How leaf removal and dropping fruit affects berry ripening

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Sonoma Co. Grape Day 7 February 2019

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From the Canopy to Crop Load

- Shoot system of the grapevine:
  - Stems
  - Leaves
  - Clusters
- Collectively: <u>Microclimate</u>
  - Length
  - Height
  - Width
  - Leaf area
  - Shoot density
  - Leaf layer number

Climate within the Grape Canopy

- Microclimate is affected by:
  - Amount of leaf area
  - Distribution of leaf area
  - Their interaction with above ground climate

Fruit Maturity: The point at which fruit composition most closely matches that required to make the style of wine desired

Desirable Aspects

- Uniformly ripe fruit
- Sound fruit
- An abundance of flavor
  - With correct composition
- Reaches peak at ideal time
  - Avoiding inclement weather
  - Winery logistics

Berry growth development

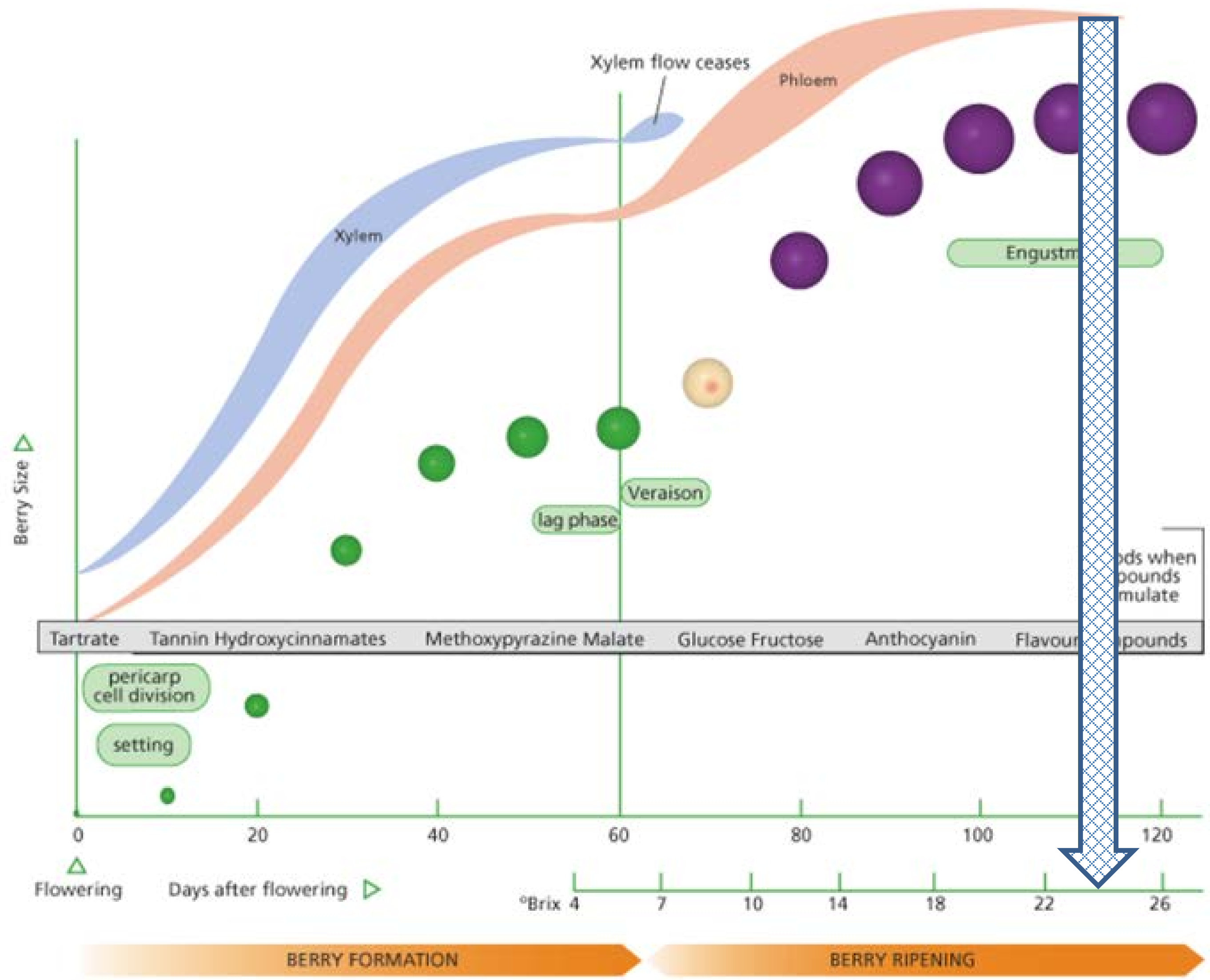
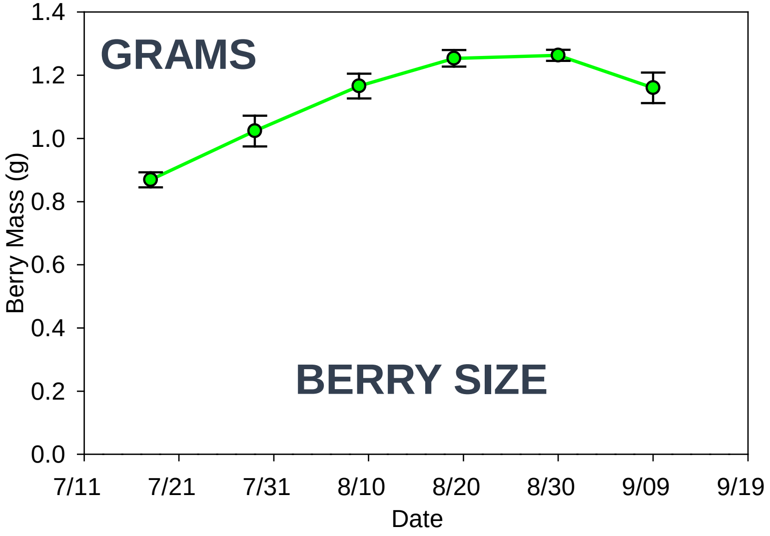
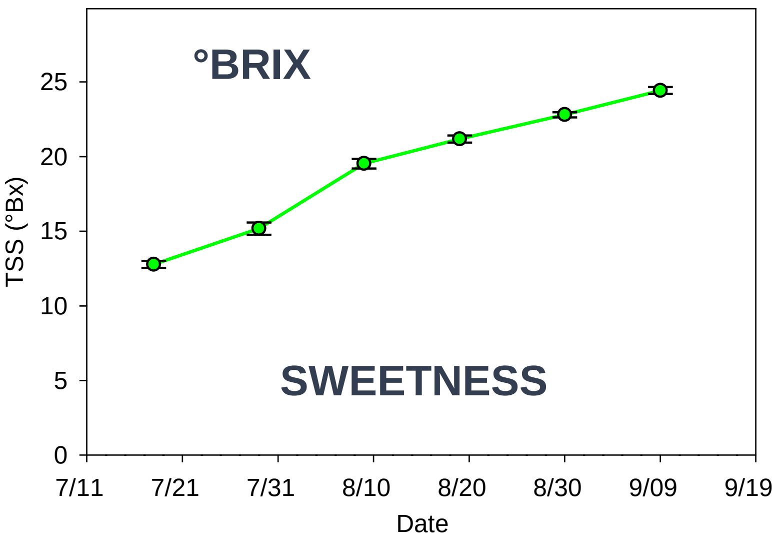


