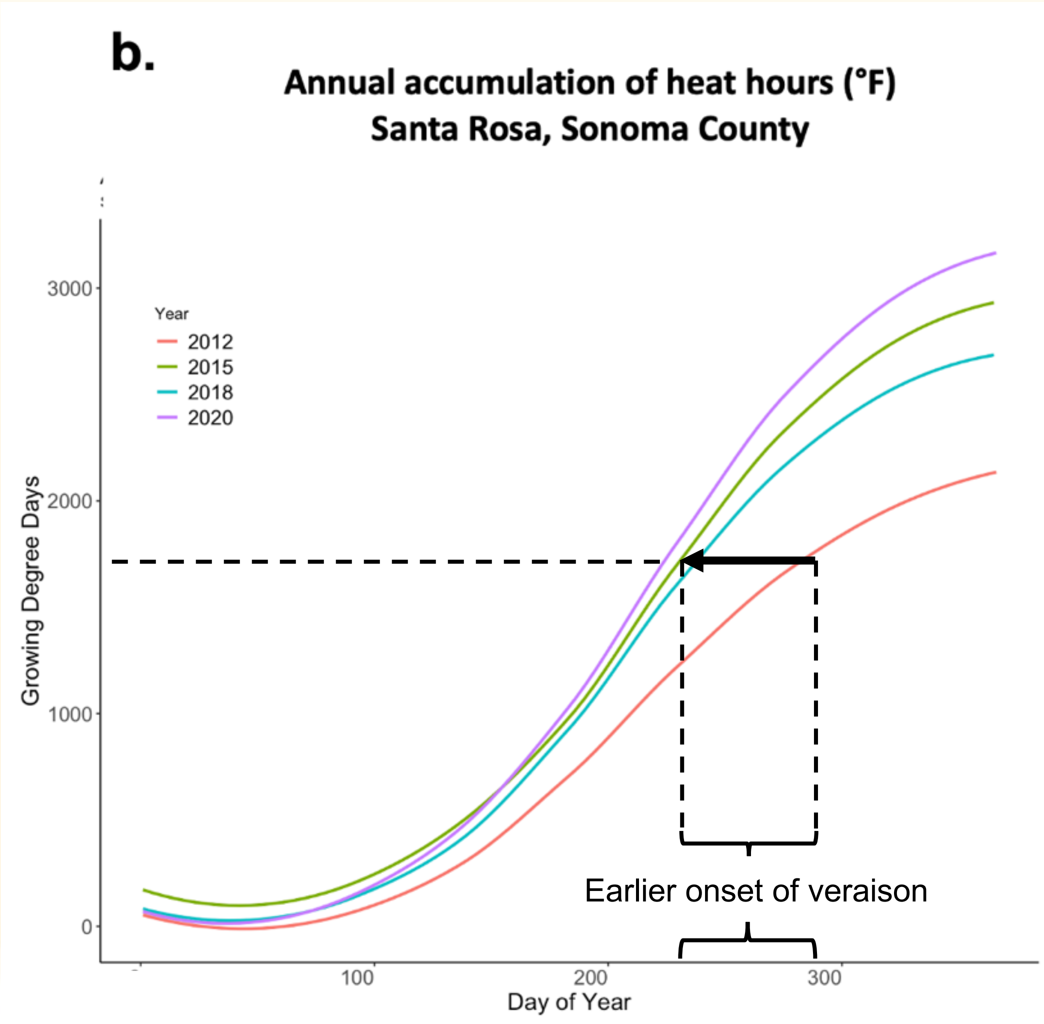
Total GDD increasing

Heat hours accumulating earlier in the year

Changing phenological timing for grapes

Options

- Shade netting
- Row orientation
- Canopy management
- Irrigation scheduling



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

Increasing Temperatures

Shade netting

Artificial shading

- **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.

