Environmental Grapevine Physiology and Effects of Climate Change on Grapevine

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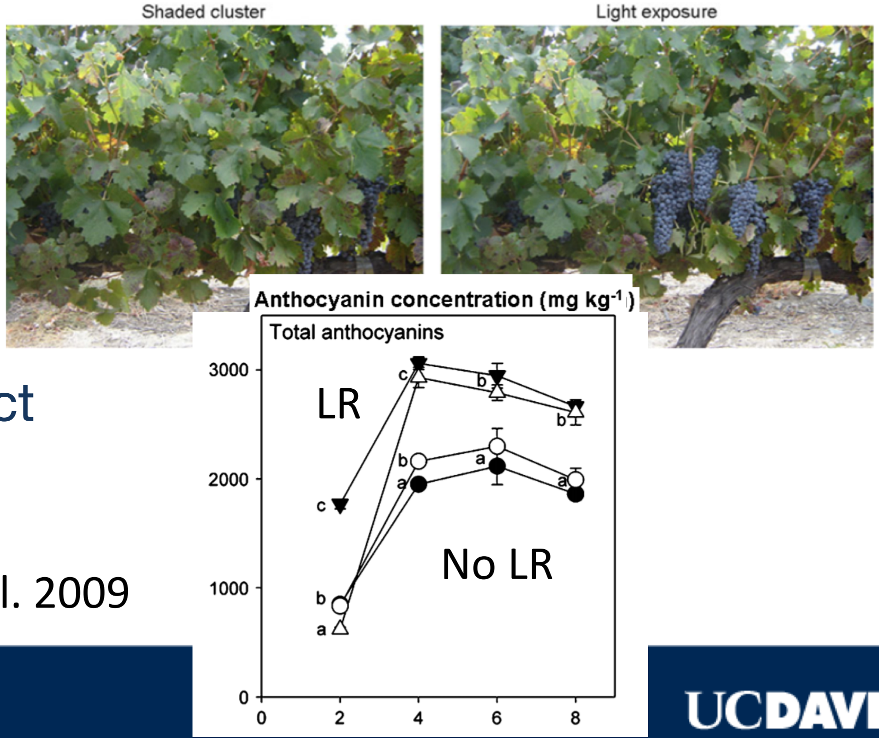
Introduction

- Grapevine needs a suite of canopy management practices
  - Dormant pruning
  - Green pruning
    - Shoot removal
    - Leaf removal
- Flavonoids and sun exposure
  - May have a beneficial effect



Matus et al. 2009

EXPOSED LEAF AREA

Carbon (CO_2) assimilation

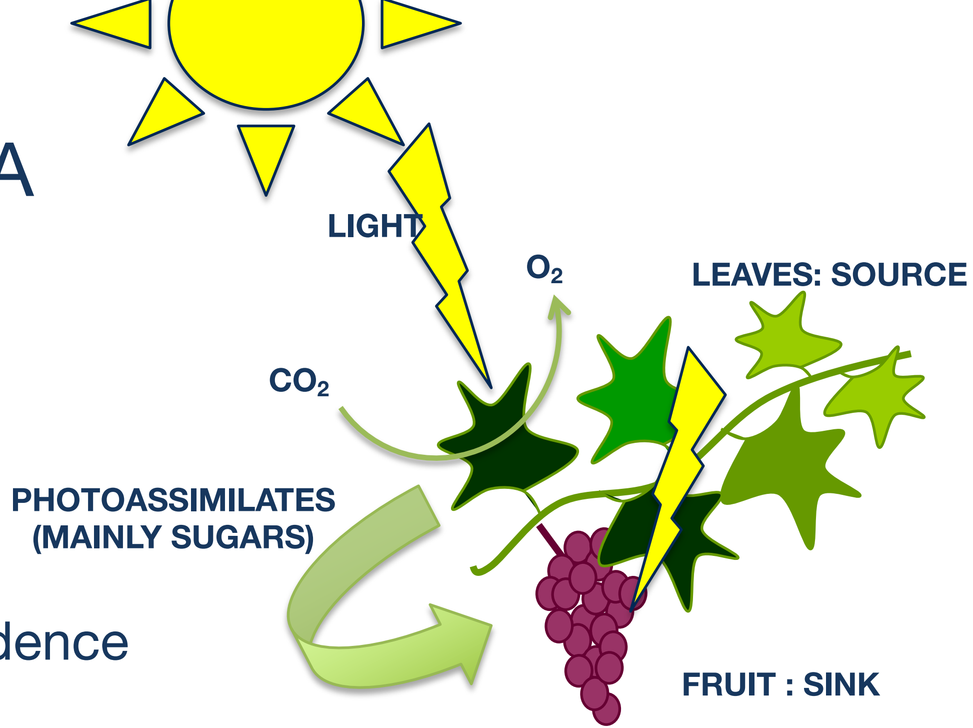
- Ripening
- Yield precursors

Canopy microclimate

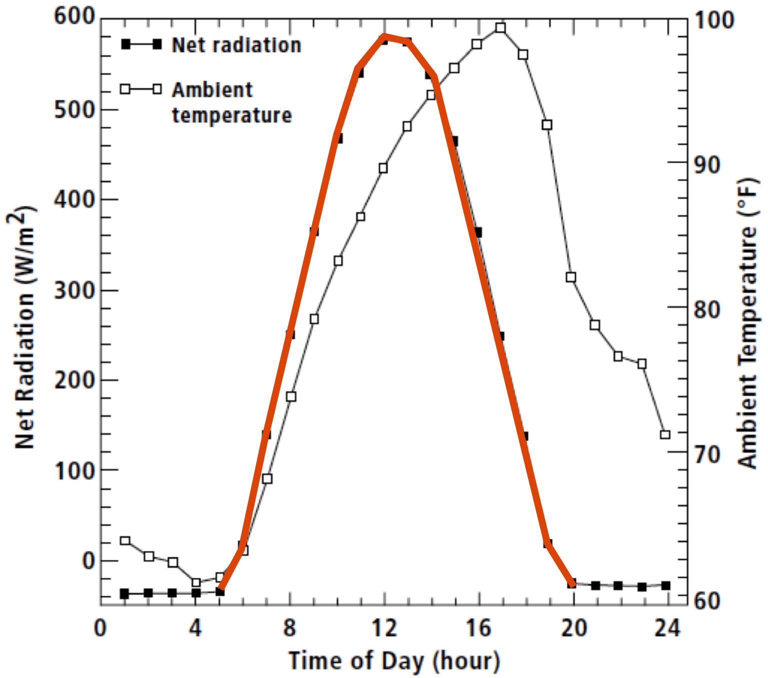
- Fruit composition
- Fungal infection incidence

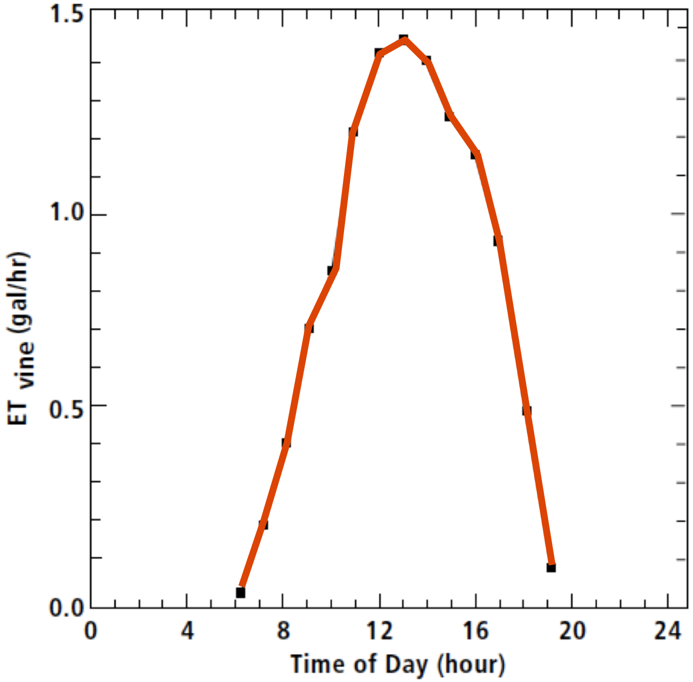
Irrigation requirements

- Leaf area
- Transpiration



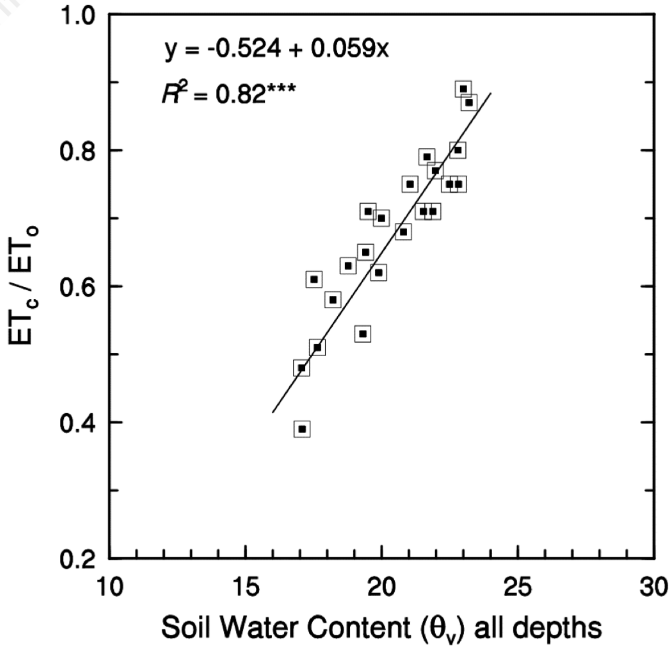
Solar radiation drives vine evapotranspiration