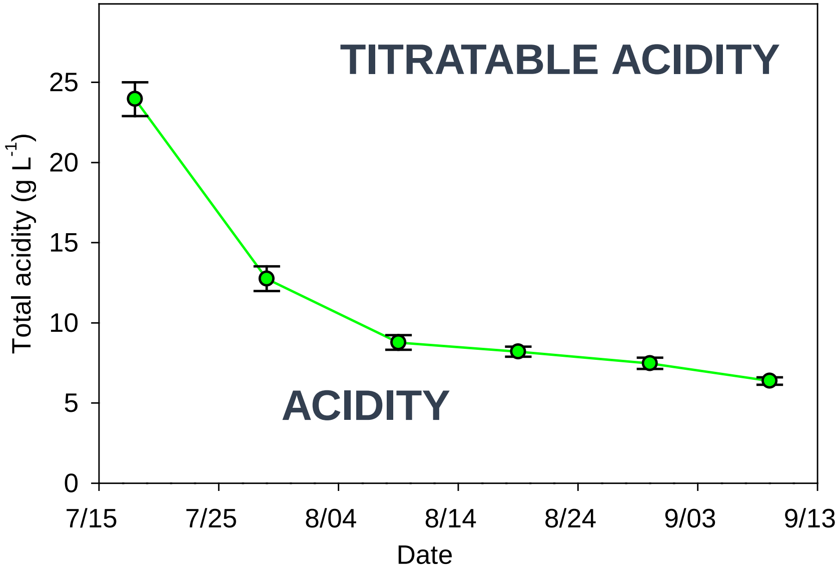
Figure 2: Diagram showing relative size and color of berries at 10-day intervals after flowering, passing through major developmental events (rounded boxes). Also shown are the periods when compounds accumulate, the levels of juice °brix, and an indication of the rate of inflow of xylem and phloem vascular saps into the berry. Illustration by Jordan Koutroumanidis, Winetitles.

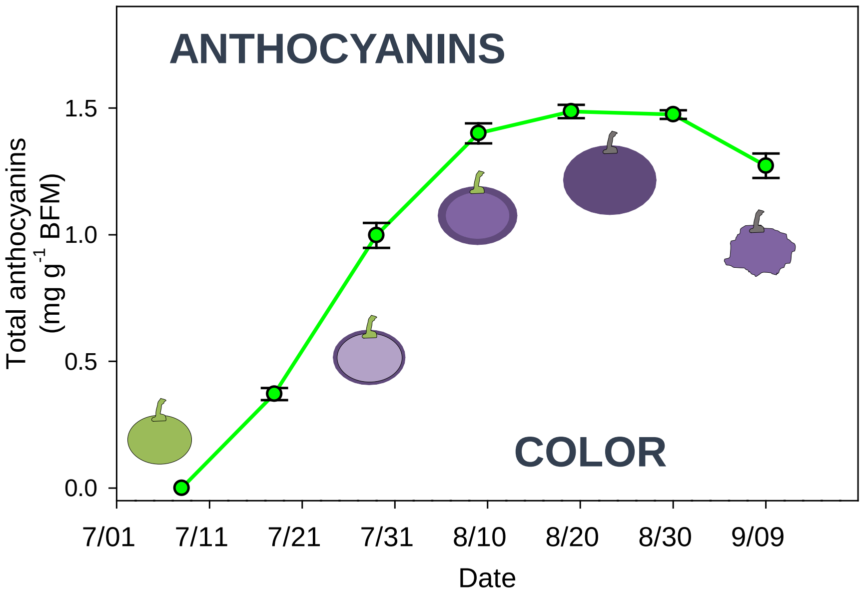
Illustration by Jordan Koutroumanidis, Winetitles