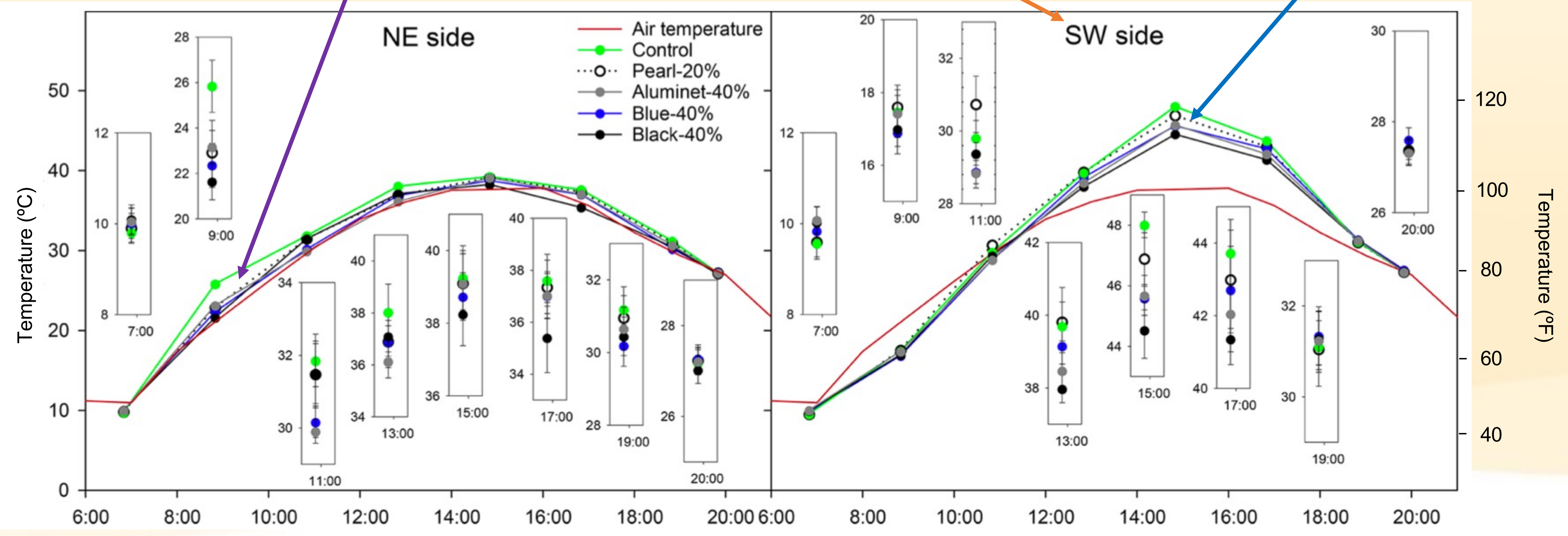
Increasing Temperatures

Shade netting

Very effective when either side is in direct sunlight

Impact last longer on the more exposed side of the canopy

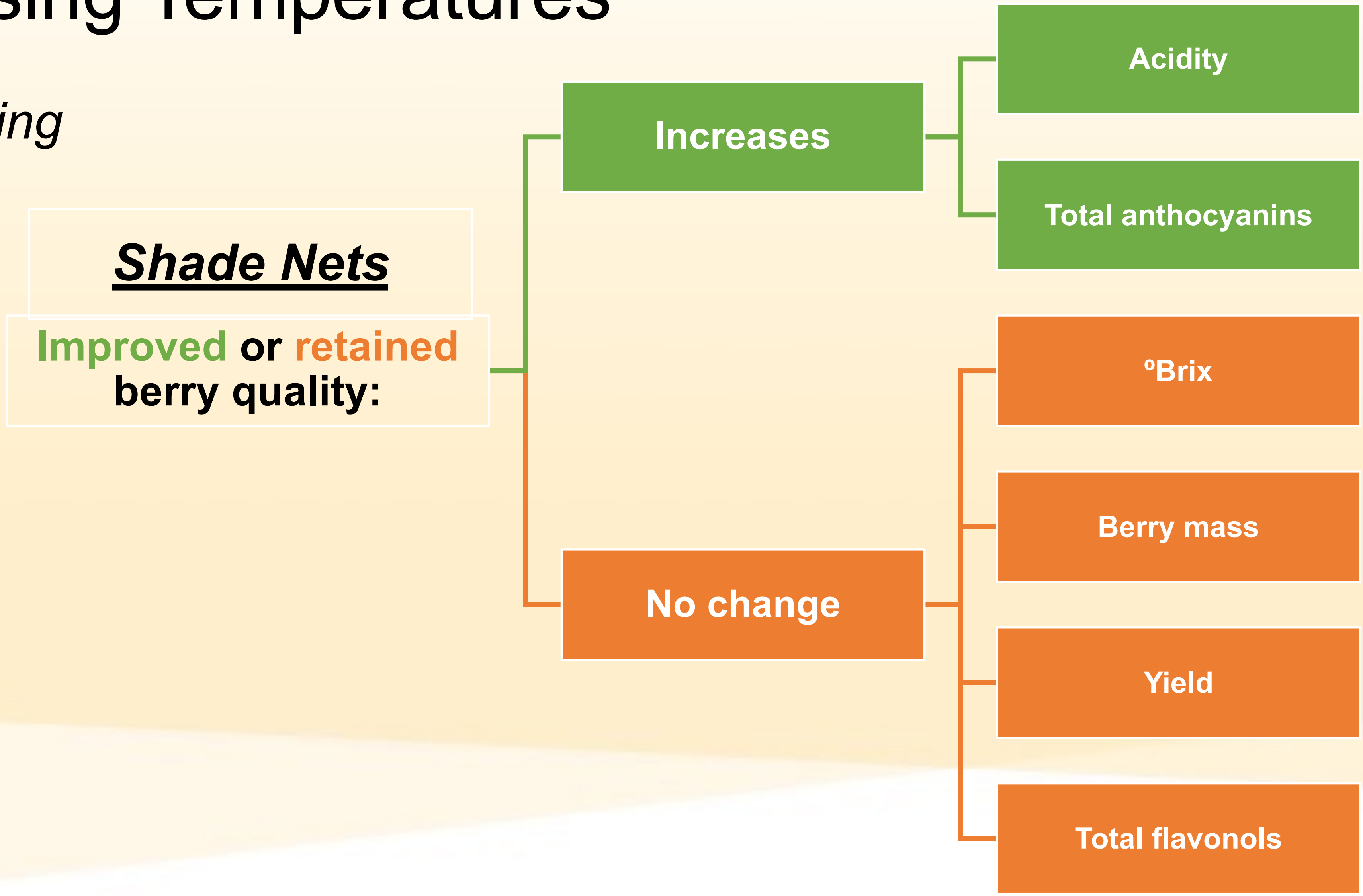
Can be up to **5 ºF cooler** under the canopy [2]



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

Shade netting



Increasing Temperatures

No shade netting

Shade netting

a

b

c

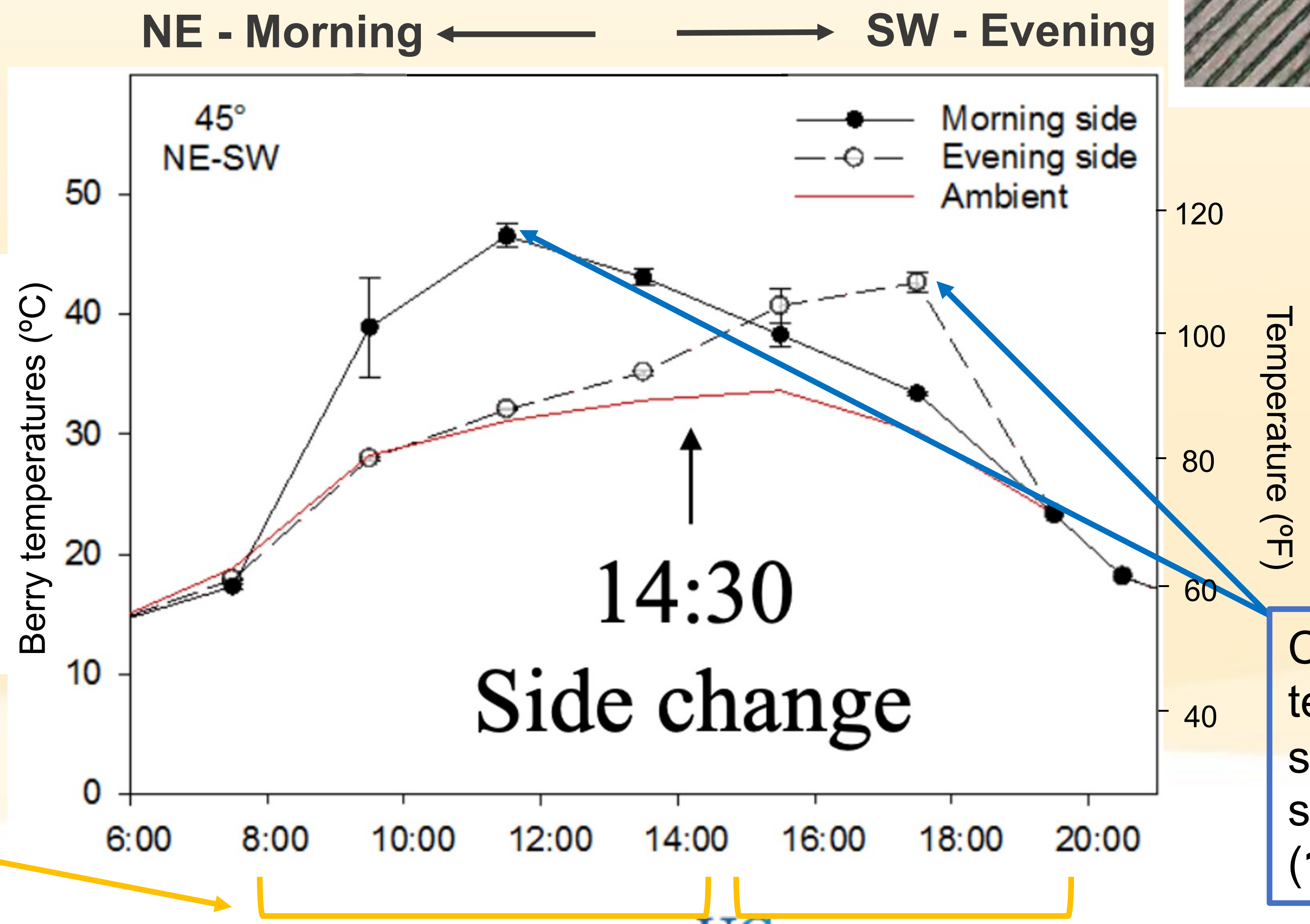
Left to Right: (a) no shade net applied; (b) example of black shade net applied following fruit set; (c) resulting cluster protected by shade net; all images were taken on the same day in Oakville, CA in August 2017.

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



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)

UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources Cooperative Extension

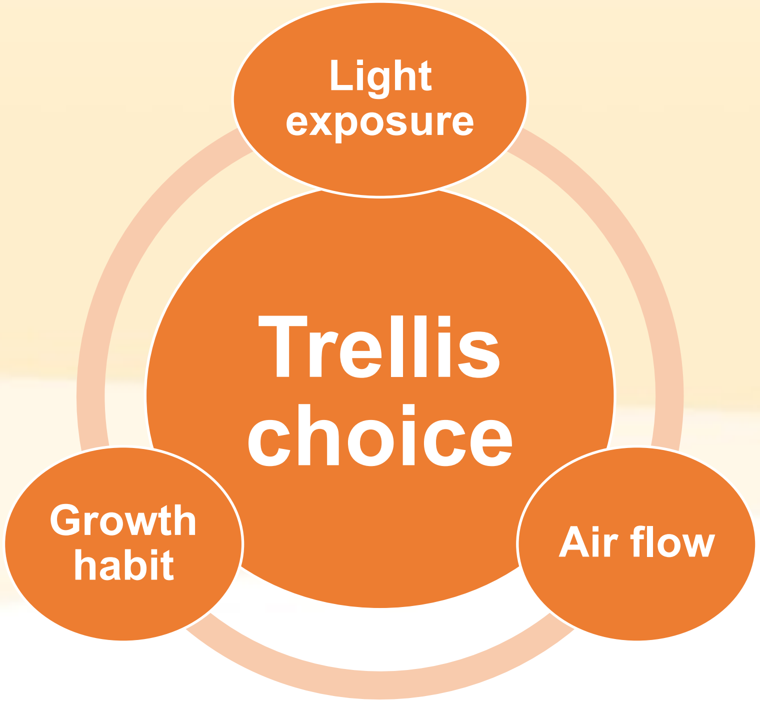
Increasing Temperatures

Canopy management and Trellis type

Trellis type:

Greatly influences incidence of exposed fruit

(e.g., VSP vs. CA Sprawl)