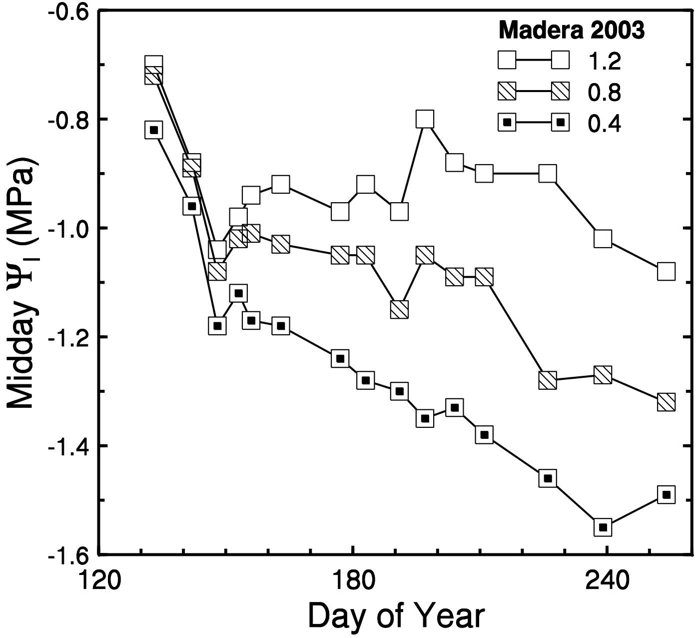




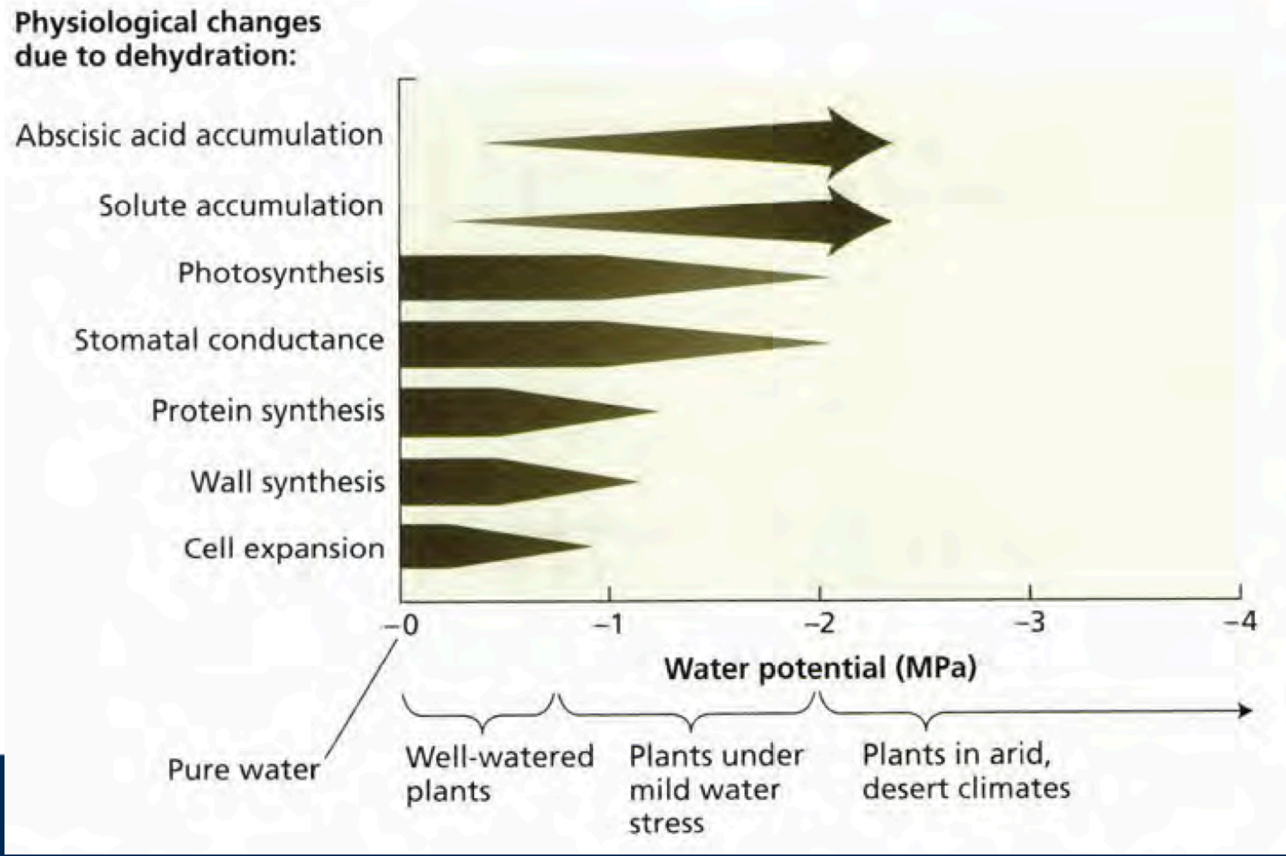
LEW (2000)

Water use declines with depletion



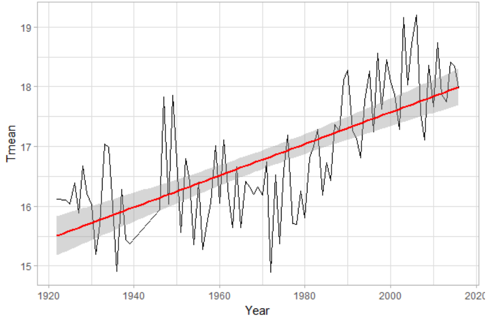


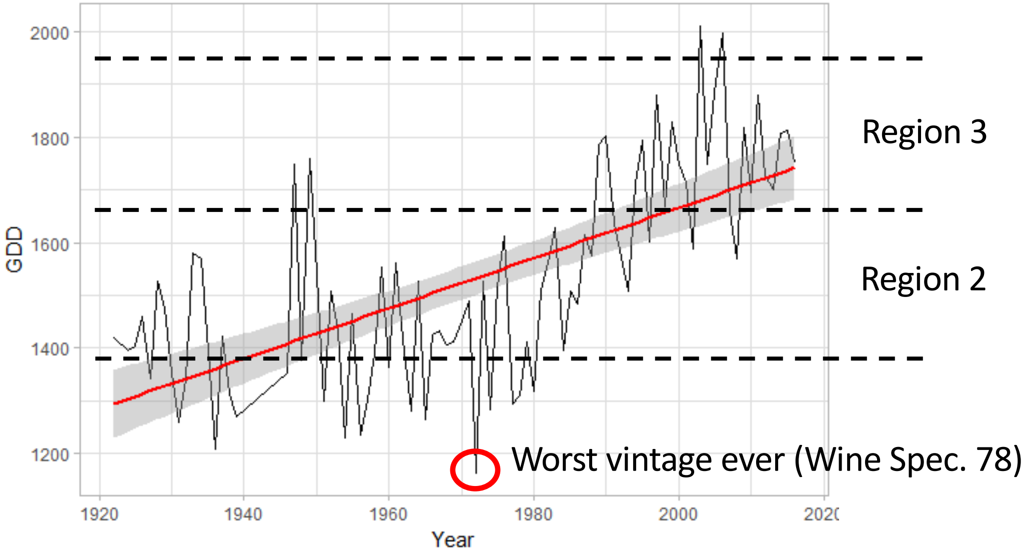
Water deficits affect grapevine physiology

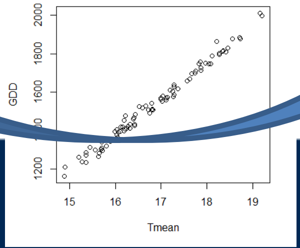


The planet is getting warmer …and so are Viticulture regions

Napa, CA Temperature







Growing degree days

1°C = 1.9°F

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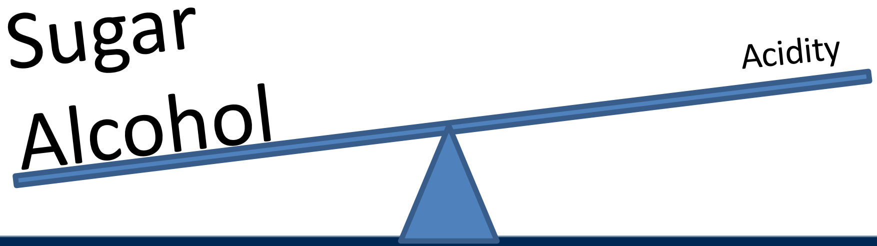
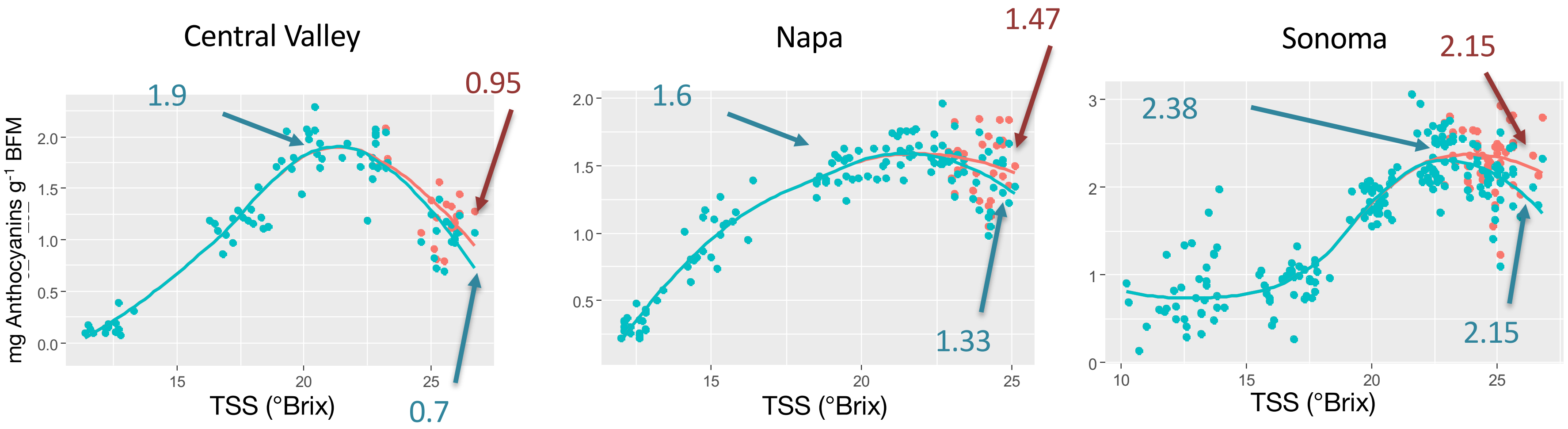
Heat…the more the better?

Polyphenols in danger

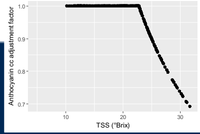


Anthocyanin loss during "hang time" in three plots



	Plot 1	Plot 2	Plot 3
Raw data	50%	8.1%	9.6%
Adjusted	63.1%	16.9%	24.4%

Martinez et al. 2018



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Wine Grape quality is an extremely complex topic:

- Subjective
- Gradually changing
- Hundreds of chemical compounds, hard to measure and hard to give a relative importance to each
- Aspects not related to grape quality determining wine price: Market niche and how much invested in winemaking

…Nobody likes sour grapes

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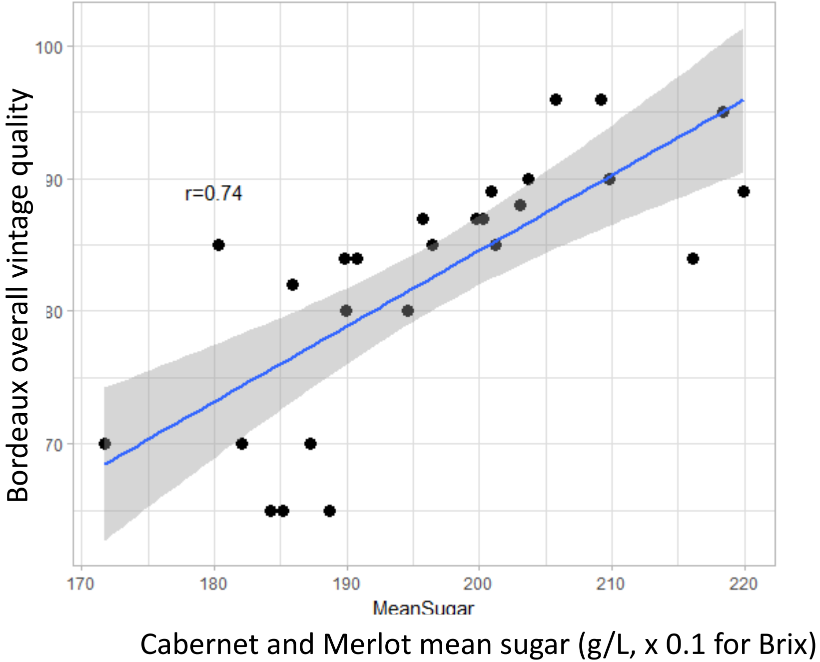
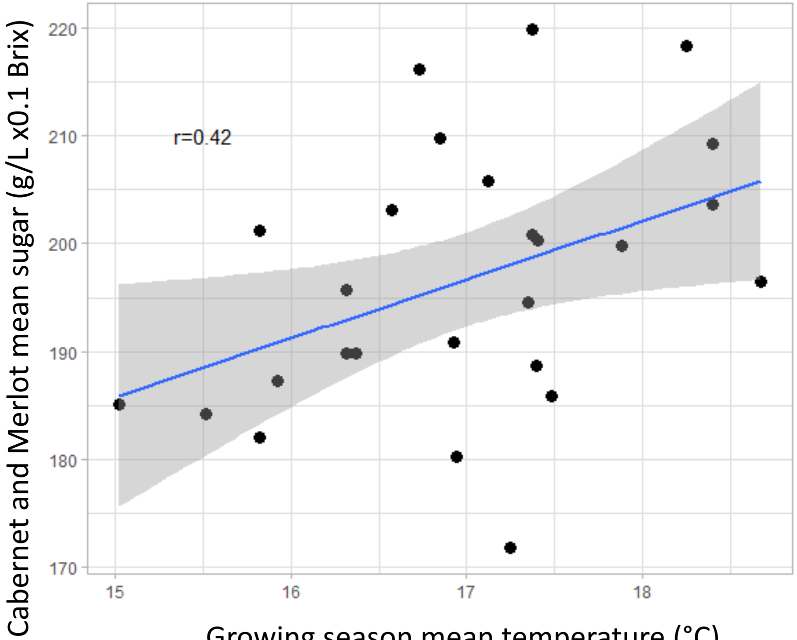
Vintage failure is strongly associated to reaching a certain sugar level