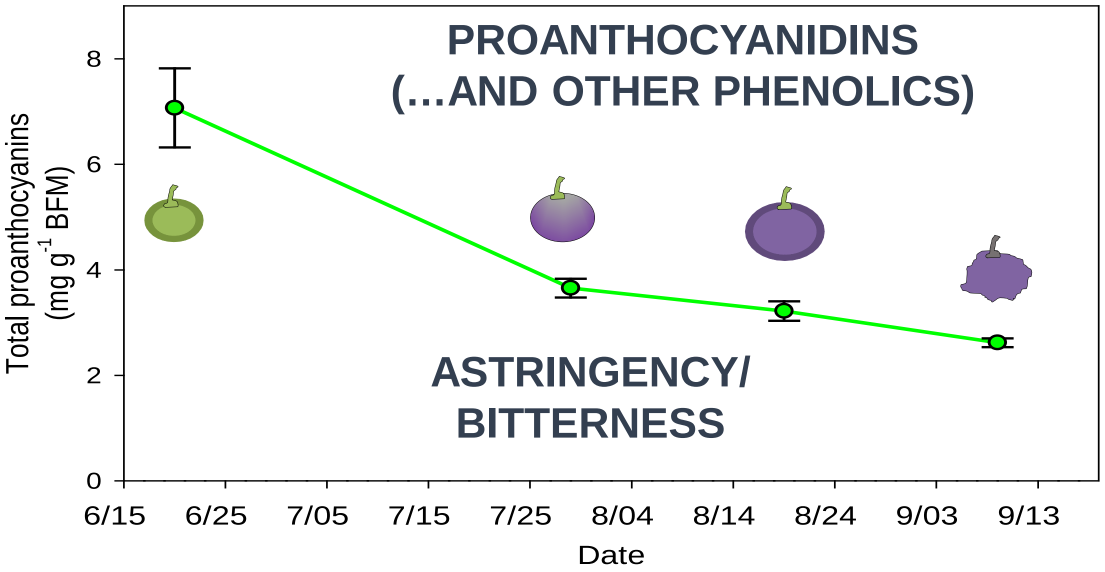
EVOLUTION OF GRAPE COMPOSITION AT OAKVILLE, CA



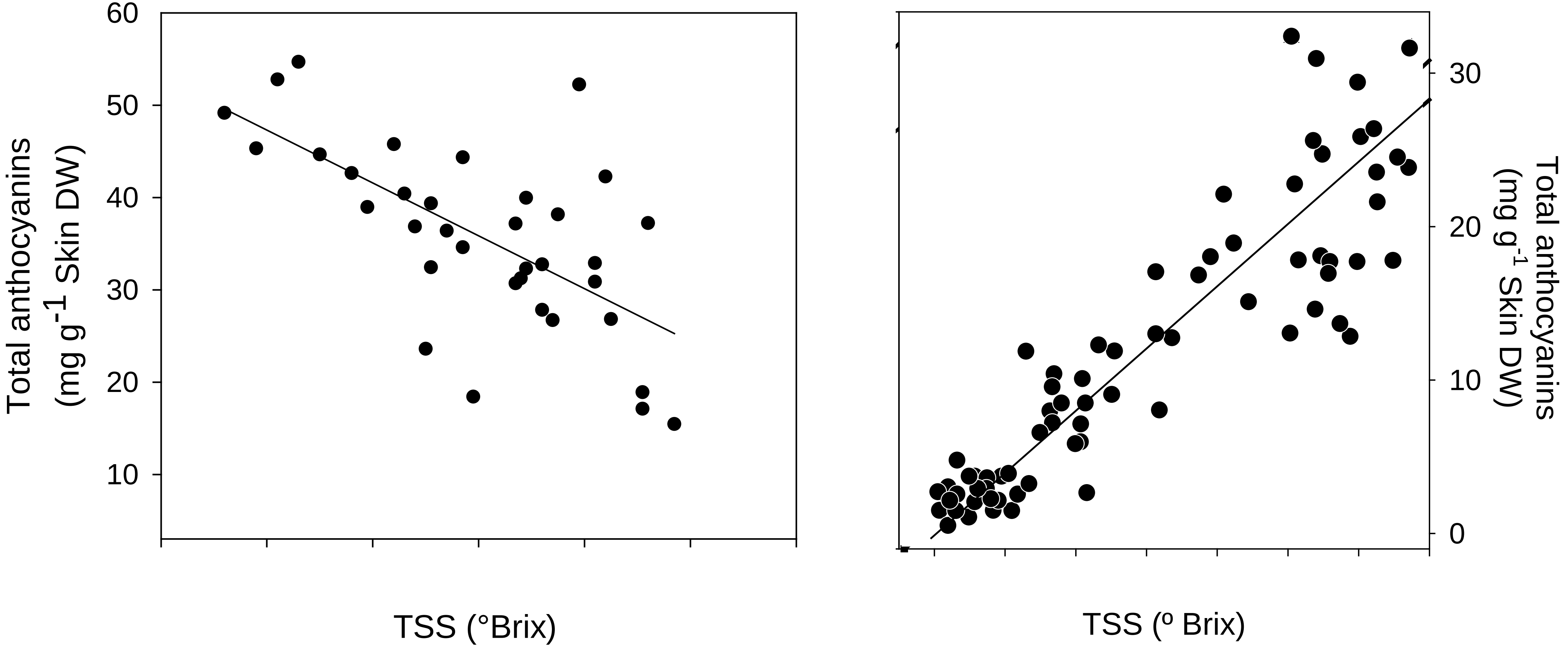








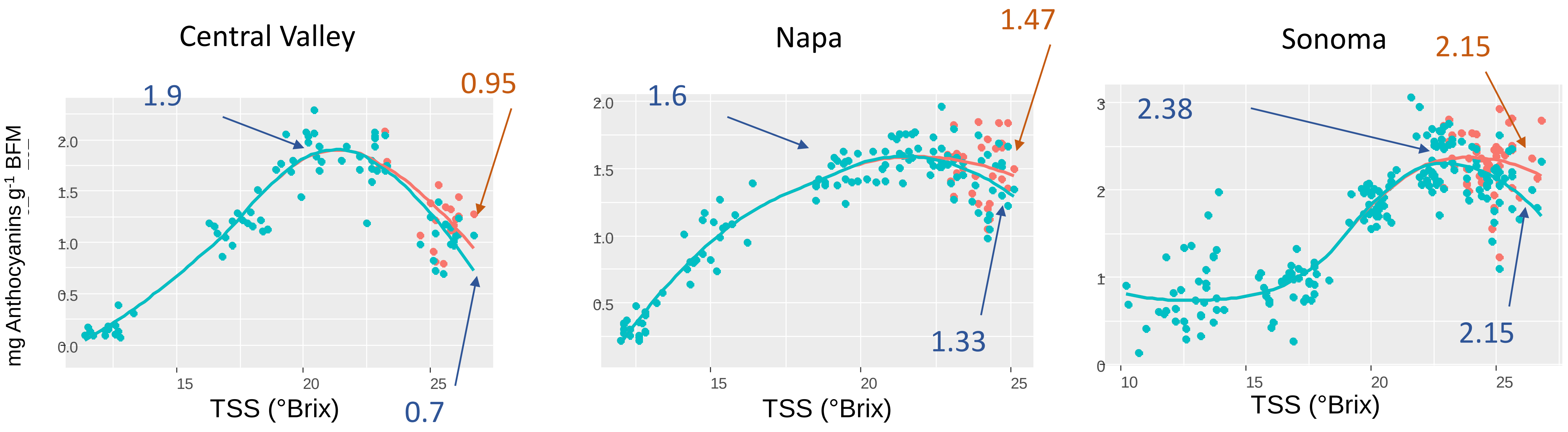
RELATIONSHIP BETWEEN TSS AND COLOR



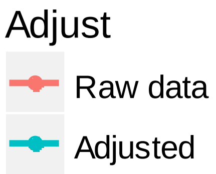
SHRIVELING VS RIPENING IN C. SAUVIGNON

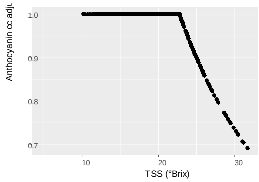
Martinez et al. 2018

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

Optimum light environment in the fruit zone during ripening

- Maximize diffuse or indirect sunlight within the canopy interior
- Minimize exposure of clusters to direct sunlight – particularly in <u>warm climates</u>

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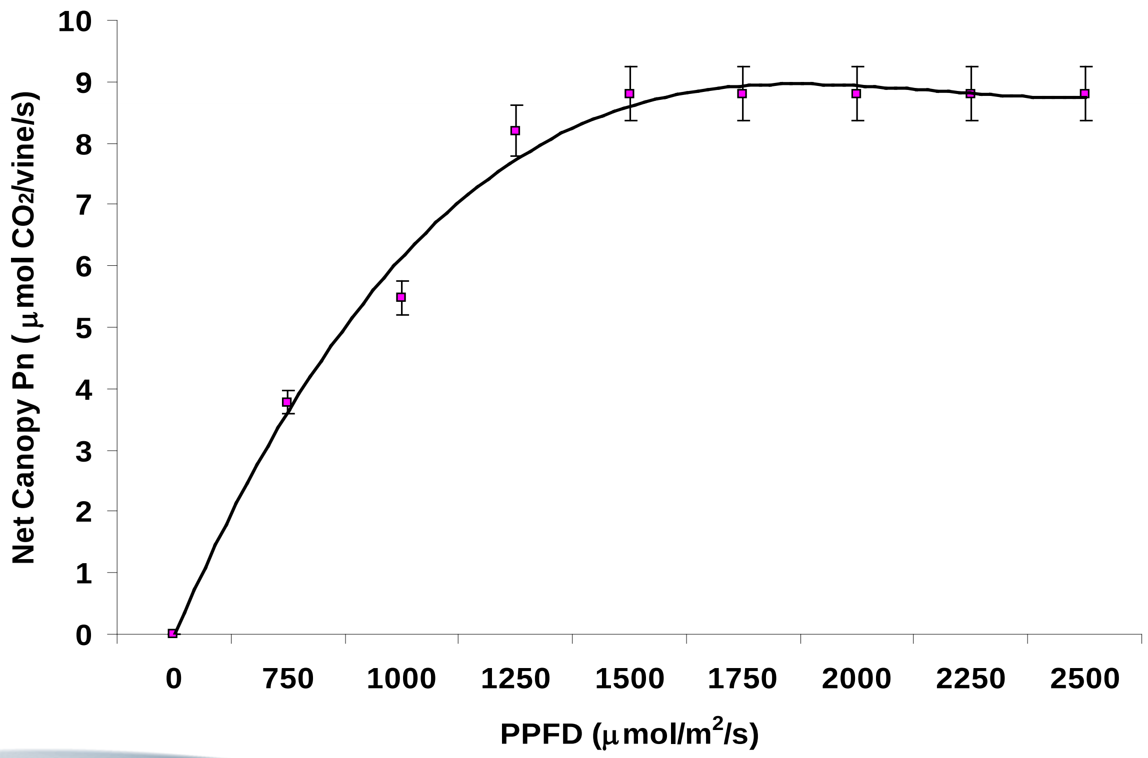
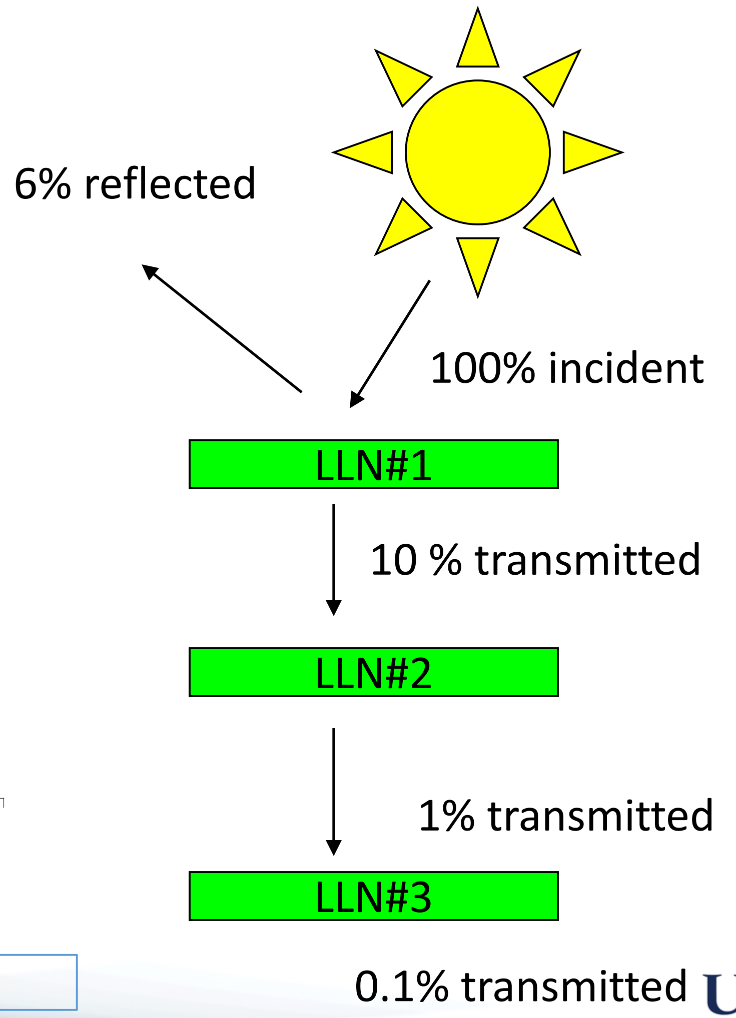
Effects of Solar Radiation on Fixing Carbon by A Grapevine