Vertical shoot positioned

CA sprawl

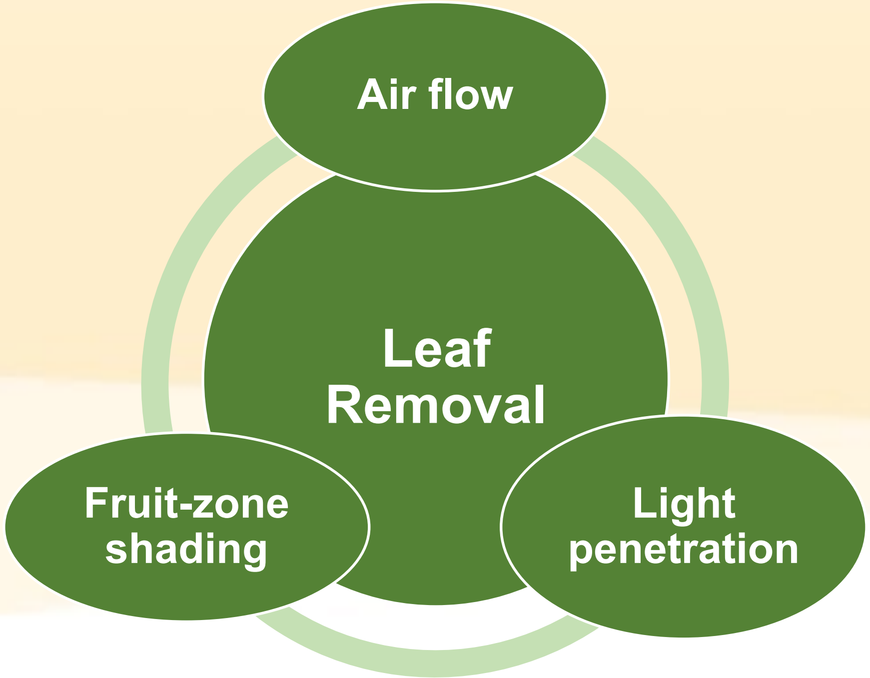
UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources Cooperative Extension

Increasing Temperatures

Canopy management and Trellis type

Leaf removal:

Can achieve similar results as shade nets with additional benefits

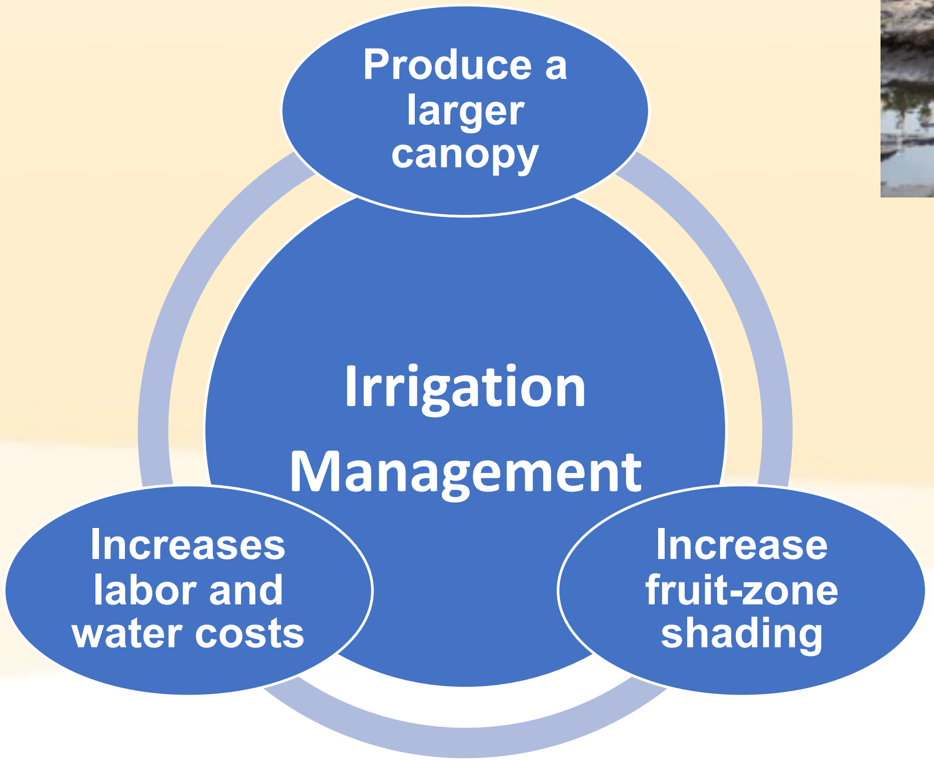


Excessive leaf removal; Oakville, CA - 2017
(*photo courtesy of Dr. Runze Yu, Asst. Prof CSU Fresno*)

Increasing Temperatures

Irrigation scheduling

Developing a canopy

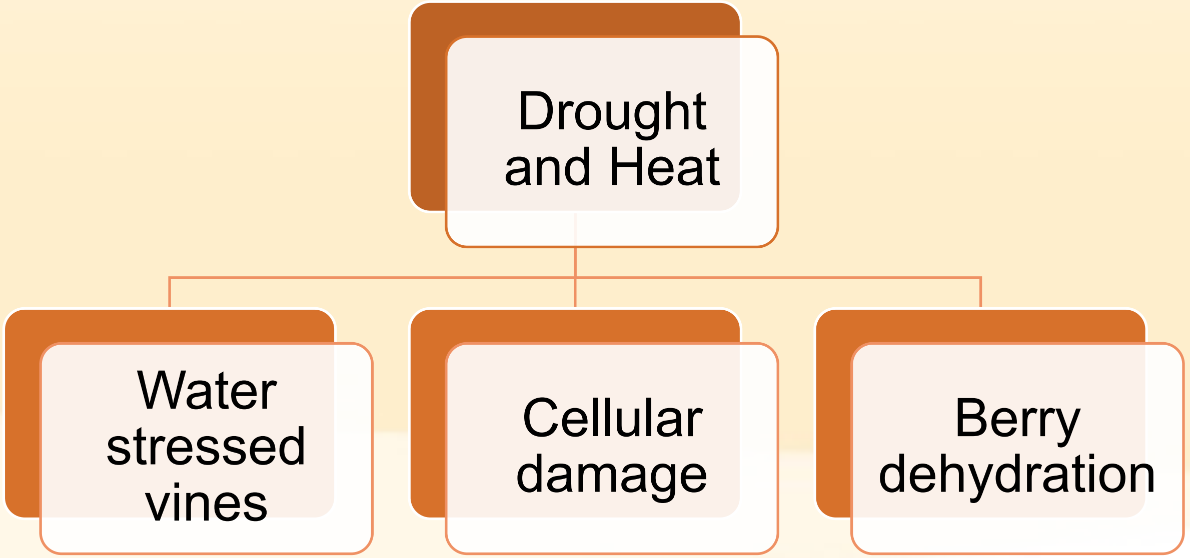


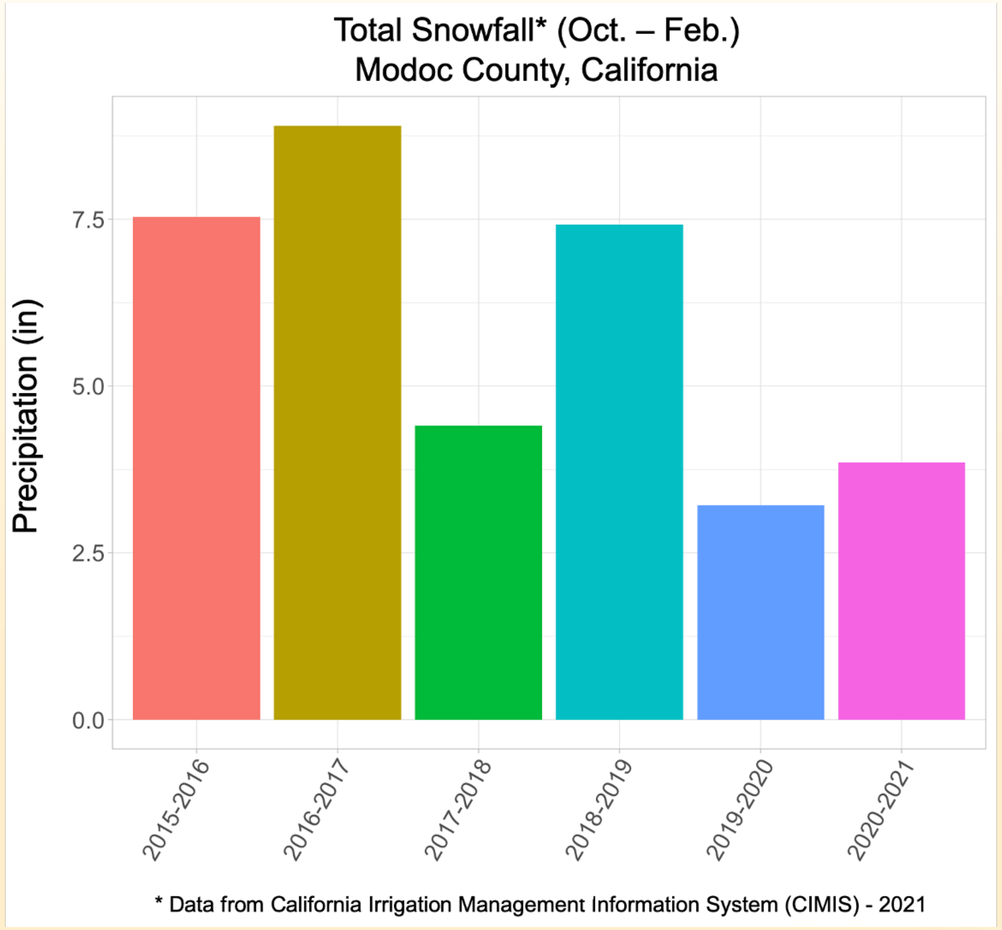
UC CE UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources Cooperative Extension