Source: Bordeaux Vintage quality
Ribereau-Gayon, P., and G. Guimberteau. Vintage Reports: 1988-1997.
NOAA: Bordeaux Airport meteorological station
Reanalyzed from Jones and Davies 2010 AJEV

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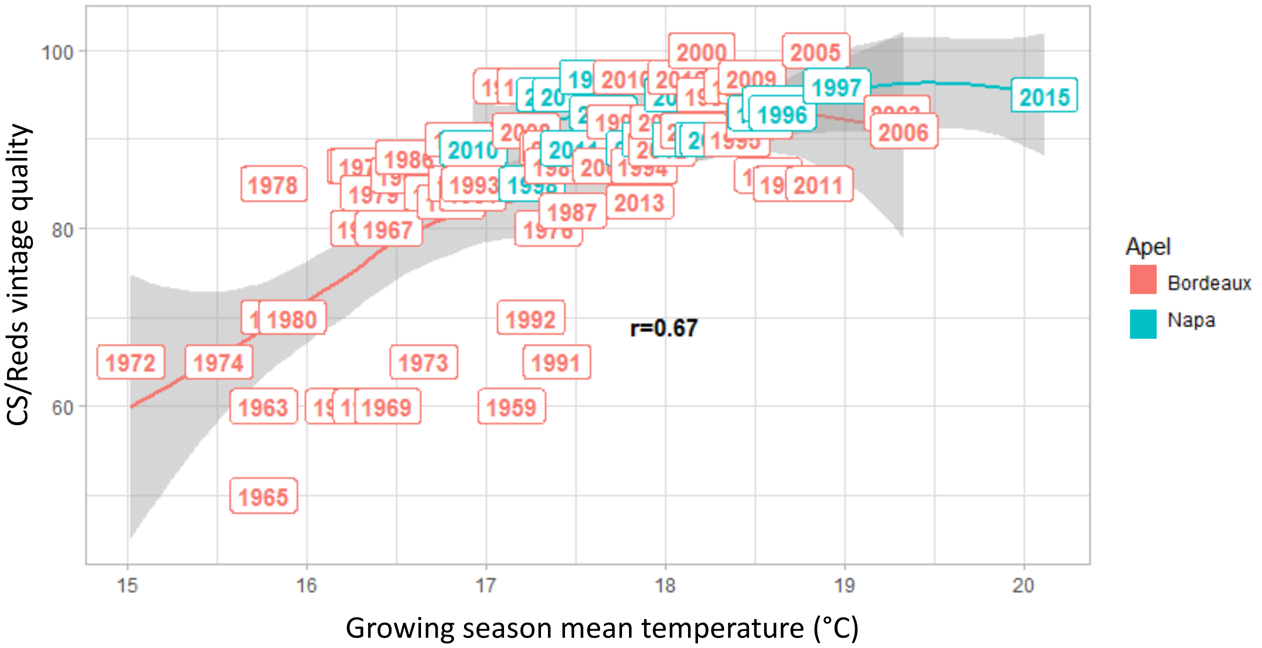


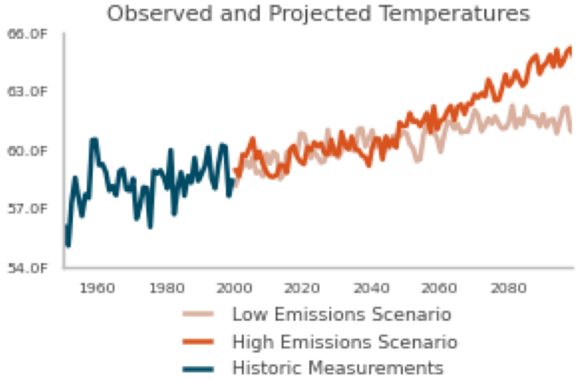
60F 61F 63F 64 F 66F 68F

Although temperature is key for sugar. Harvest precocity can be also based on sudden events that force the decision of picking

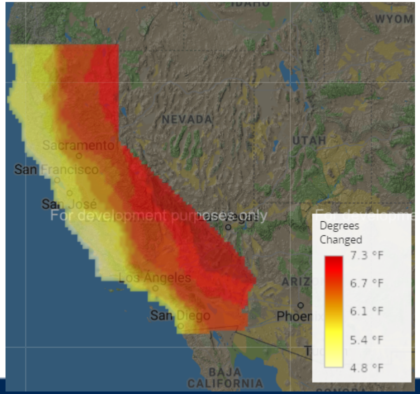
What if it gets warmer?

- Addition of water and tartaric
- Shade nets (kaolin applications did not work for us)
- Breeding efforts for low sugar (INRA and University of Montpellier): 135-150 g/L at ripe stage (max berry vol.)
- IPCC projections:
  - 77% increase of surface burned annually by the end of the century

Projections Sta. Helena

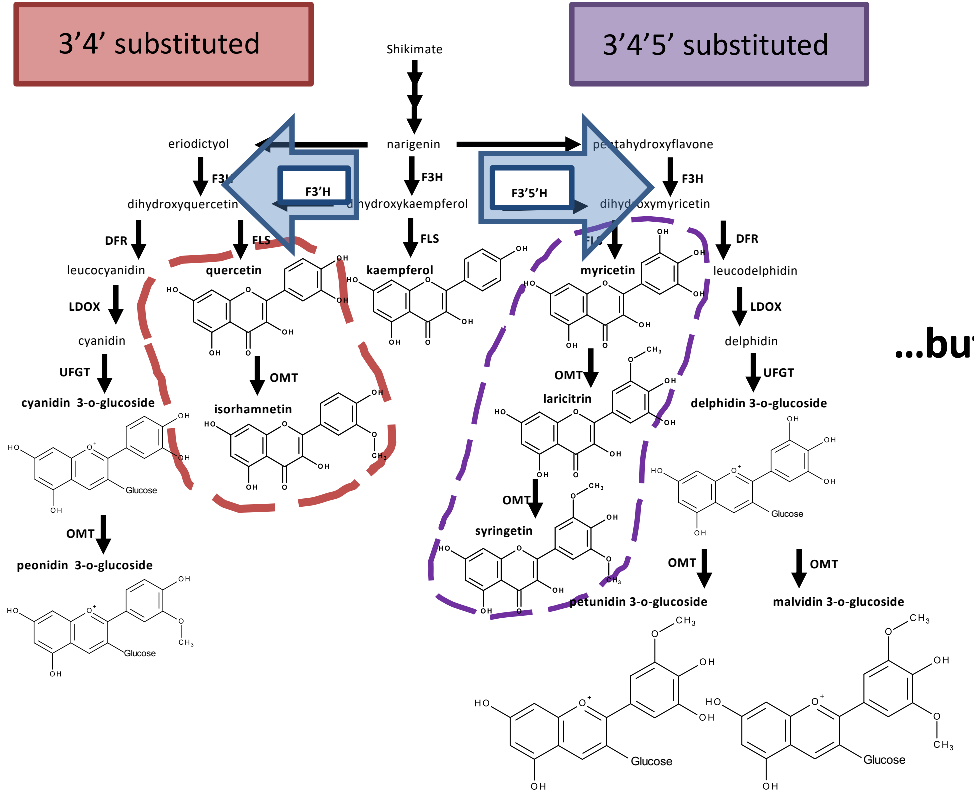


Source: cal-adapt.org
SCRIPPS

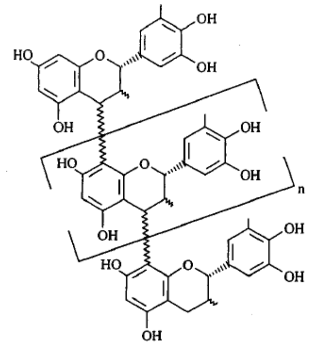


Can you breed a variety to produce cold weather

Water deficits affect secondary metabolism in *Vitis* sp.

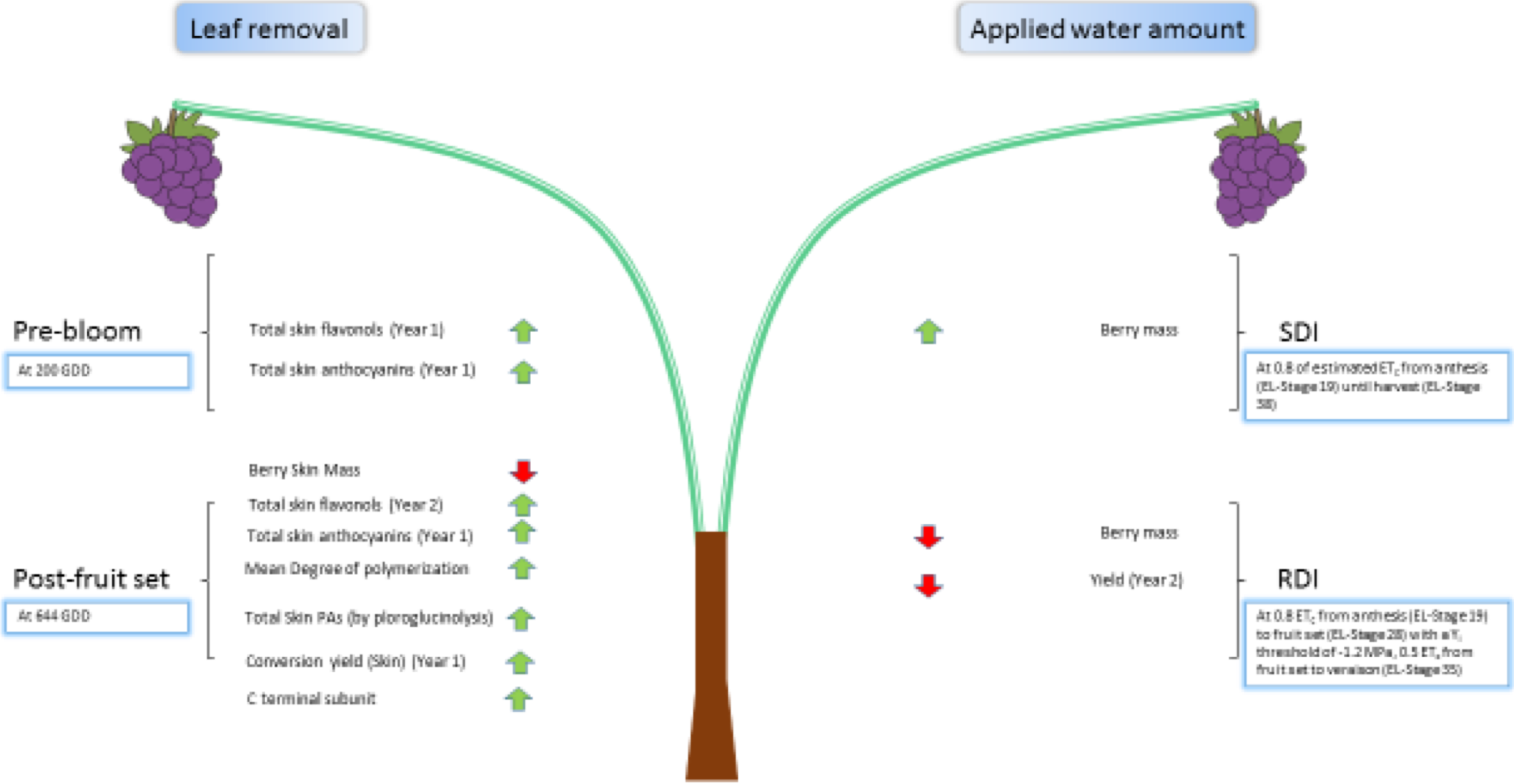


...but proanthocyanidins?