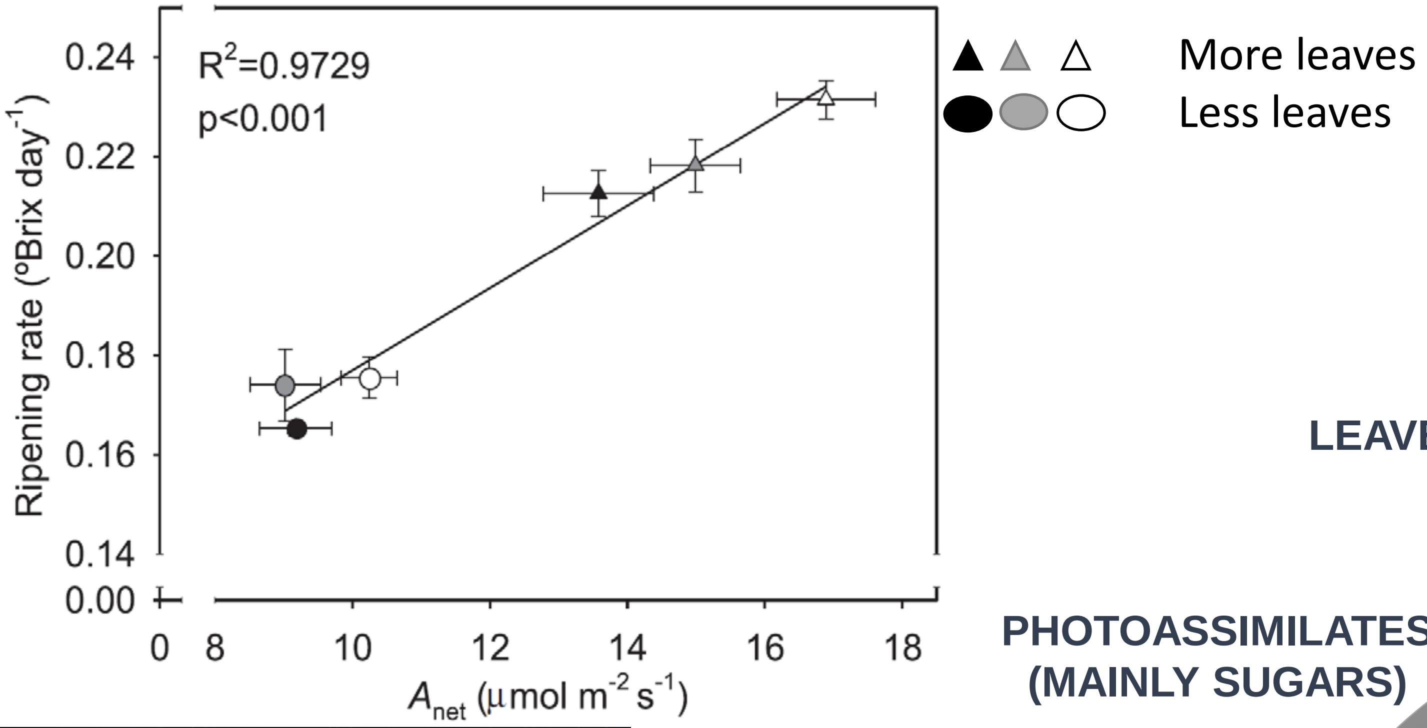


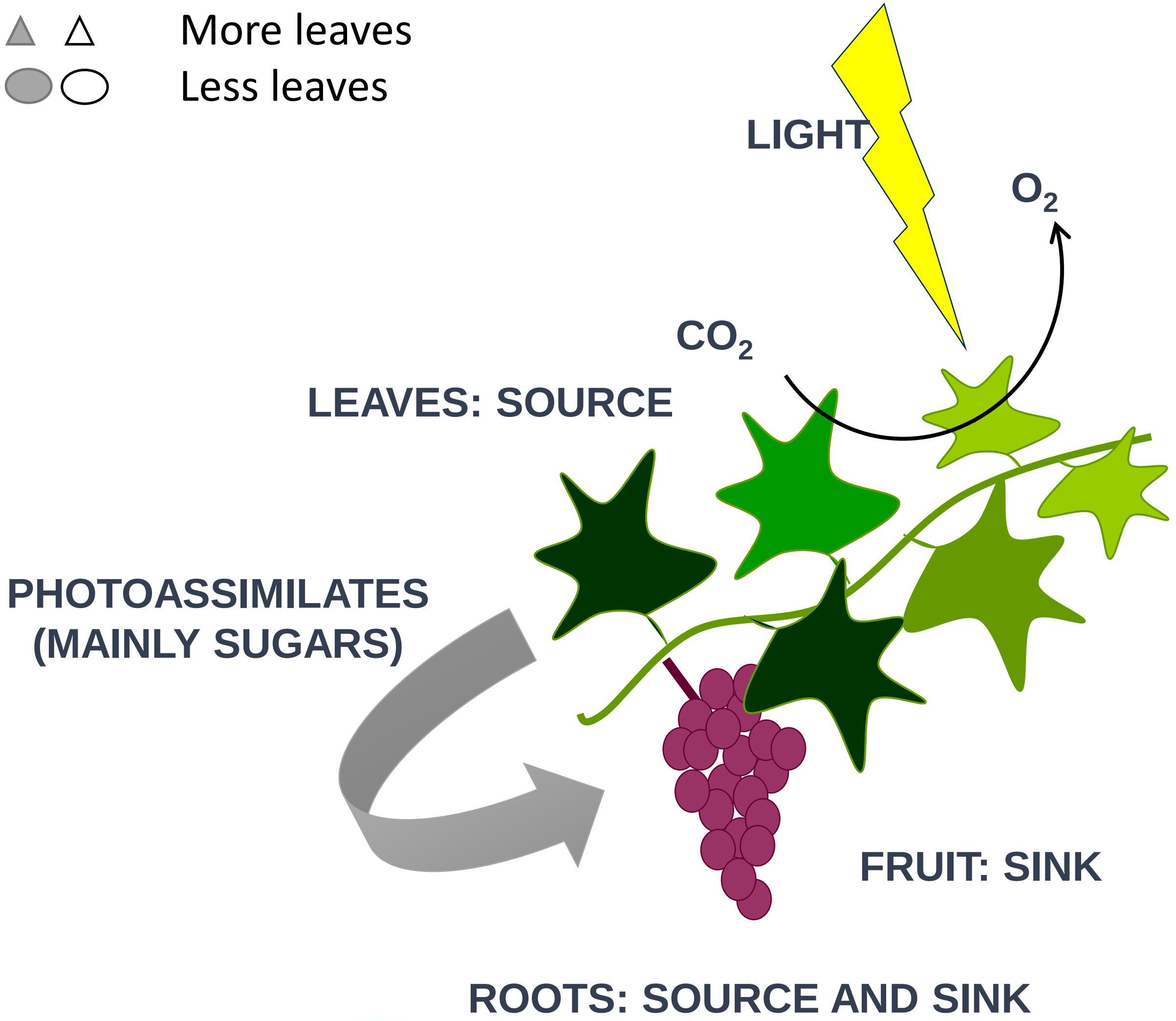


Kurtural et al. 2003; Dami et al. 2005; Kurtural et al. 2005; 2006

UC DAVIS

ROLE OF CANOPIES: To fix Carbon – Make Sugar!