Drought

Drought

Hard to separate effects of drought from heat.





Percentage of total precipitation in Modoc County, California over six years from October to February each year since 2015. (Data from https://cimis.water.ca.gov)

Drought

Kaolin – Clay particle film

Improves vine **WUE** by **+26%** in water-stressed vines [3]

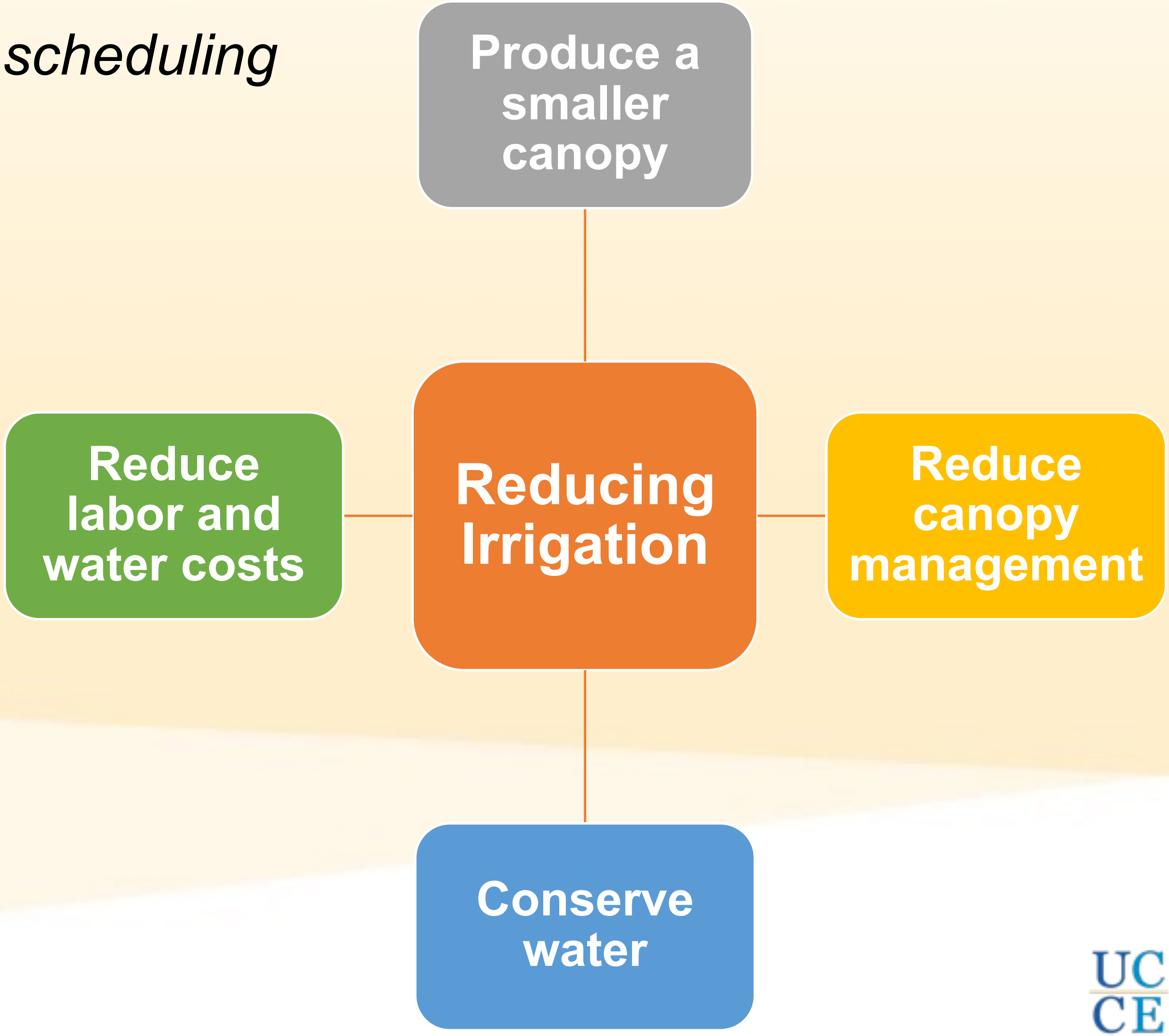
Can improve final wine ratings

No negative effects on berry quality

Kaolin particle film applied to Cabernet Sauvignon clusters pre-veraison; Oakville, CA 2016

Drought

Irrigation scheduling



Drought

Drought tolerant rootstocks

Desired characteristics:

- Vigorous
- Deep rooting
- Good root development

Examples:

- 140 Ruggeri
- Ramsey (Salt Creek)
- St. George

140 Ru

101-14 mgt

140 Ru – deep rooted

101-14 mgt – shallow rooted

Drought - summarized

Best practices

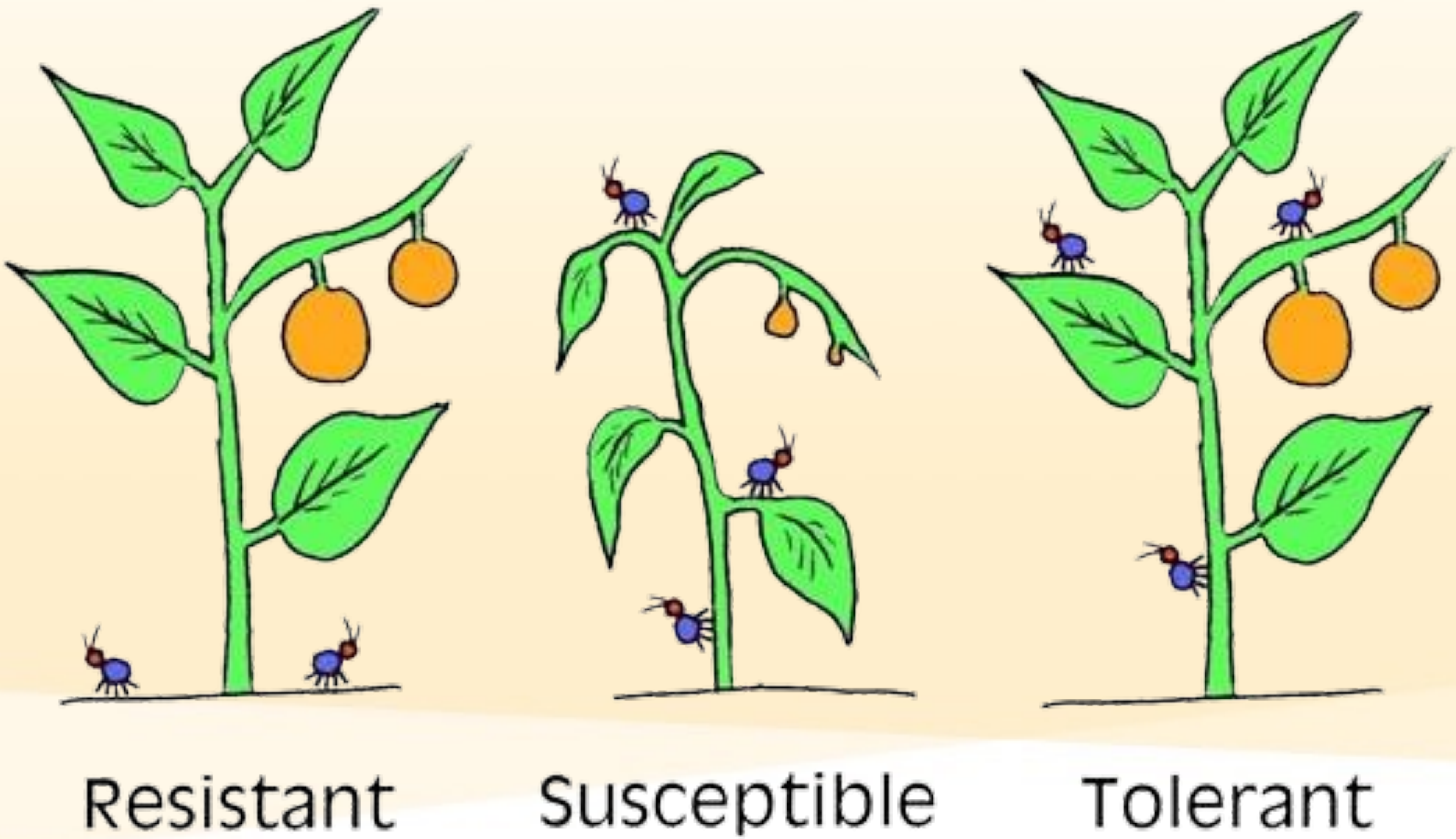
- Kaolin applications:
  i. Leaf and clusters
- Improved irrigation scheduling
- Selecting drought tolerant rootstocks