Castellarin et al., 2007 (Planta; BMC Plant Biology; Plant Cell and Environment)

Previous work in hot climate (Yu et al. 2016 JAgFoodChem)



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Experiment

- Randomized complete block
- 3 leaf removal (mechanical)
  - Control
  - Pre-bloom (200 GDD)
  - Post-fruit set (602 GDD)
- 3 applied water amounts
  - 25% ETc
  - 50% ETc
  - 100% ETc (Control)

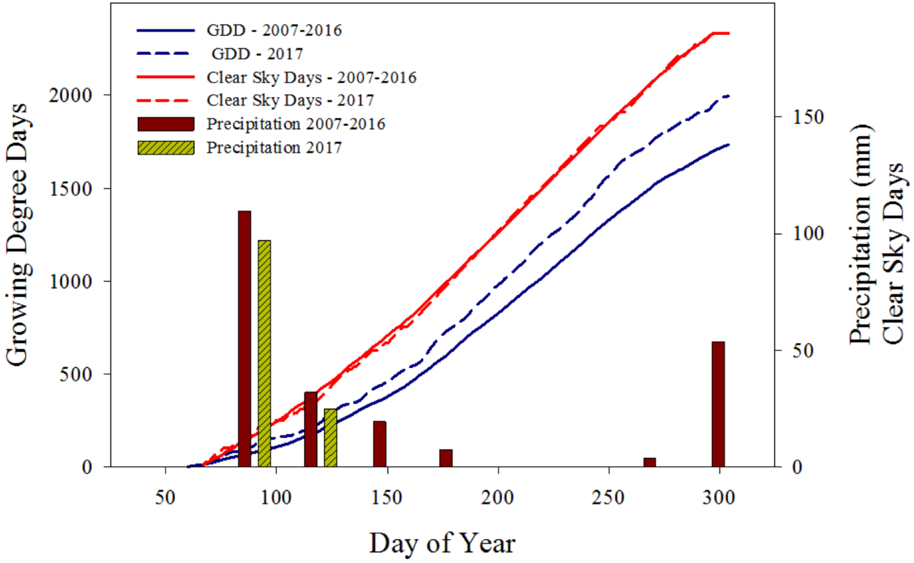
- Conducted at UC Davis Oakville Experimental Vineyard Napa Co. CA
- Bale loam soil series (USDA 2013)
- Drip-irrigated 4 L/vine/hr system
- Spacing 2.4 m x 2.0 m (row x vine)

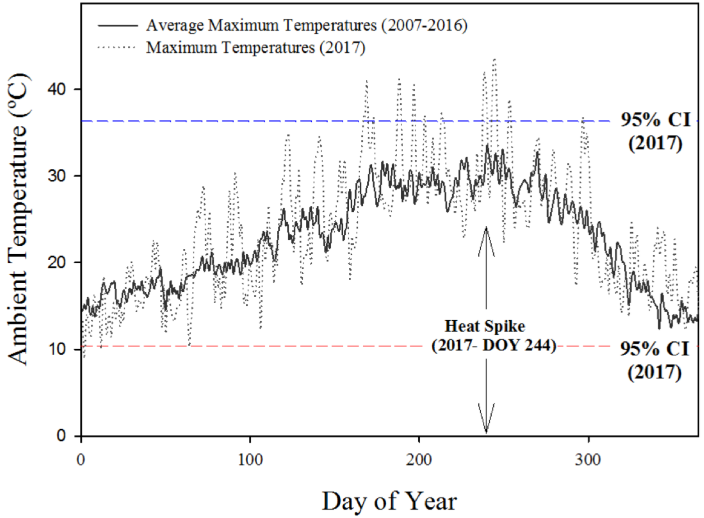
Variables monitored

- Primary metabolism
  - Canopy
  - Plant water status
  - Leaf gas exchange
  - Yield components
  - Berry chemistry
- Secondary metabolism
  - Flavonols
  - Anthocyanins
  - Proanthocyanidins

RESULTS

Weather at the experiment site





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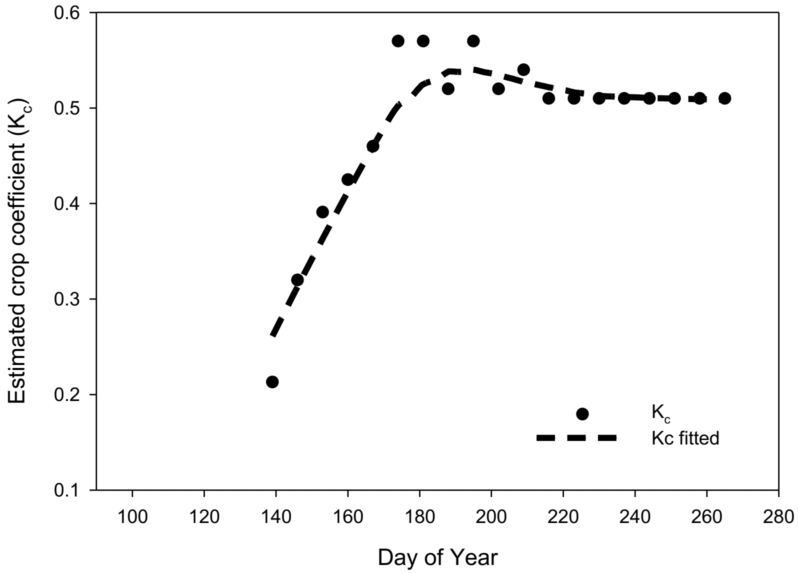
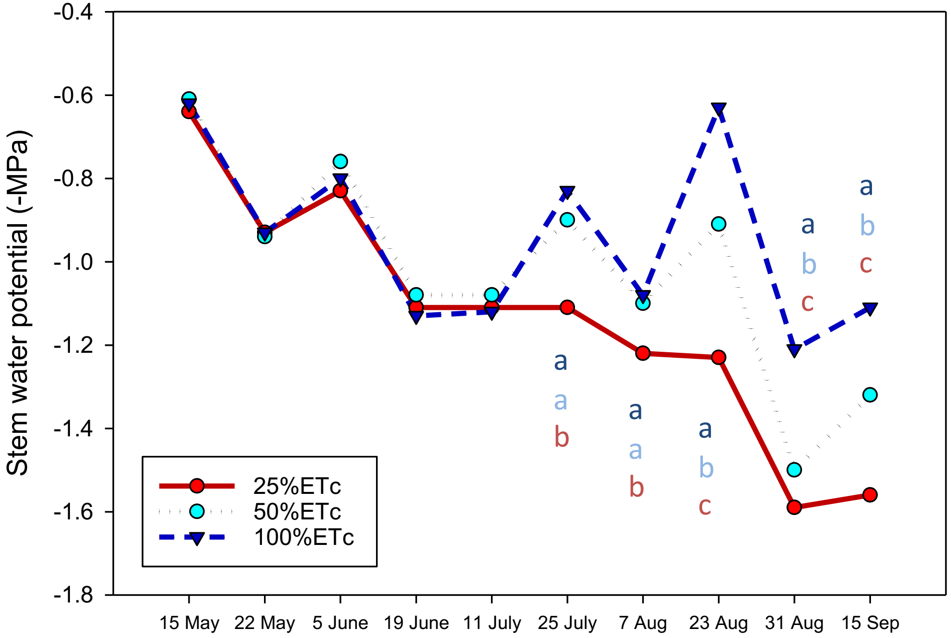
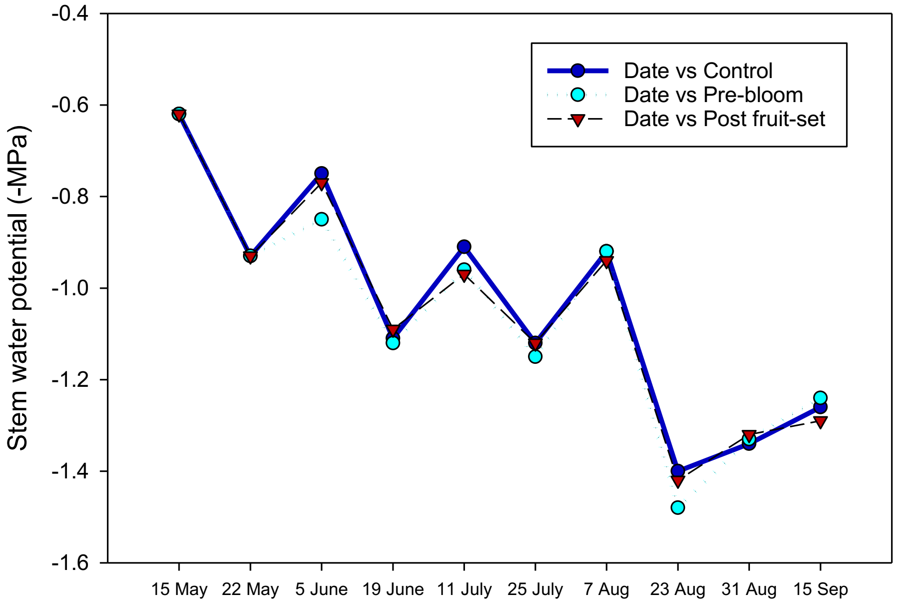
Estimated crop coefficient and applied water amounts



Phenology stage	Applied water (L/vine)		
	100% ETc	50% ETc	25% ETc
Bud-break to fruit set (9 April-31 May)	187.4	93.7	46.9
Fruit-set to veraison (31 May-23 July)	887.4	443.7	221.9
Veraison to harvest (23 July-12 Sept.)	810.8	405.4	202.7
Sum (L/vine)	1885.7	942.8	471.4

Plant water status





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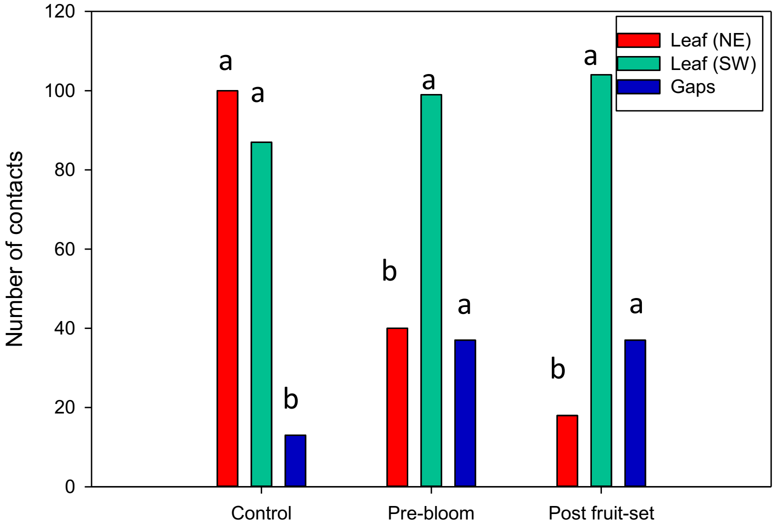
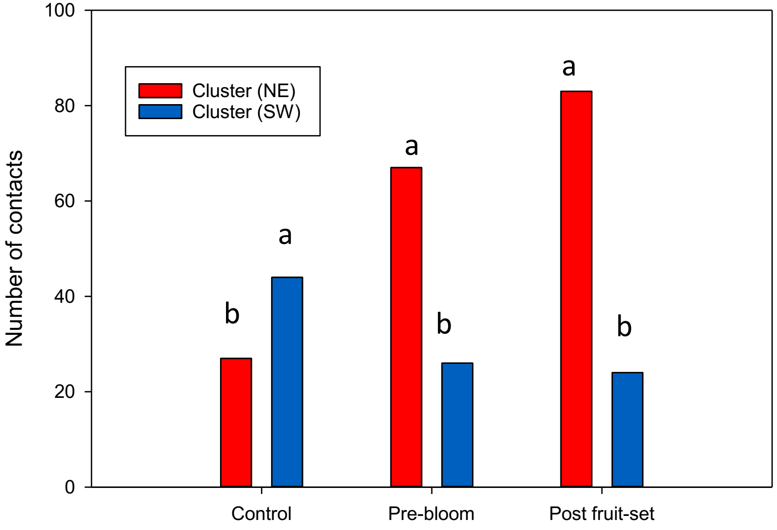
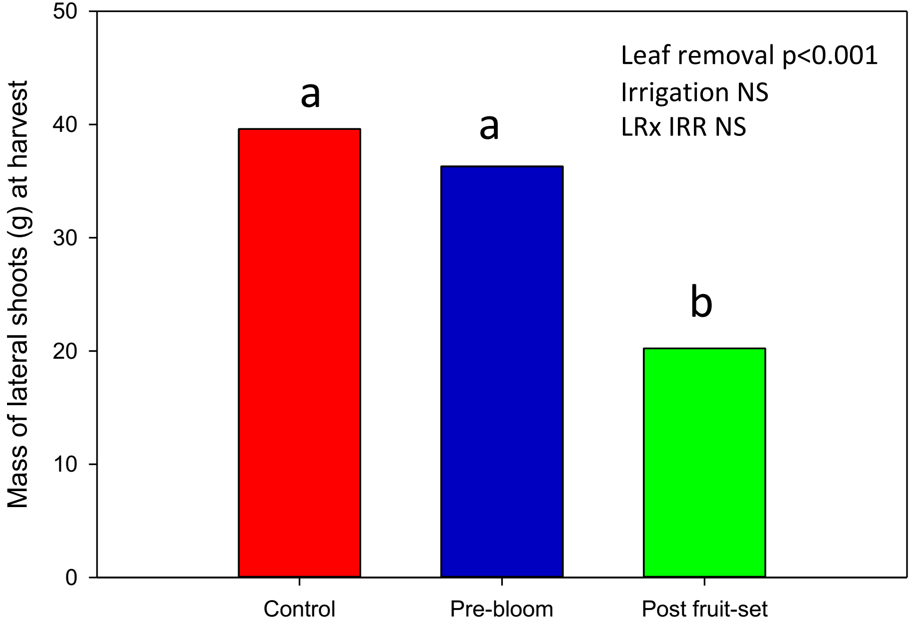
Canopy microclimate at veraison