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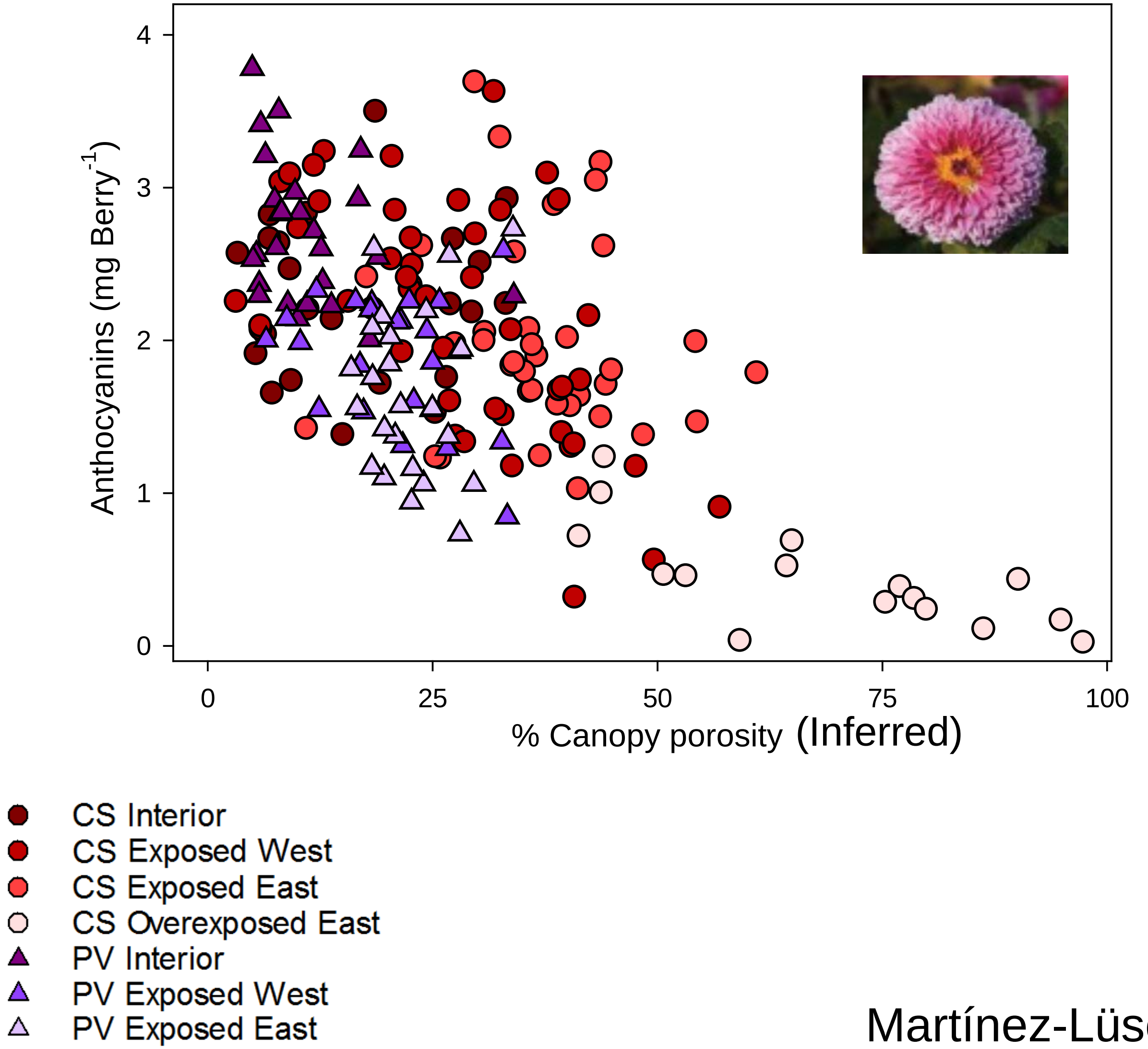
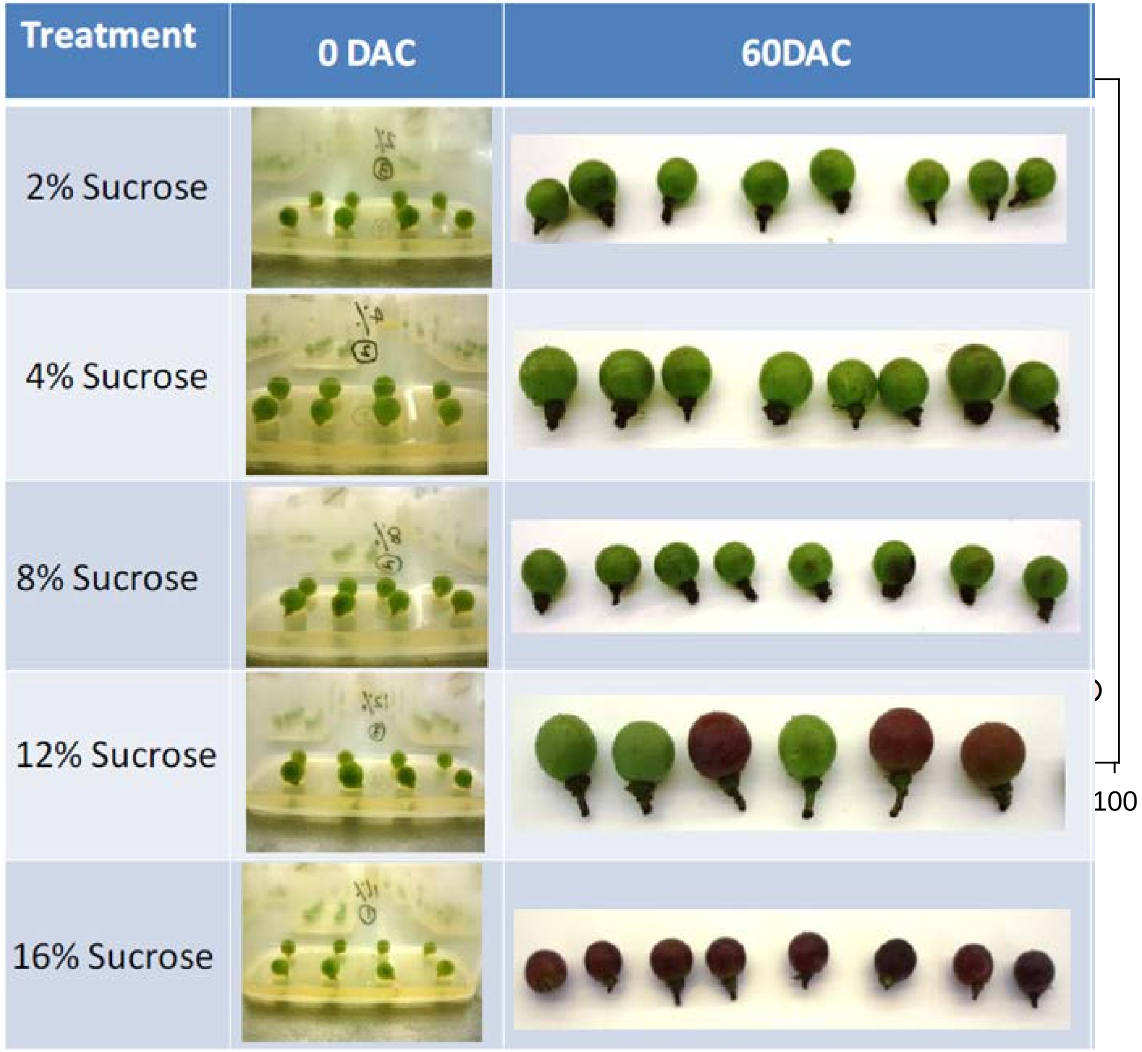
Martinez-Luscher et al., 2015 Plant Science