Drought Tolerant Rootstocks

Drought **Tolerance** vs. Resistance

Resistance – implies that the stressor has little/no impact on the vine

Tolerance – the vine has the ability to reduce the impact of drought



Resistant
Susceptible
Tolerant

Plant Strategies for Drought

1. Grow slowly
   - Desert plants (cacti) grow very little over centuries
   - Uses less resources when fewer resources are available or unreliably available

UCCE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

Plant Strategies for Drought

1. Grow slowly

2. Root architecture
    - Shallow roots take up water faster
    - Tap roots seek deep groundwater
    - Depends on the frequency and volume of precipitation

140 Ru

140 Ru – deep rooted

101-14 mgt

101-14 mgt – shallow rooted

Desert Plants and Redwoods

Shallow roots = quick uptake of water

Can be either drought tolerant or resistant

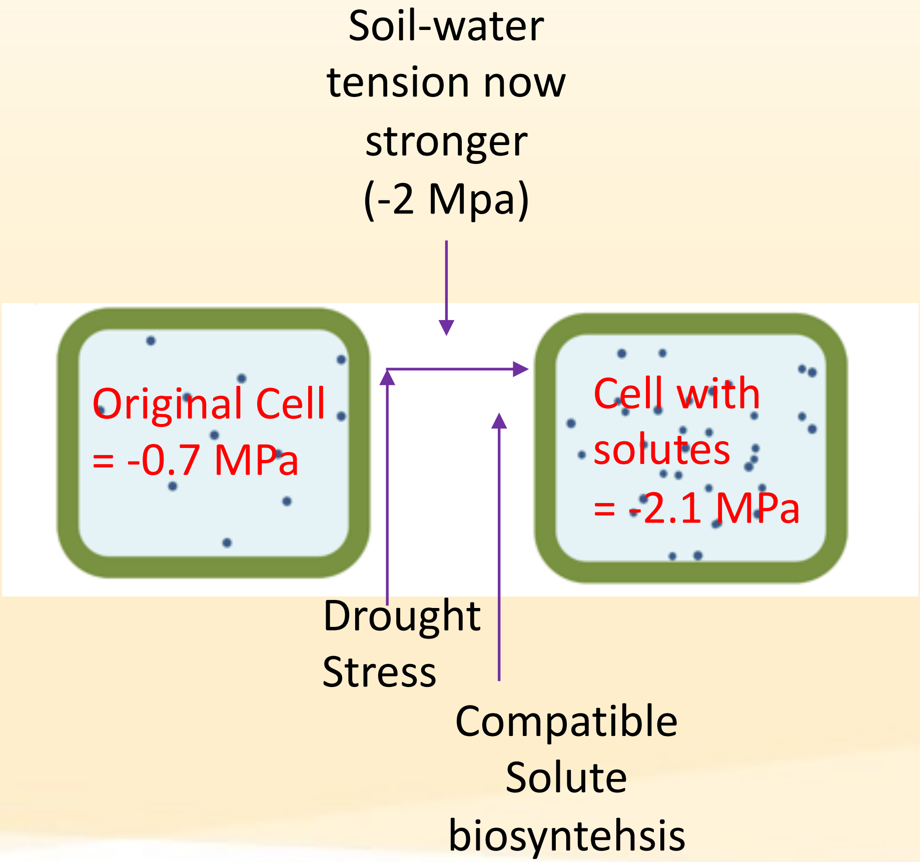
UC CE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

Plant Strategies for Drought

1. Grow slowly
2. Root architecture
3. Leaf structure
   - Leaf surface area impacts water loss by transpiration
   - Narrow or small leaves decreases the boundary layer
   - Thicker leaves have more chlorophyll per cm^2 surface area

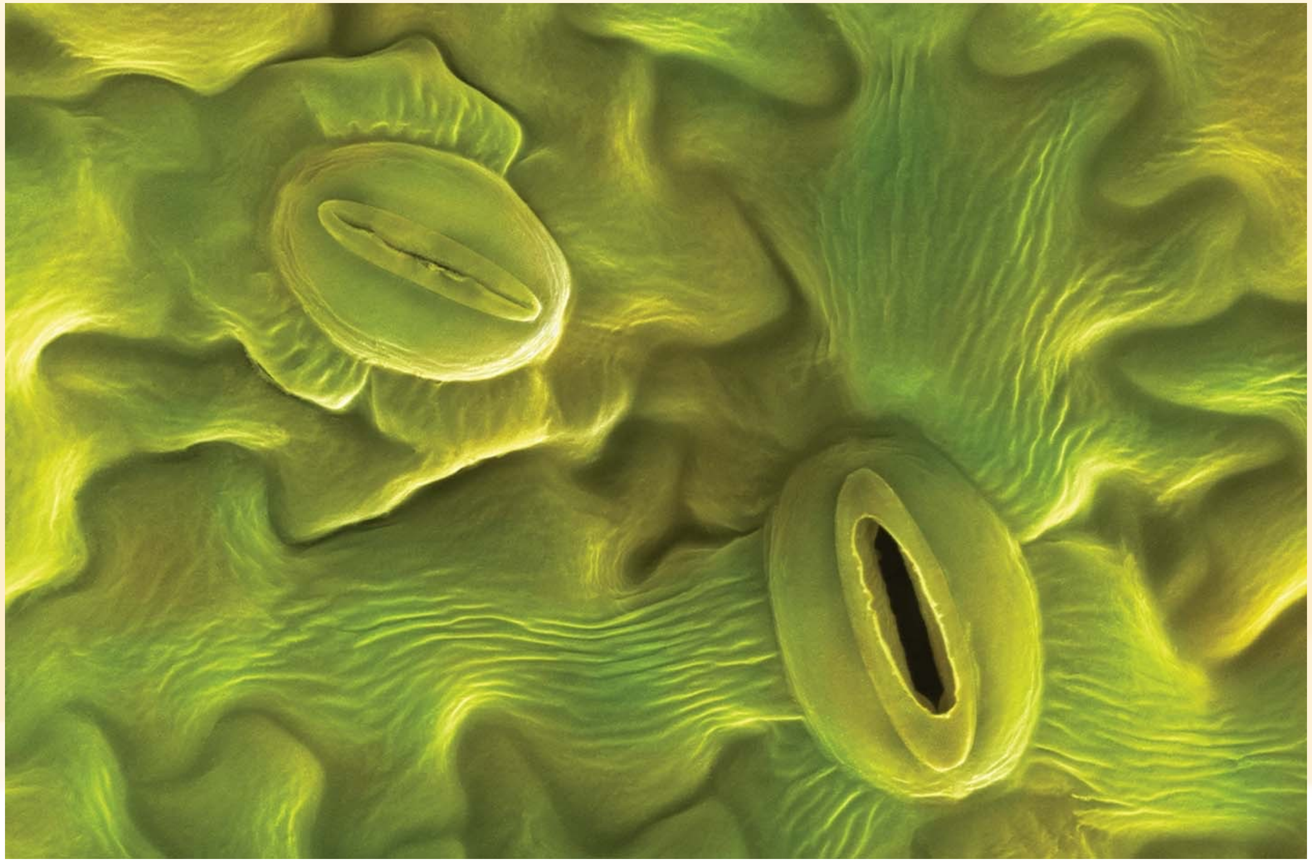
Plant Strategies for Drought

1. Grow slowly
2. Root architecture
3. Leaf structure
4. Osmotic adjustment
   - How quickly can the plant adapt to drought
   - Biosynthesizes compatible solutes to acclimate to more soil-water tension under drought