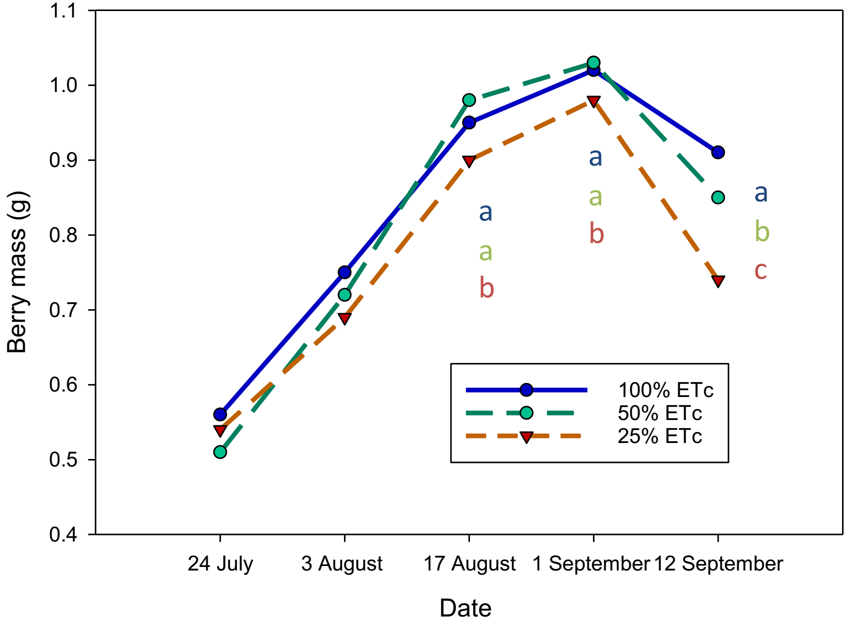


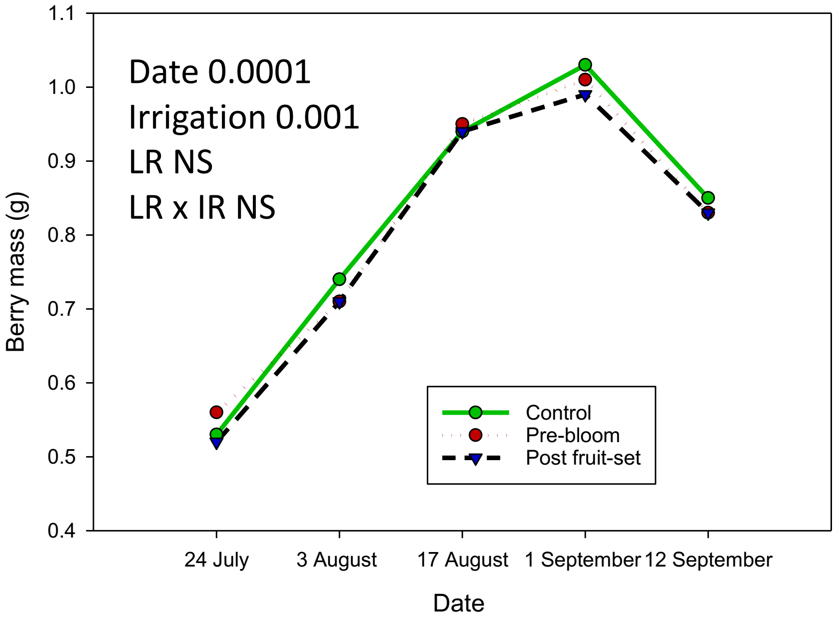


Vegetative compensation of canopy at harvest



Berry mass development





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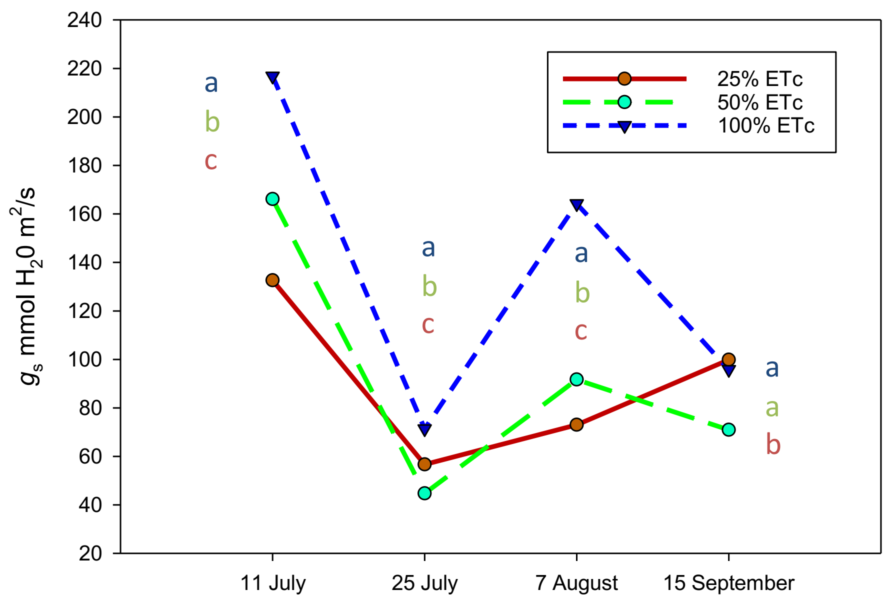
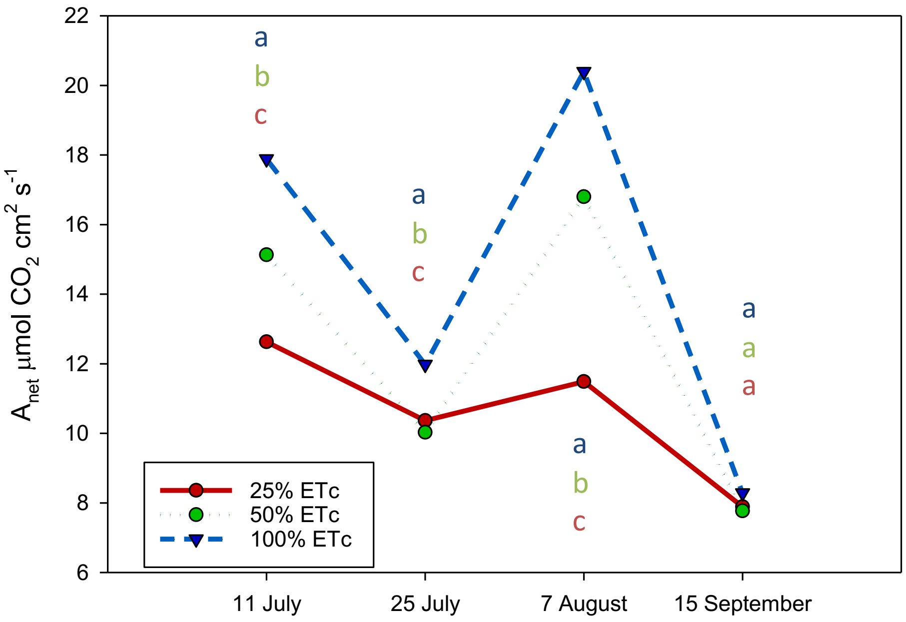
Net gas exchange



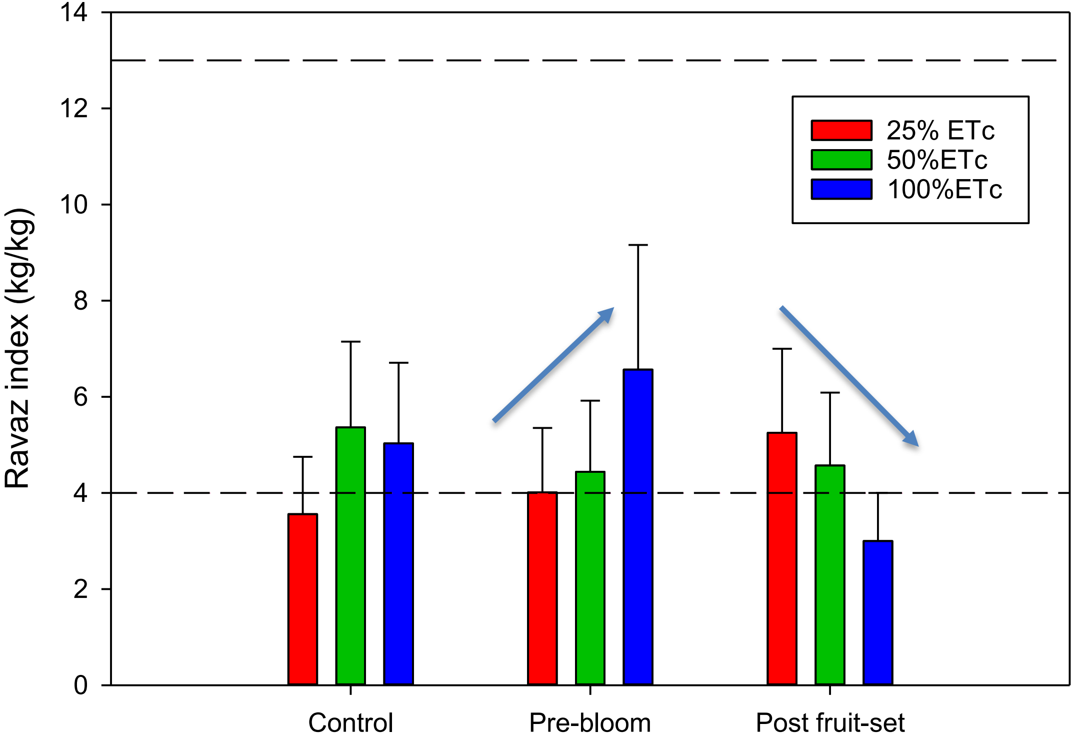


Components of yield

	Berry mass (g)	Skin mass (mg)	Cluster wt (g)	Berries/cluster	Cluster/vine	Yield (t/ha)
Irrigation						
100%ETc	0.93 a	1.011	111 a	119	35	8.3 a
50%ETc	0.88 b	1.117	98 b	111	39	8.1 a
25%ETc	0.72 b	1.043	84 c	116	36	6,2 b
P value	0.0001	0.0877	0.0001	0.9450	0.0915	0.0001
Leaf removal						
Control	0.85	1.068	103	121	37	7.5
Pre-bloom	0.83	1.073	91	109	37	7.1
Post fruit-set	0.83	1.031	100	120	37	7.7
P value	0.9550	0.6164	0.0618	0.0781	0.9963	0.3776
LR x IRR	0.4490	0.0794	0.0909	0.2611	0.1756	0.1756