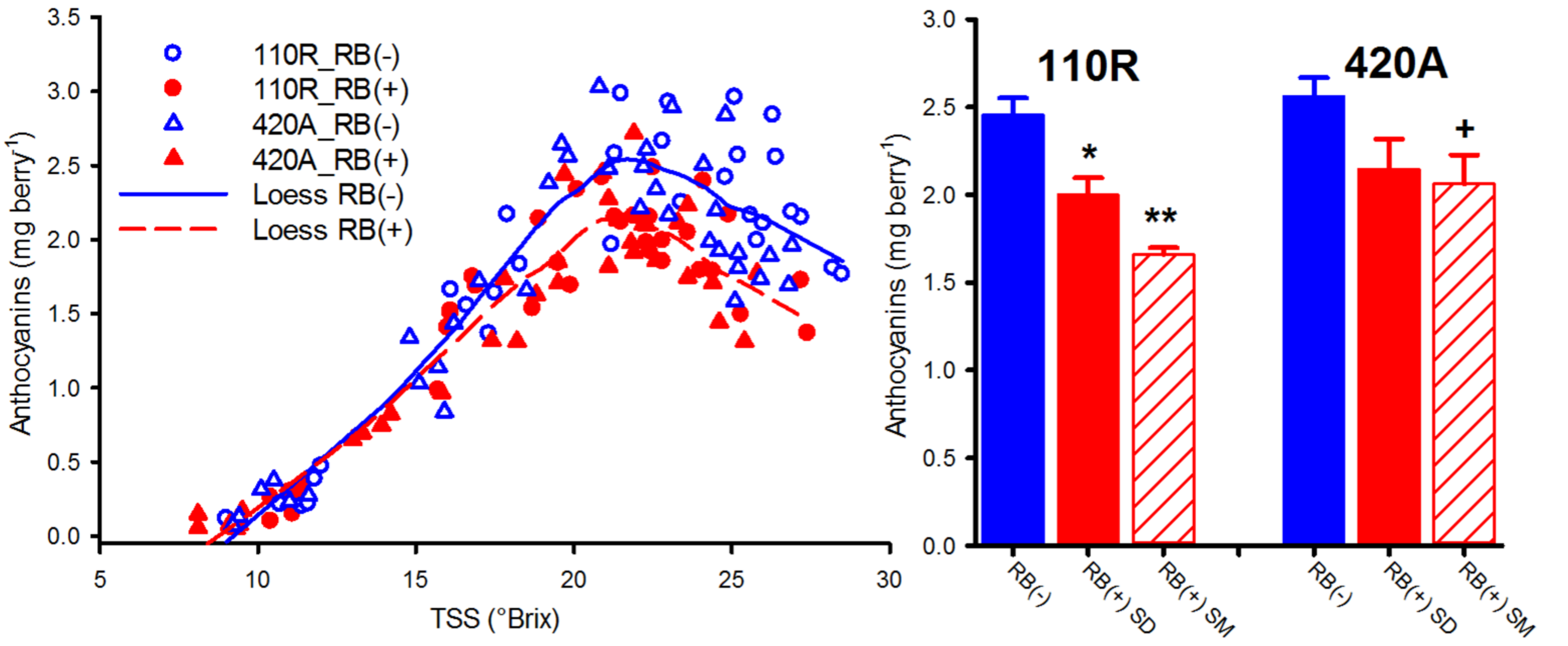
EXPOSURE TO SOLAR RADIATION IS NOT NECESSARY TO REACH MAXIMUM SKIN ANTHOCYANINS





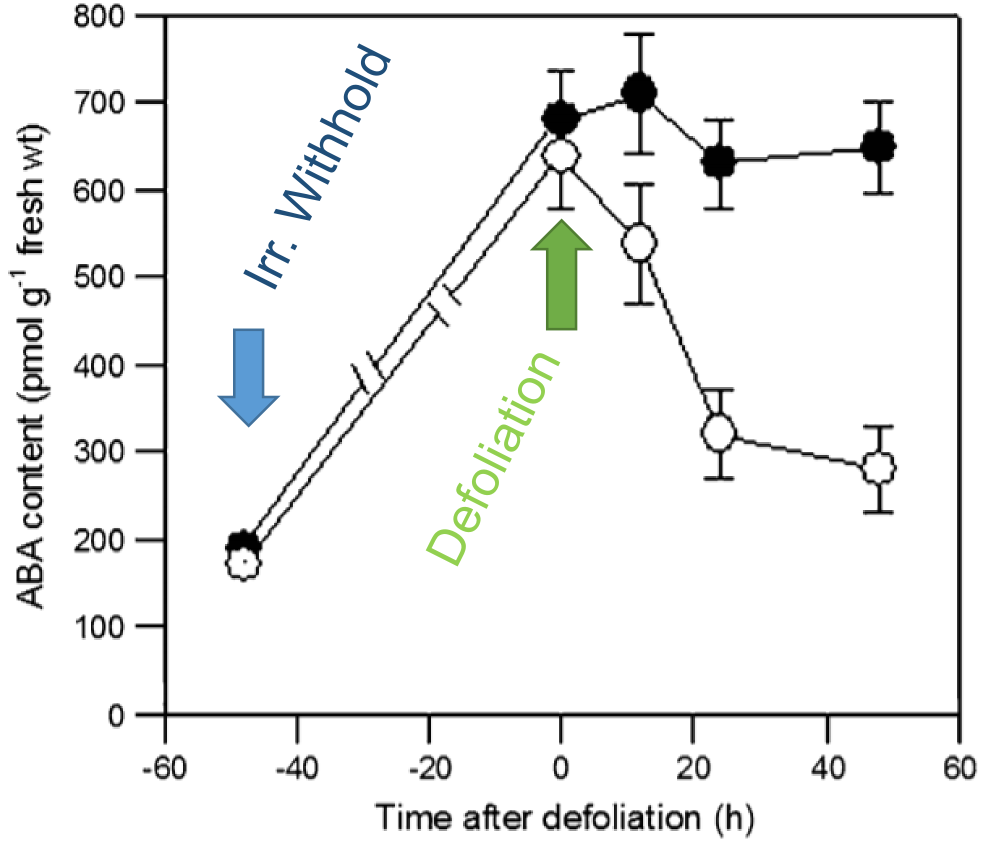
Martínez-Lüscher et al., 2019

Sugar influx kick starts anthocyanin production



ROLE OF CANOPIES:
Regulation - synthesis of ABA precursors (ripening signal)

● Deficit irrigation
○ Leaf removal



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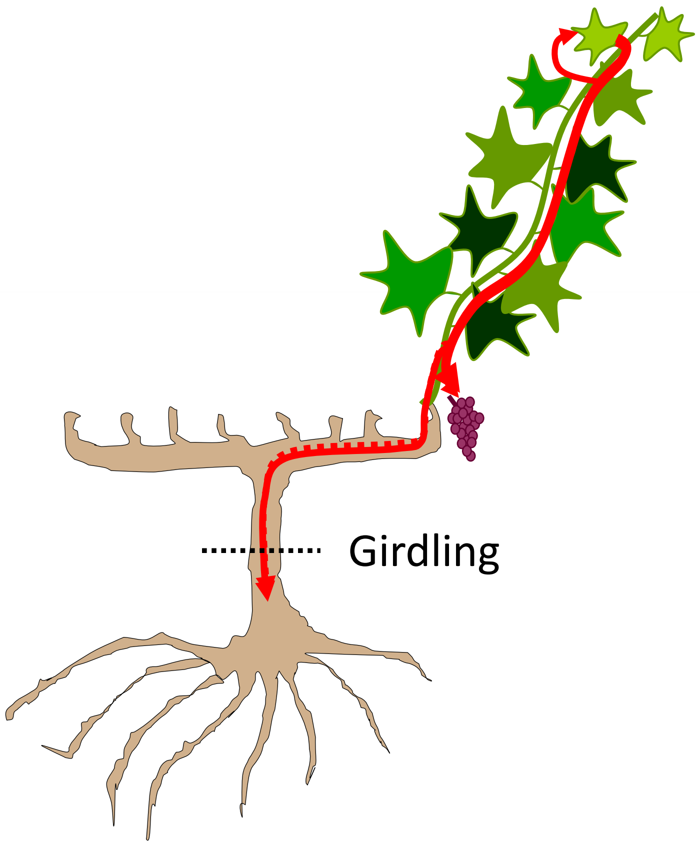
Ren et al., 2007 J. Exp. Bot.