Plant Strategies for Drought

1. Grow slowly
2. Root architecture
3. Leaf structure
4. Osmotic adjustment
5. Stomatal regulation
   - Plant has more control of opening or closing stomata based on external conditions



Plant Strategies for Drought in Vineyards

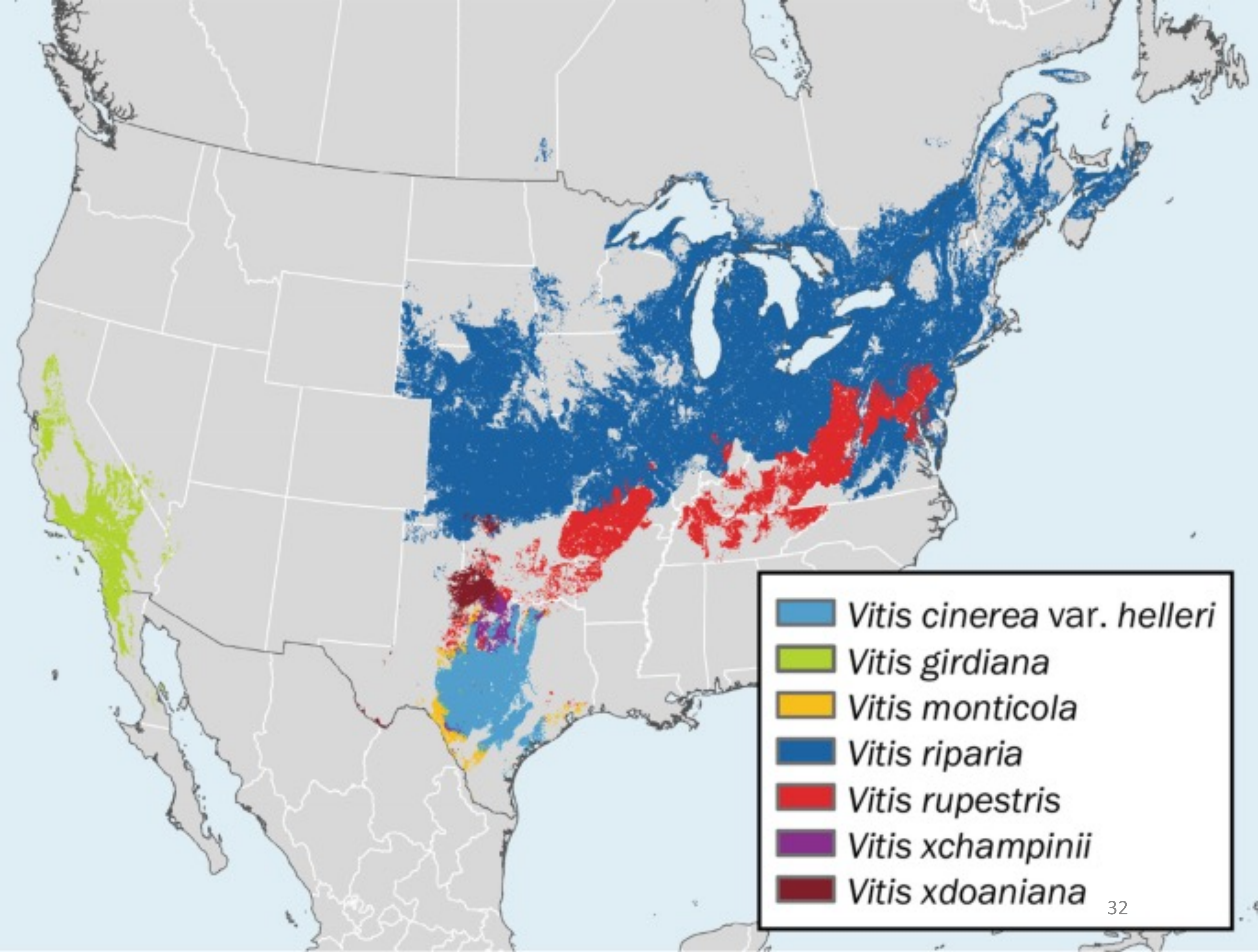
1. Grow slowly	=	MAYBE (both)
2. Root architecture	=	YES (rootstocks)
3. Leaf structure	=	MAYBE (scions)
4. Osmotic adjustment	=	YES (both)
5. Stomatal regulation	=	YES (scions)

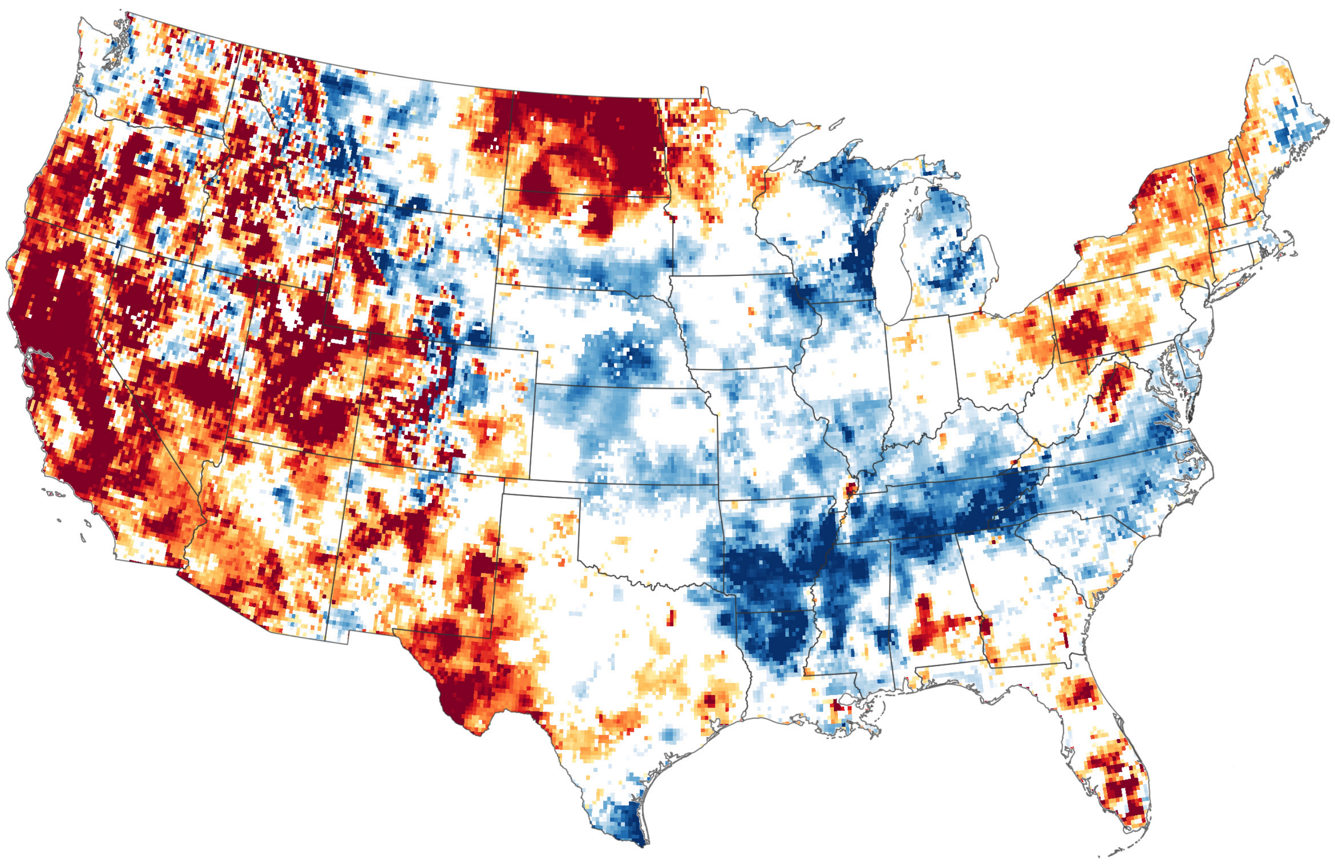
Traits to look for in rootstocks

1. Root Architecture
   - Deep roots for regions with ample groundwater
   - Shallow roots for regions with sudden and high-volume precipitation
2. Osmotic Adjustment