Vine balance

Range: 4 to 13 kg/kg



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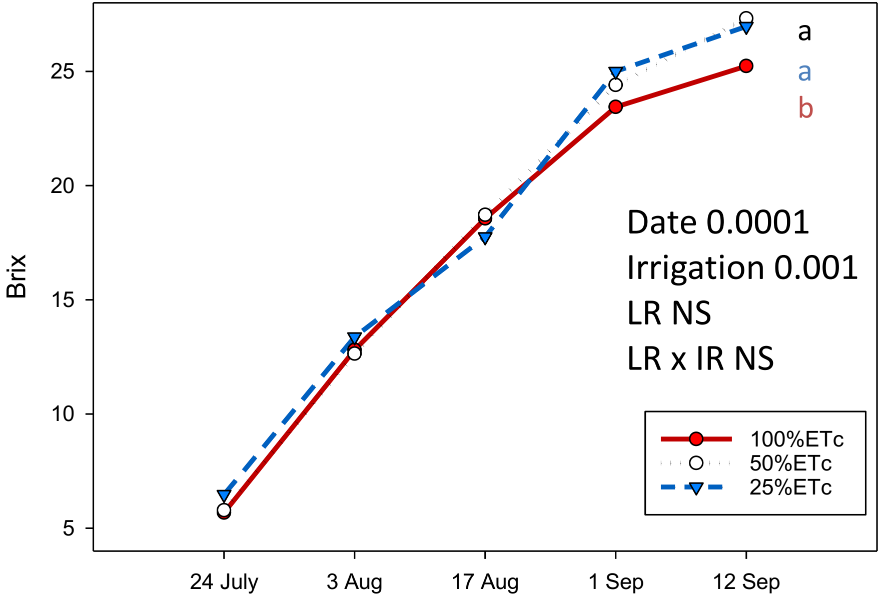
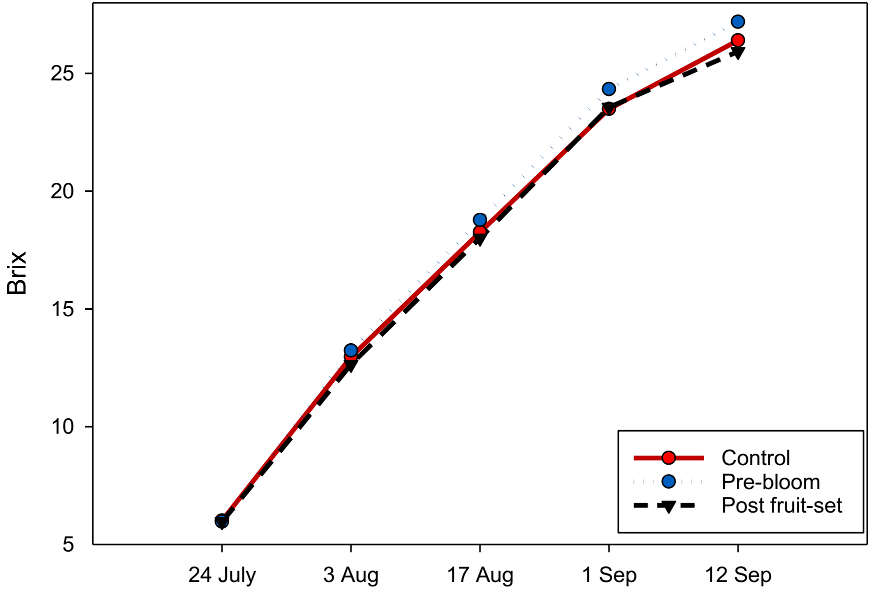
Berry chemistry





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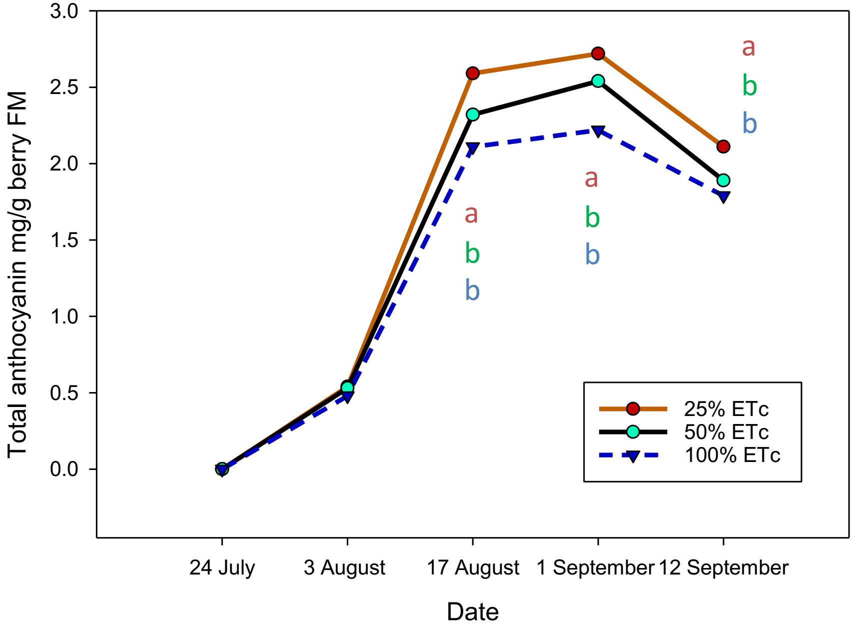
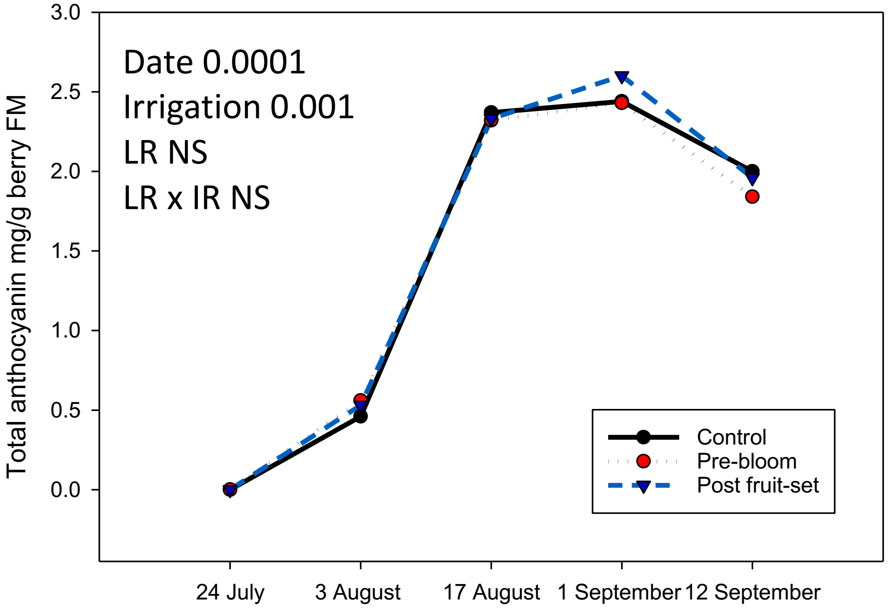
Anthocyanin content and concentration at harvest

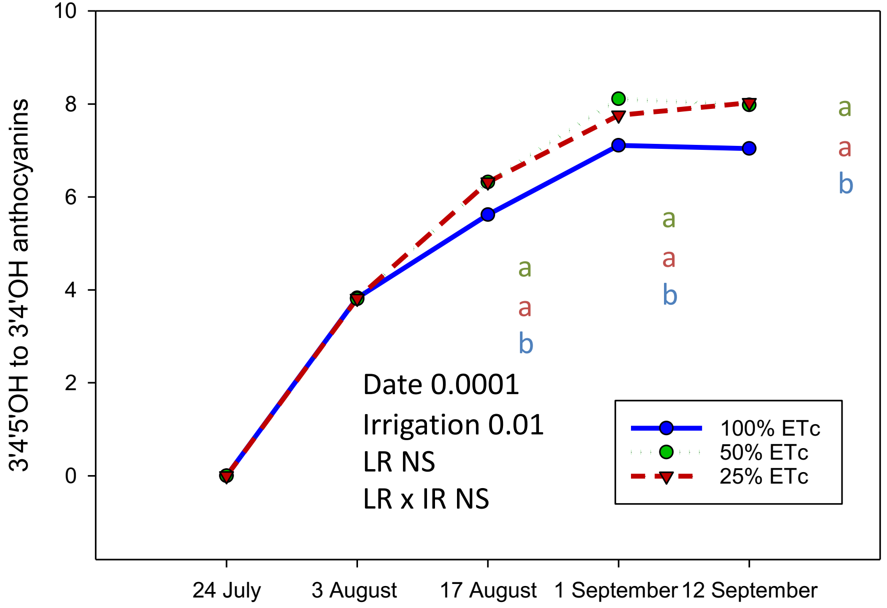
	Skin mass (mg)	Total anthocyanin (mg/berry)	Total anthocyanin mg/g FM
Irrigation			
100%ETc	1.011	1.682	1.785 b
50%ETc	1.117	1.639	1.897 b
25%ETc	1.043	1.710	2.113 a
P value	0.0877	0.8710	0.0364
Leaf removal			
Control	1.068	1.709	2.000
Pre-bloom	1.073	1.582	1.834
Post fruit-set	1.031	1.740	1.960
P value	0.6164	0.4790	0.3599
LR x IRR	0.0794	0.7480	0.6954

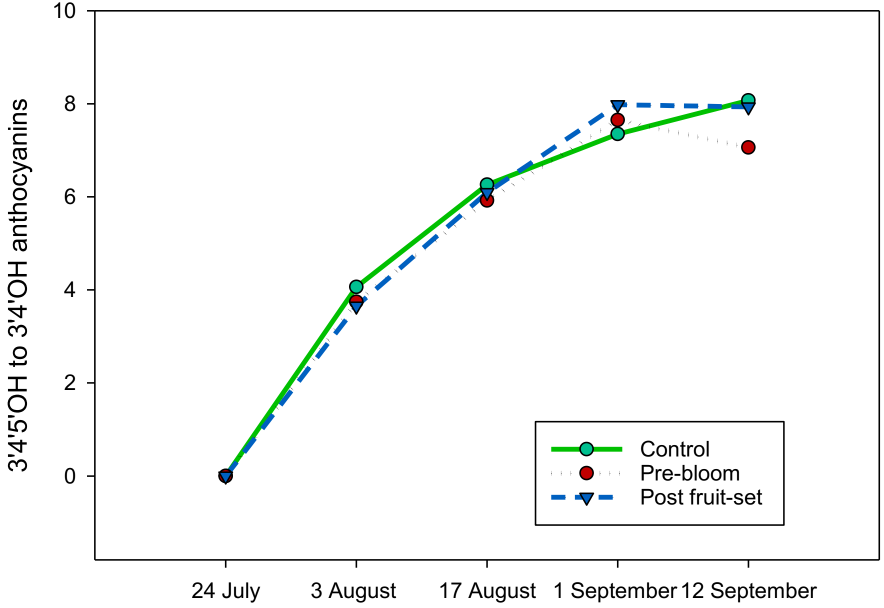
Kinetic development of total anthocyanin concentration