How do photoassimilates travel within the plant?

Table IV. *Total Carbohydrate Content of 4-Year-Old Trunk Girdled and Control Thompson Seedless Grapevines*[a]

Vine Organ[b]	June 3		June 18	
	Control	Girdled	Control	Girdled
	g carbohydrate/vine[c]			
Clusters	39	61	128 a	236 b
Leaves	78 a	219 b	84	120
Stems	61	82	65	106
Canes	22	43	26	46
Trunk	79	70	84	77
Roots	197	105	261 a	157 b
Vine total	476	580	648	742



Roper and Williams, 1989 Plant Phys.

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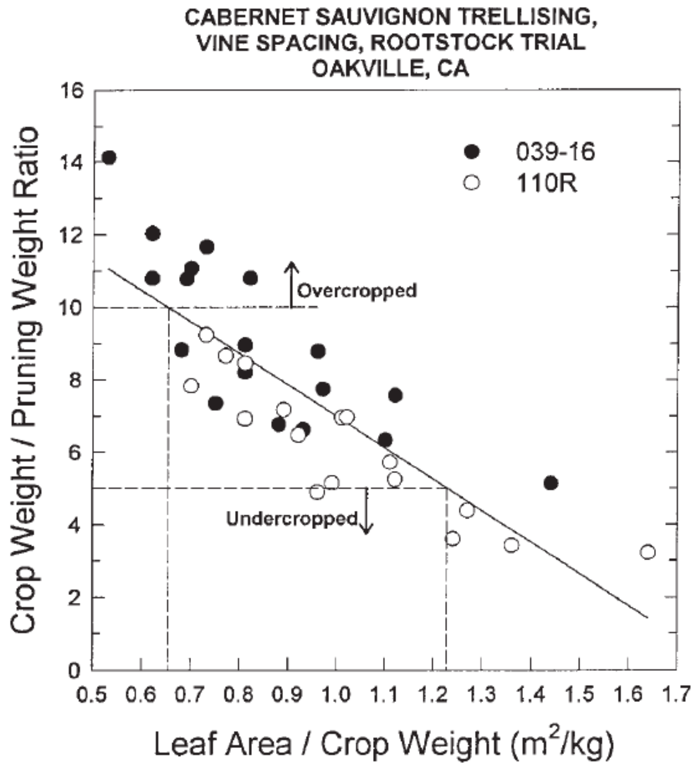
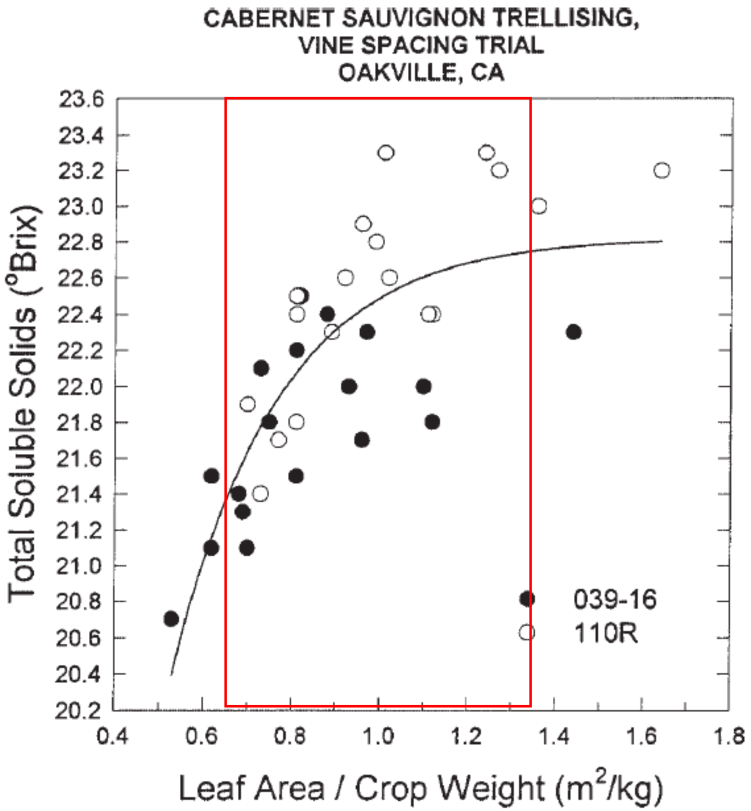
Leaf area:Fruit Ratio or Ravaz Index: INTERCHANGEABLE





<0.65 m2/Kg → 10 Ravaz → Over cropped
>1.23 m2/Kg → 5 Ravaz → Under cropped

Kliewer and Dokoozlian, 2005 AJEV; Bravdo et al., 1984 and 1985 AJEV

YIELDS IN WINE GRAPE

LETS DROP LESS FRUIT…
…NOT SO SIMPLE

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THERE IS AN APPARENT TRADE OFF BETWEEN YIELDS AND QUALITY

YIELDS AS A MULTIPLIER OF REVENUE

District X

1,300,000 tons

$380M

$300 a ton

77,000 Acres

16 tons/acre

5000 $/acre

600 Vines/acre

QUALITY AS A MULTIPLIER OF REVENUE

District Y

140,000 tons

$683M

$5000 a ton

45,000 Acres

3.1 tons/acre

15,300 $/acre

800 Vines/acre

Source: Grape Crush report (Approximate data)