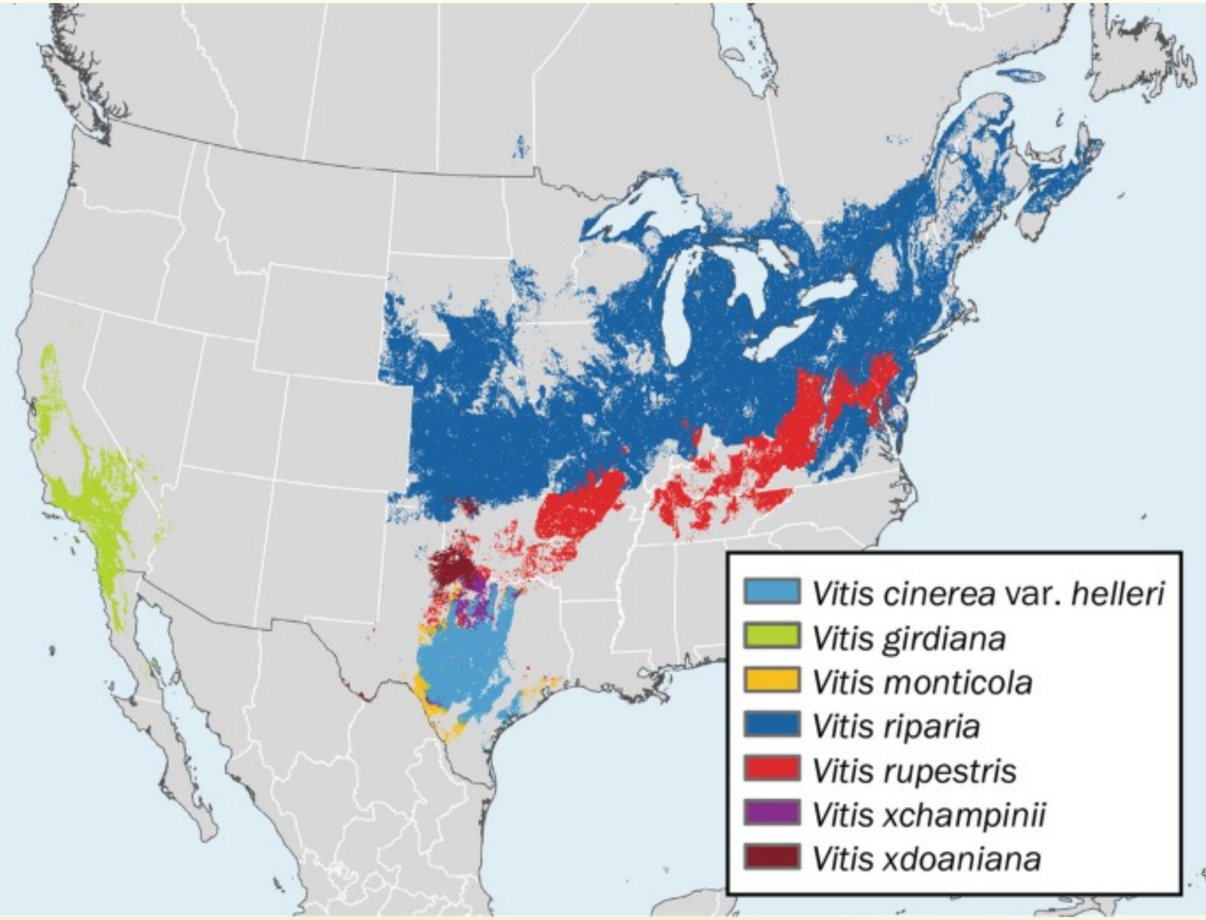
Trait sourcing

Wild vines

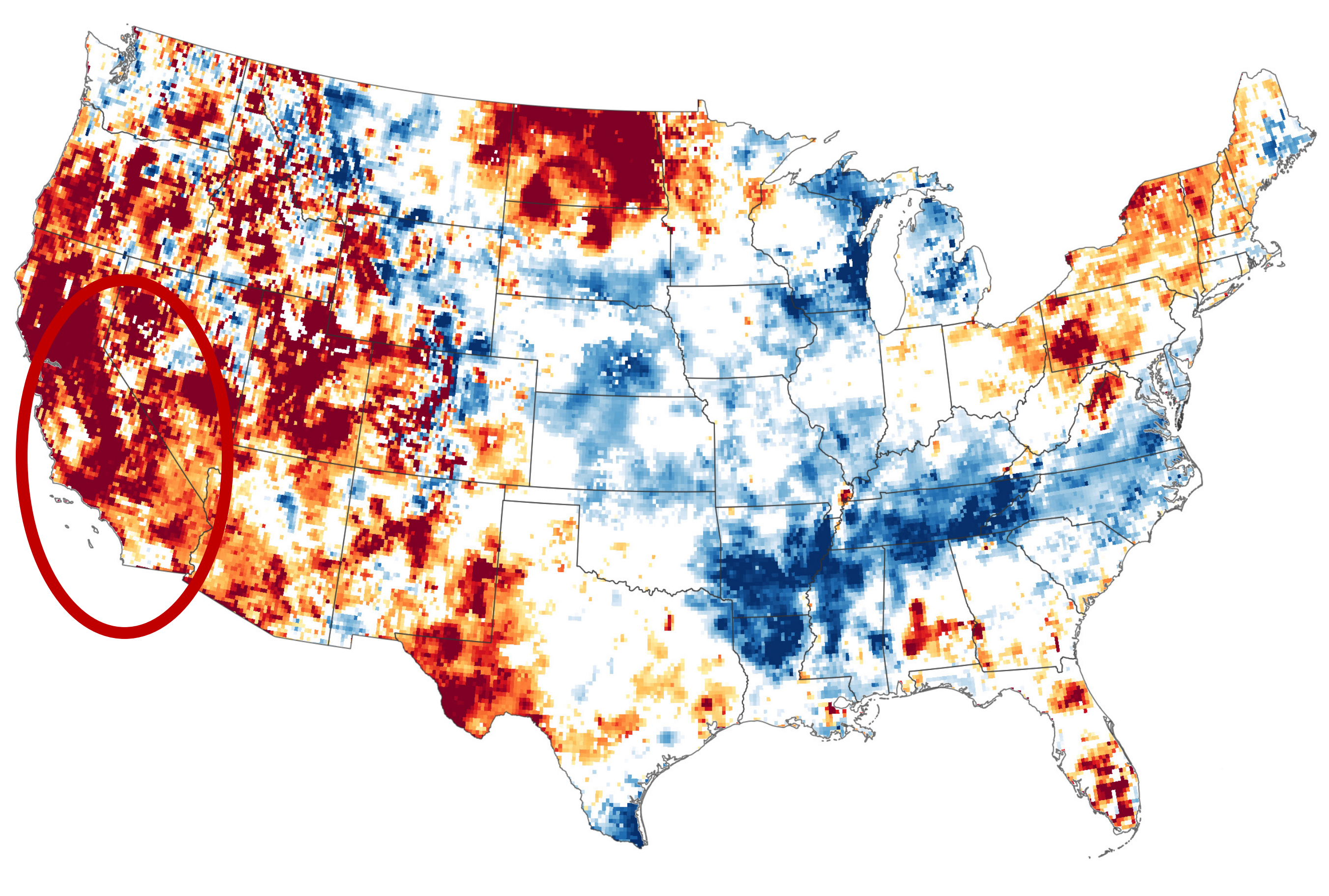




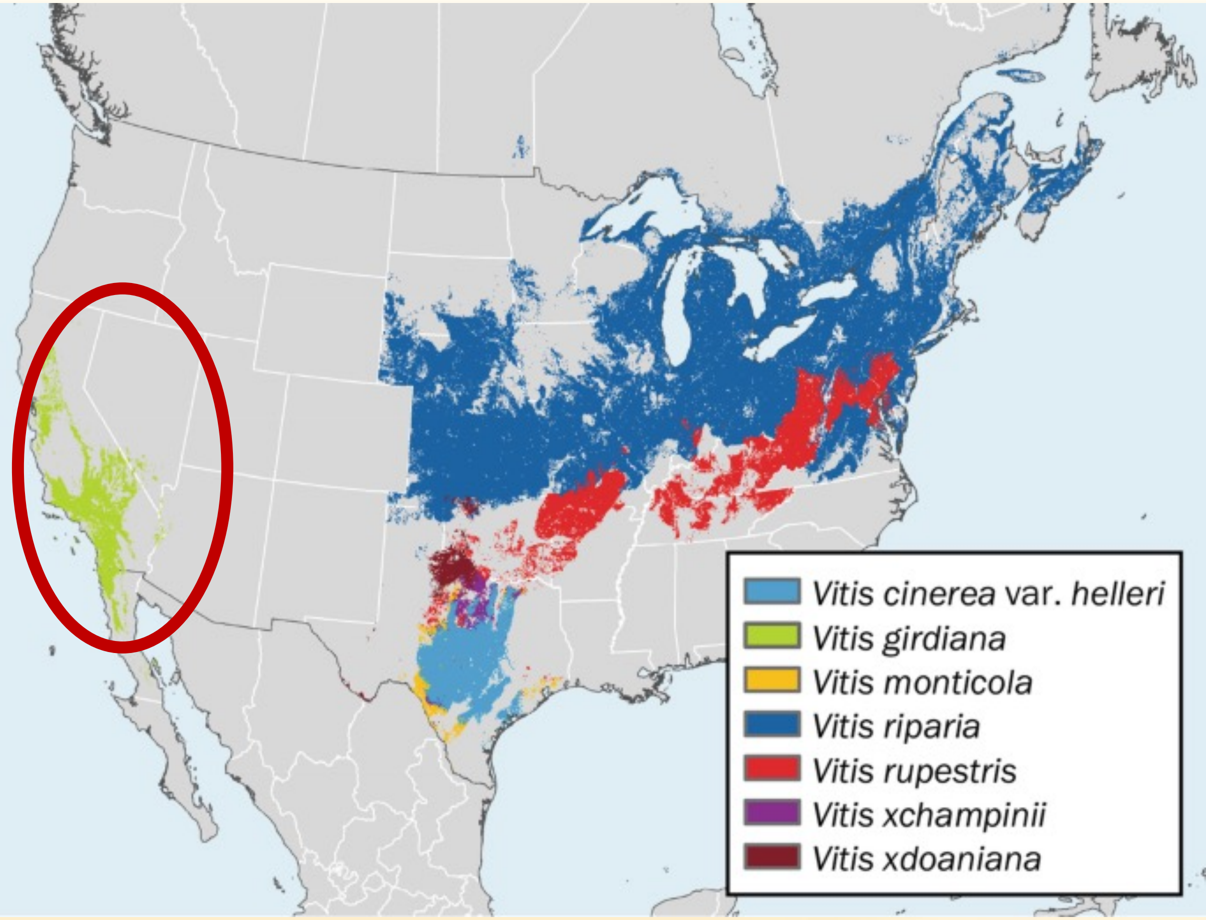
Drought conditions – 2021 (NASA)



Heinitz et al. 2019



Drought conditions – 2021 (NASA)



Heinitz et al. 2019

Existing rootstocks which have drought tolerant traits

- Have deeper tap roots
- Often also have fibrous, shallow roots
- Can devigorate the scion
- Examples
  1. 110 Richter
  2. 1103 Paulson
  3. Ramsey/Salt Creek
  4. 420A

110 Richter

- Has both deep and shallow roots
- Somewhat devigorating for scion
- Small canopy = Lower water demand
- Adaptable to many water availability situations
- Second most deeply rooted cultivar
- Second fastest recovery for stomatal conductance

1103 Paulson

- Has both deep and shallow roots
- Not as devigorating as 110R
- 'Universal' rootstock
- Adaptable to many water availability situations

Ramsey/Salt Creek

- Partially wild N. American species background
  - *V. Champinii*
- Conserves resources under drought
  - 101-14 (drought susceptible) creates new roots when drought is imposed
  - Ramsey does not and recovers quickly when water is reintroduced
- Has more deep roots than most rootstocks
- Has fastest recovery for stomatal conductance

UCCE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

420A

- Devigorates scions
- Less vigor = less resource demand
- Promotes a smaller canopy
- Inherently less water use

Rootstocks with poor drought tolerance

- 101-14 Mgt
- 039-16
- 3309C
- 5C
- SO4
- Riparia ‘Gloire’

Most of these are either very shallow-rooted or increase scion vigor resulting in higher water demand via transpiration.

Developing a Drought Tolerant Rootstock

How Plant Breeding Works

1. Select the cropping system
2. Identify a desirable trait
   - Often using Marker-assistance
3. Find examples of that trait in a compatible species
   - Resulting in fertile offspring
4. Cross pollinate the current crop with the species containing the desired trait
5. Continue cross pollination until final generation has the **desired trait** and **retains agronomic traits** of the original parent