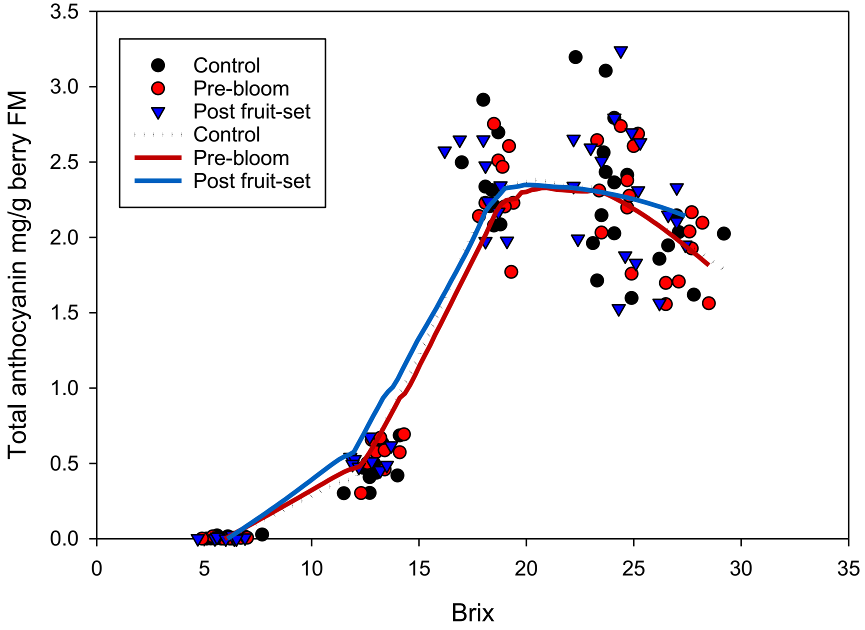


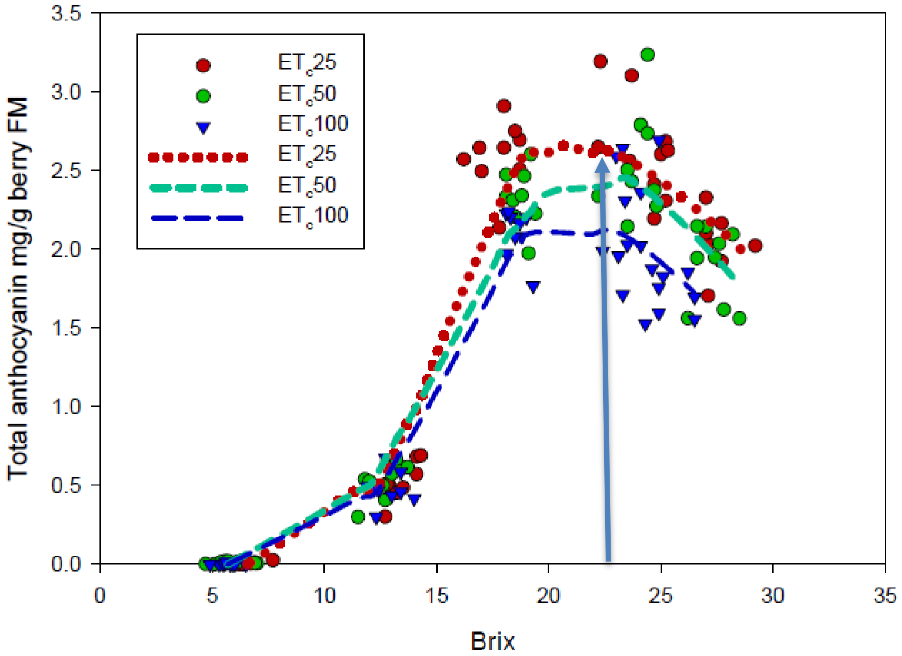
Hydroxylation ratio of anthocyanins





Regression of Brix vs total anthocyanin





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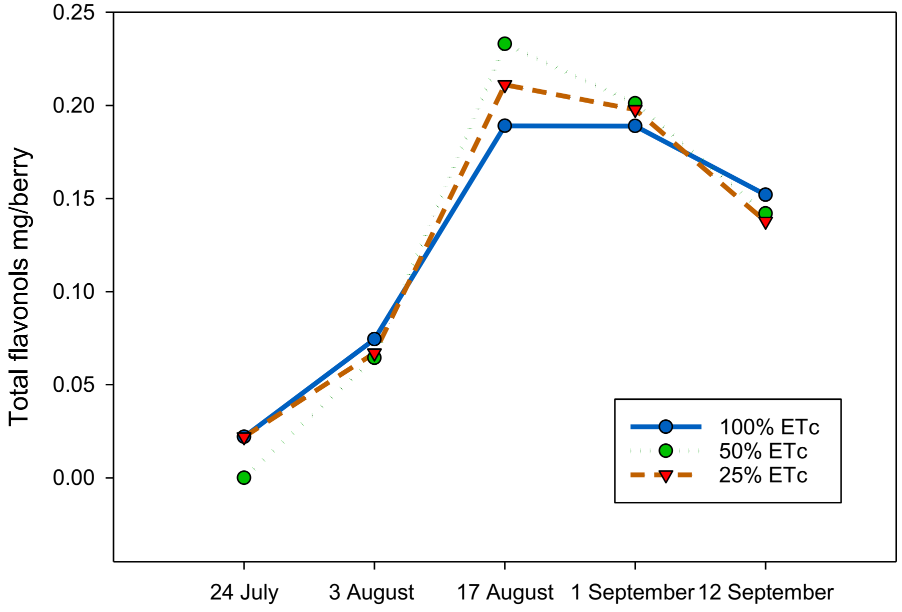
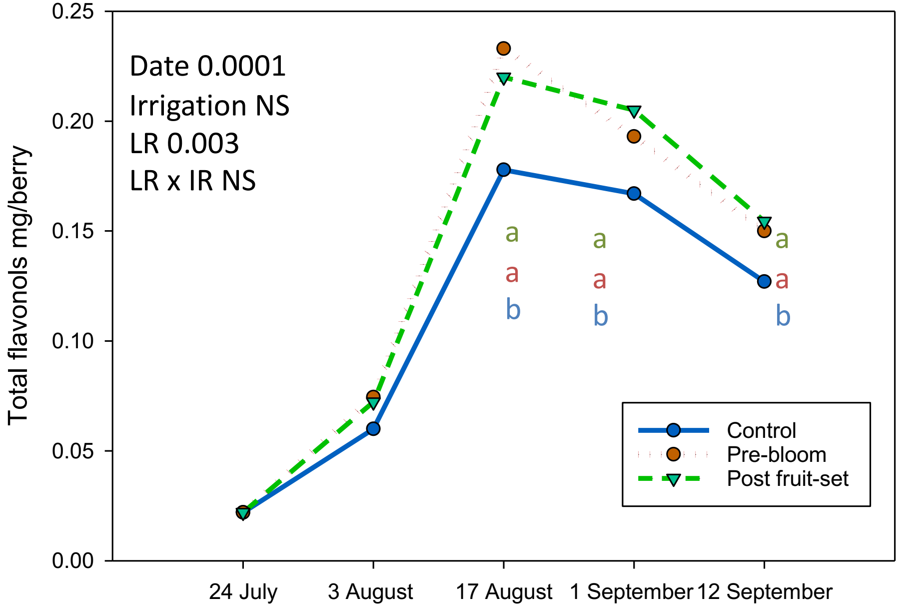
Total flavonols content and concentration

	Skin mass (mg)	Total flavonols (mg/berry)	Total flavonols mg/g FM
Irrigation			
100%ETc	1.011	0.153	0.163
50%ETc	1.117	0.136	0.153
25%ETc	1.043	0.143	0.187
P value	0.0877	0.1905	0.0625
Leaf removal			
Control	1.068	0.127 b	0.152 b
Pre-bloom	1.073	0.151 ab	0.177 a
Post fruit-set	1.031	0.154 a	0.175 a
P value	0.6164	0.0132	0.0160
LR x IRR	0.0794	0.1082	0.1249

Kinetic development of total flavonol content





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Proanthocyanidin content and concentration

		Proanthocyanidins	
	Berry mass (g)	Total proanthocyanidins (mg/berry)	Total proanthocyanidins (mg/g berry)
Irrigation			
100% ETc	0,910 a	3,73 a	3,93
50% ETc	0,854 ab	3,25 ab	3,63
25% ETc	0,743 b	2,86 b	3,70
p-value	0,0157*	0,0687*	0,654
Leaf removal			
C	0,850	3,36	3,93
EL	0,825	3,13	3,63
LL	0,832	3,35	3,70
p-value	0,8903	0,7639	0,658
LR x IRR			
p-value	0,6625	0,3623	0,292

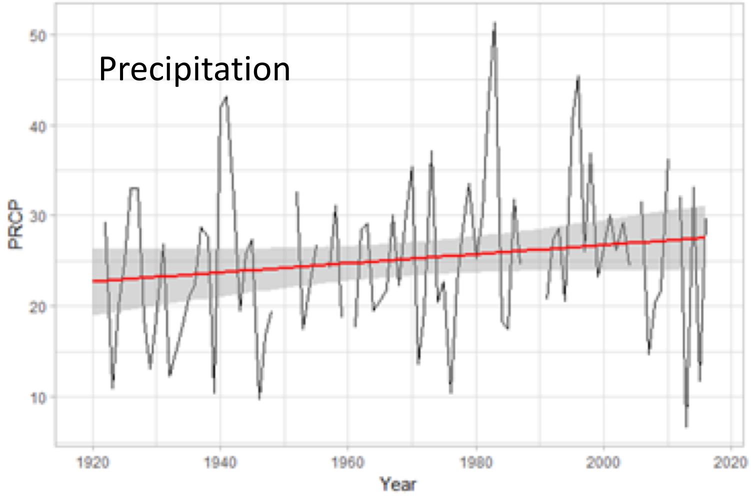
Proanthocyanidin composition (mg/berry) at harvest

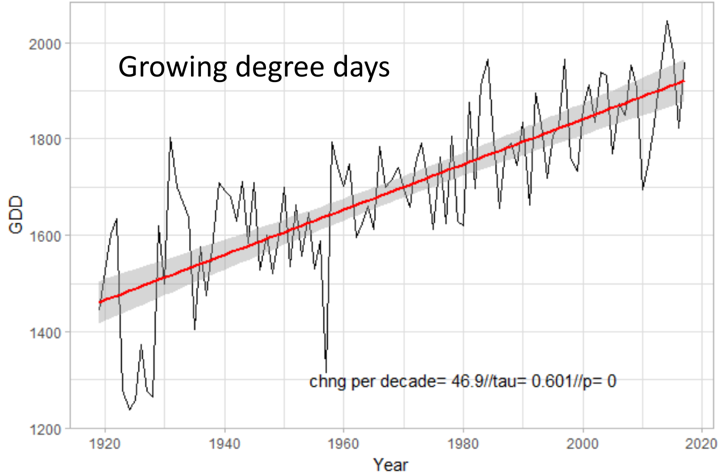
	Total proanthocyanidins (mg/berry)						
	C-P	EGC-P	ECG-P	EC-P	C	EC	mDP
Irrigation							
100% ETc	0,051	1,906 a	0,117	1,497	0,116	0,045	43,4
50% ETc	0,048	1,639 ab	0,114	1,304	0,107	0,039	41,5
25% ETc	0,042	1,432 b	0,104	1,152	0,088	0,038	42,5
p-value	0,438	0,0463*	0,61	0,3345	0,0566	0,0816	0,5900
Leaf removal							
C	0,048	1,705	0,113	1,347	0,102	0,039	44,2
EL	0,048	1,555	0,107	1,280	0,098	0,042	41,6
LL	0,046	1,718	0,115	1,326	0,109	0,040	41,7
p-value	0,9284	0,05963	0,8151	0,8179	0,6075	0,6991	0,3080
LR x IRR							
p-value	0,2390	0,2827	0,6241	0,4632	0,2396	0,7176	0,4111

PERSPECTIVES

A shifting climate in California's North Coast AVAs

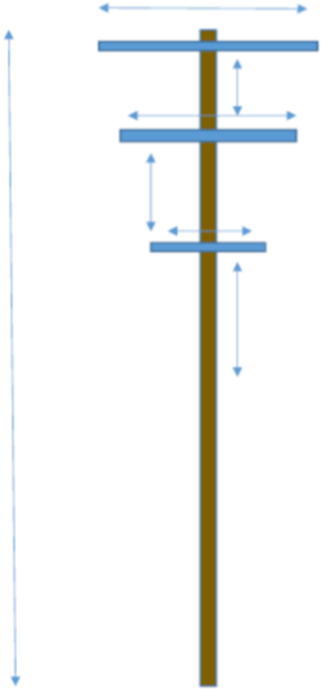
- Little to no cloud cover
- Intermittent heat spikes
- A general warming trend
- No increase in precipitation supply

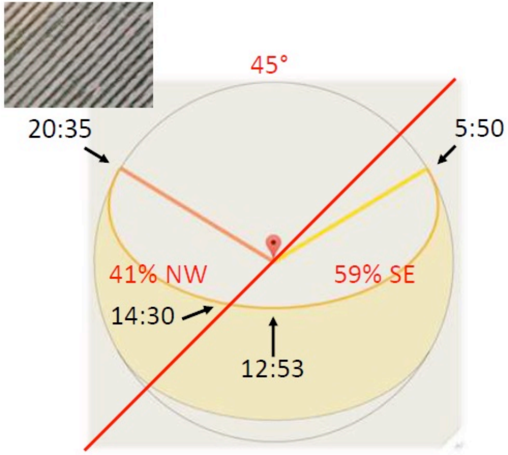


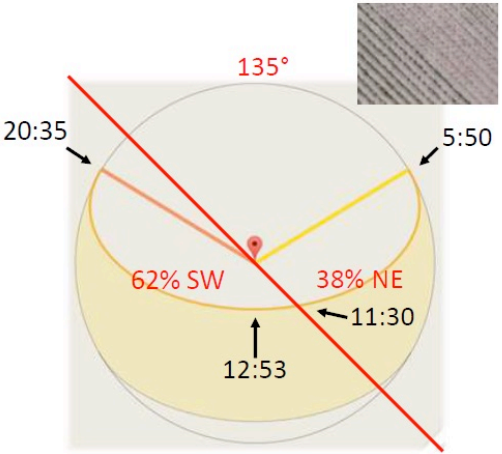


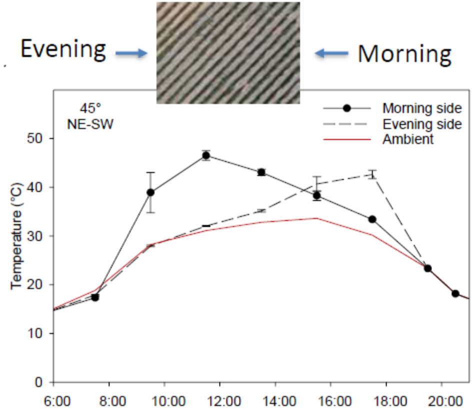
Shift towards positioned and sprawling systems

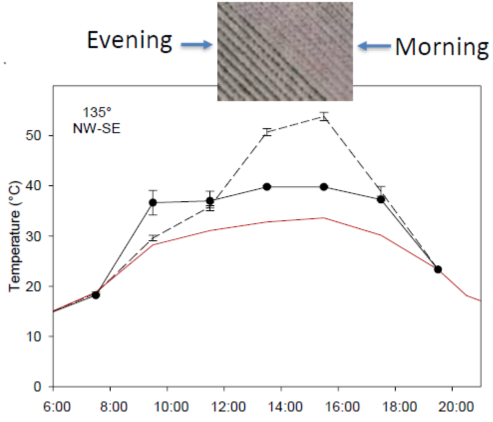
The UCDavis30 Trellis







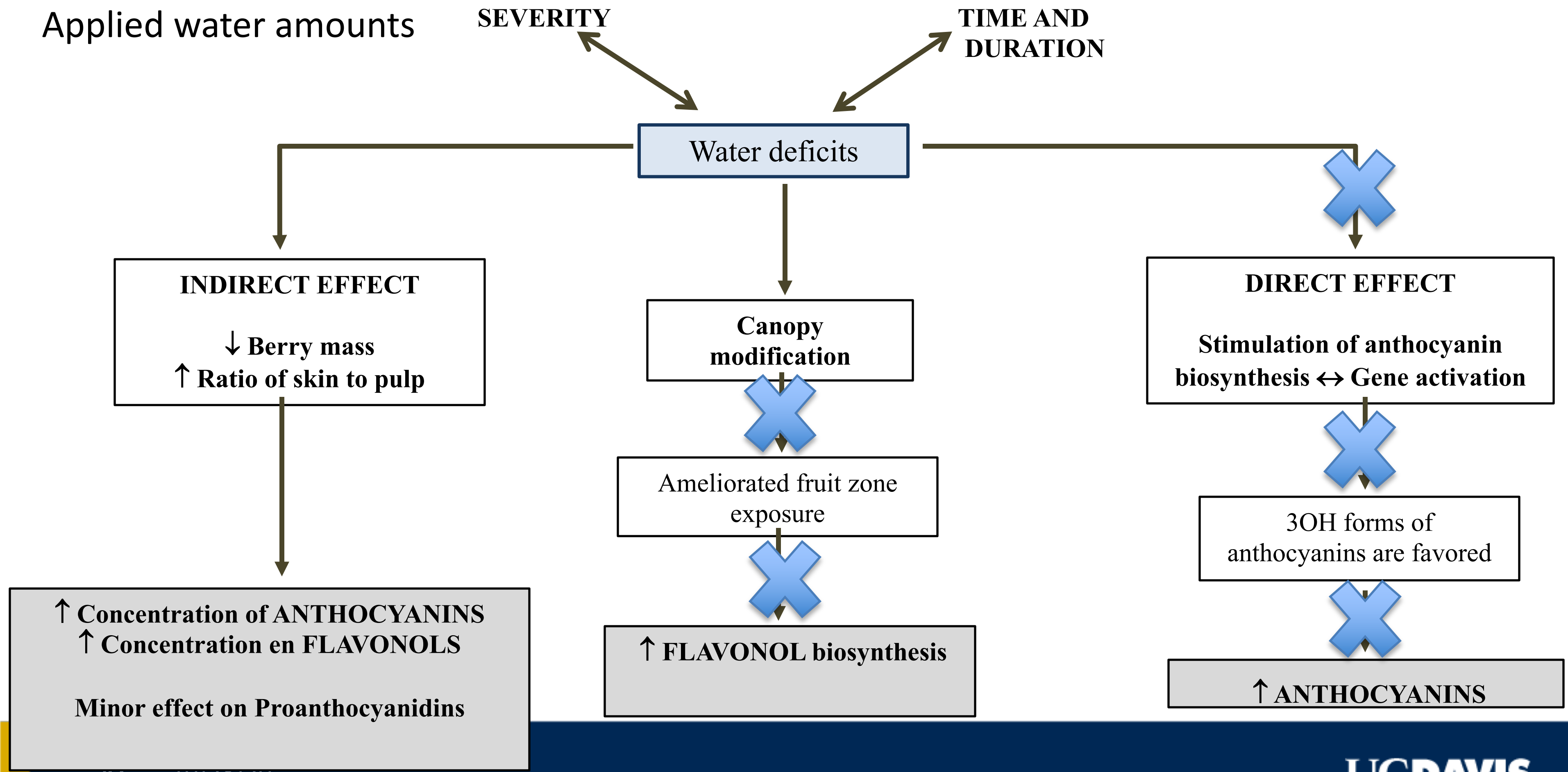




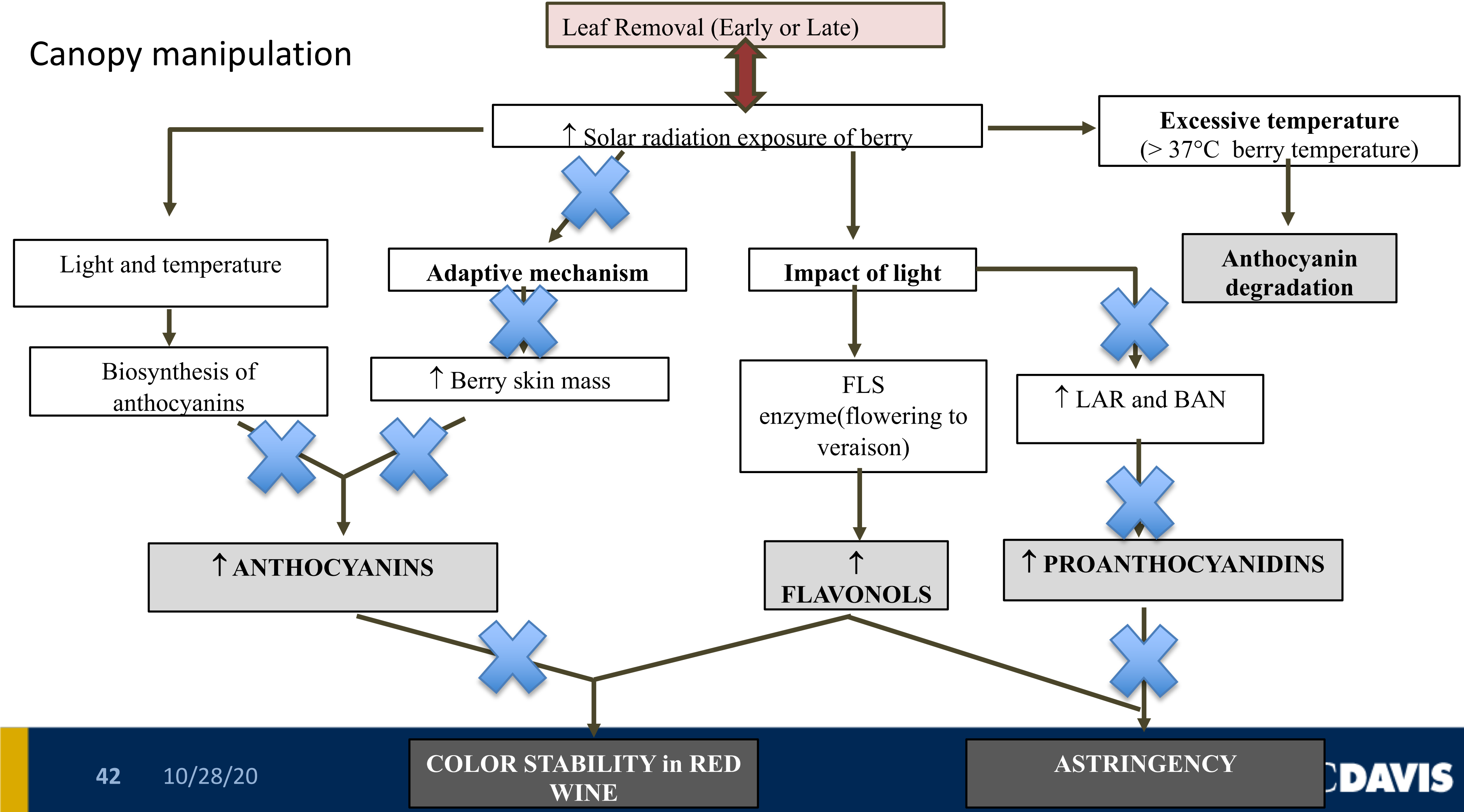
Primary metabolism summary

- Leaf removal timing
  - No effect on
    - Water status
    - Net gas exchange
    - Components of yield
      - No effect on fruit set
    - Primary metabolites
- Applied water amounts
  - Significant effect on
    - Water status
    - Net gas exchange
    - Components of yield
    - Primary metabolites
      - Only TSS

Applied water amounts



Canopy manipulation



Conclusions

- Cluster microclimate without leaf removal already optimized
- Clear skies, long periods with minimal precipitation coupled with irrigation restriction have stronger effect on primary and secondary metabolism then canopy manipulation (*e.g.* shoot or leaf removal)
    - An optimal ET replacement is 50%-60% ETc using sustained deficits.
- Although not as impactful, there seems to be interest from producers to understand the impact of leaf removal practices on berry physiology

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