Genetic Material Available

- Walker and Olmo collections at UC Davis
- Wild species

Time to a new rootstock

1. Material collection	≈	1 – 40 years	Average ≈ 20 years
2. Identifying desired trait and associated genetic markers	≈	1 – 5 Years	
3. Cross-pollination and testing new offspring populations	≈	2 years	
4. Repeat for several generations	≈	10 – 20 years	
5. Certify with FPS and propagate	≈	5 years	
6. Distribute to Nurseries	≈	2 years	
7. Time to grower adoption	≈	?	

UCCE | UNIVERSITY OF CALIFORNIA Agriculture and Natural Resources | Cooperative Extension

Current Research in Drought-Tolerance

Bartlett lab –UC Davis

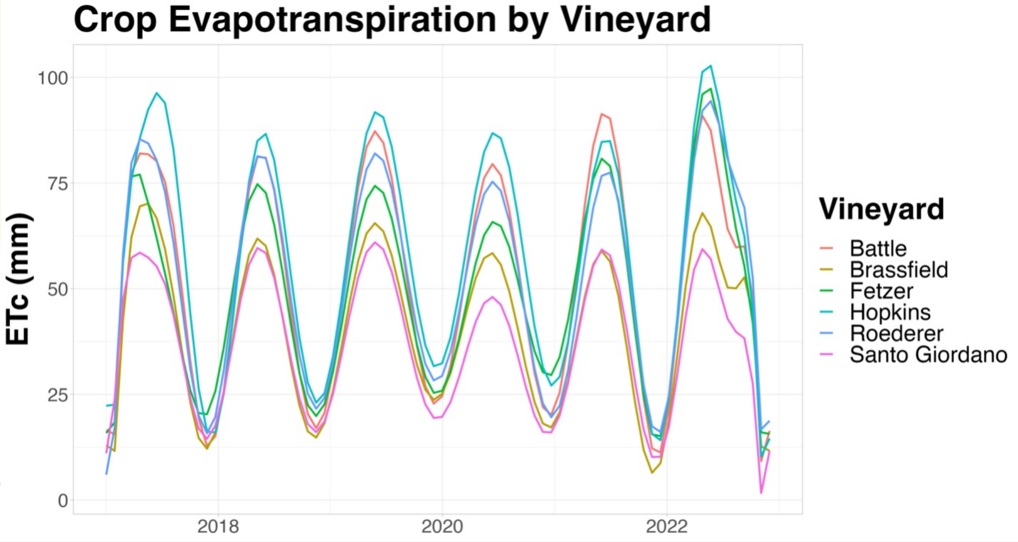
- Working to identify
  - Whole vine drought traits
  - Cellular mechanisms for drought tolerance
  - Rapid screening for drought tolerance
- Cell capacitance trait – how much they shrink and swell w/ water
- Impacts survivability of the root under drought
- New drought phenotype that she is now pursuing

Forrestell Lab – UC Davis

- Working on the whole-vineyard scale
- Looking for the best predictors of grapevine berry development using information on:
    1. Grapevine water status
    2. Irrigation inputs
    3. Soils
    4. Berry chemistry across the season
    5. Meteorological data
    6. Viticultural practice

Climate-Adaptive Rootstocks Study

- Identifying unique mesoclimates in California where grapes are grown
- Identifying the most common rootstock cultivars in California
- Analysis of their performance under drought
- Classification of each rootstock's drought tolerance in unique mesoclimates



Key Concepts

Heat and drought are **closely related problems**

Preemptive decisions are very beneficial

- i.e., Rootstock selection, early-season irrigation scheduling, row orientation

Existing rootstocks perform well and some better than others

- i.e., root architecture, devigoration of scions, quick recovery from drought damage

New research is identifying new drought-associated traits and drought-responses on the individual cell and whole-vineyard levels

- i.e., Canopy management, irrigation scheduling,

Thank You