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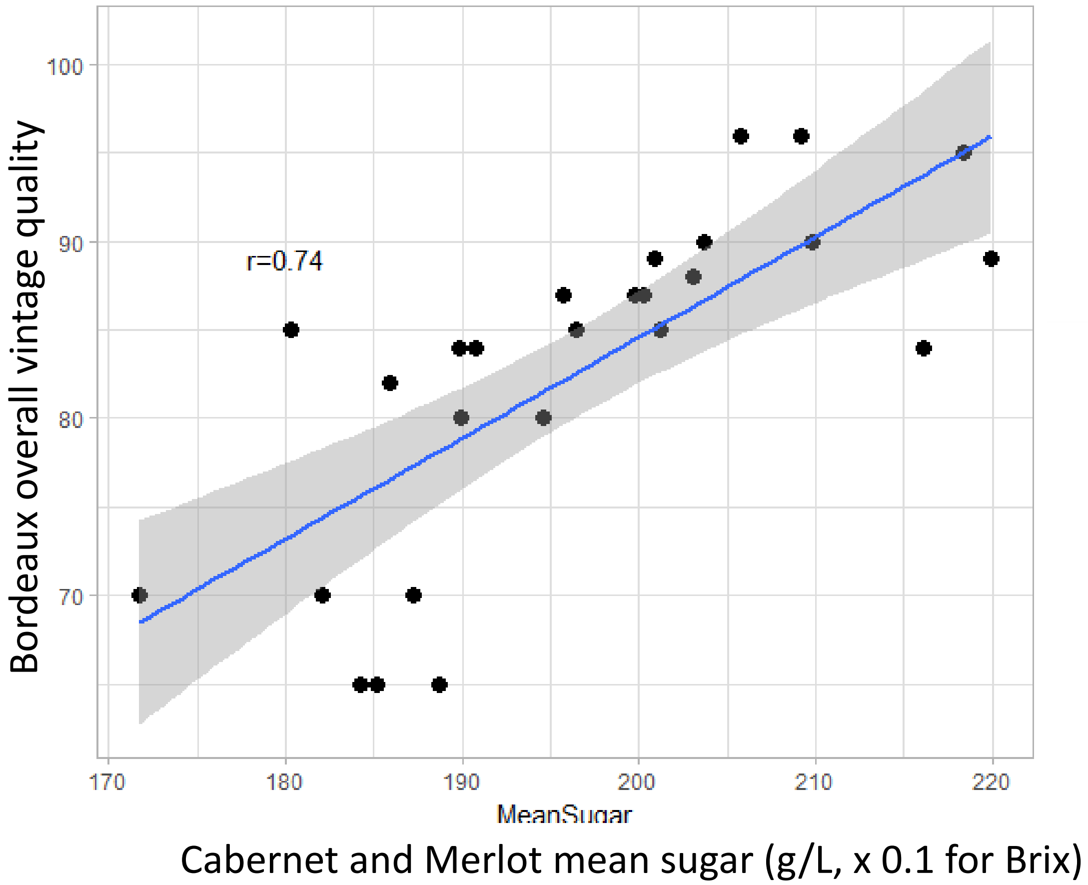
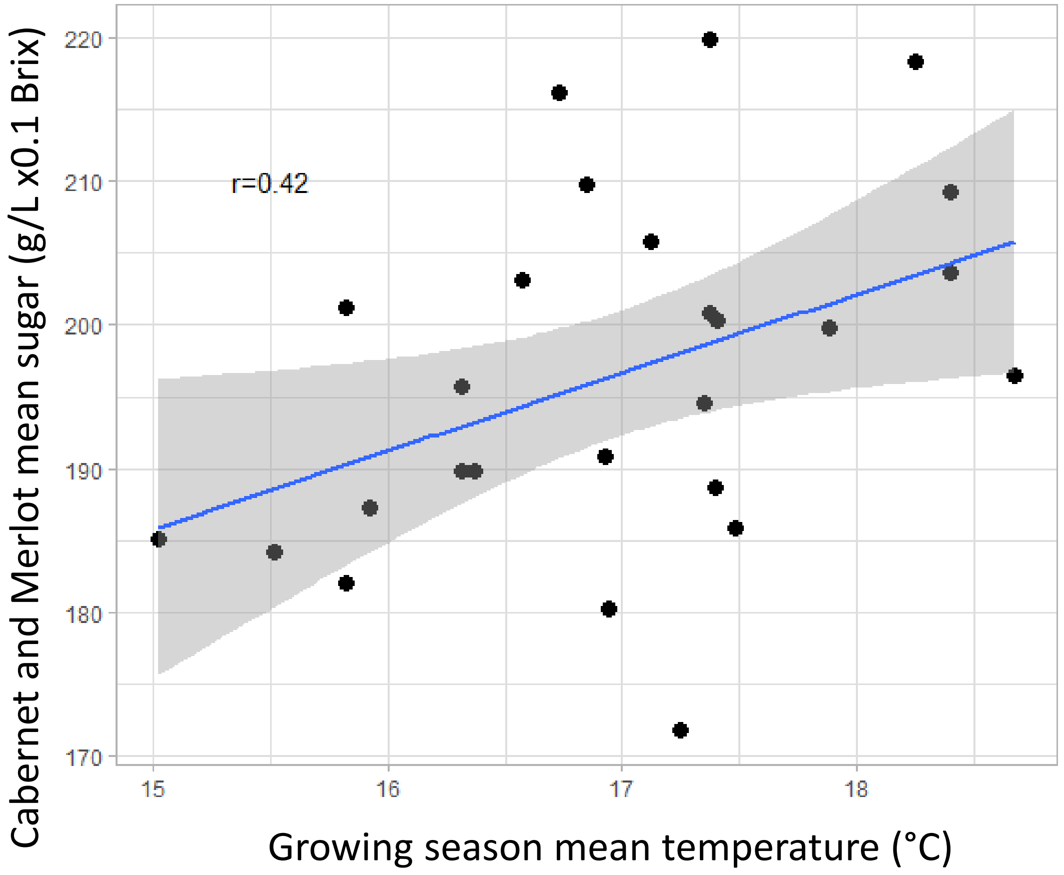
Wine Grape quality is an extremely complex topic:

- 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

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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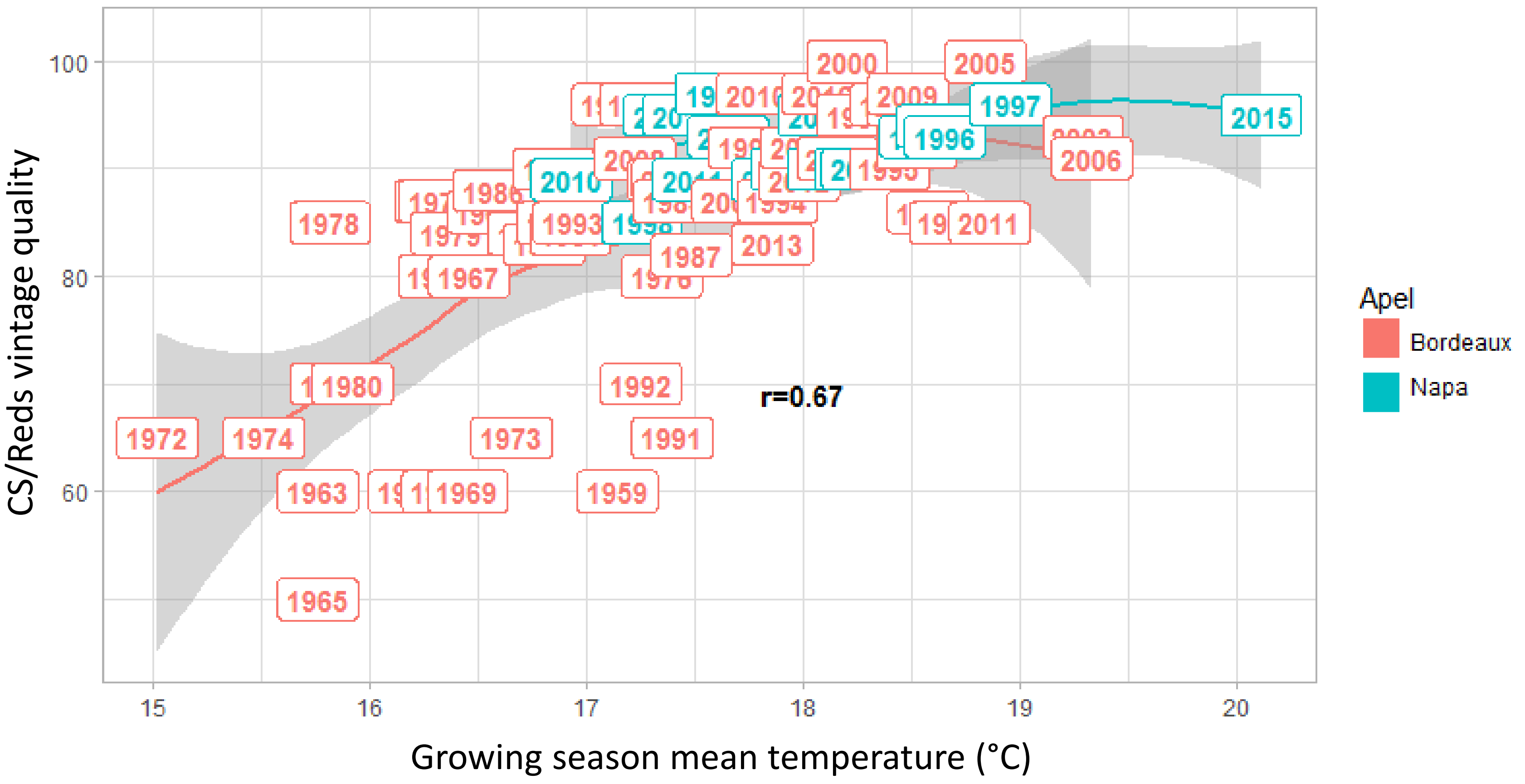
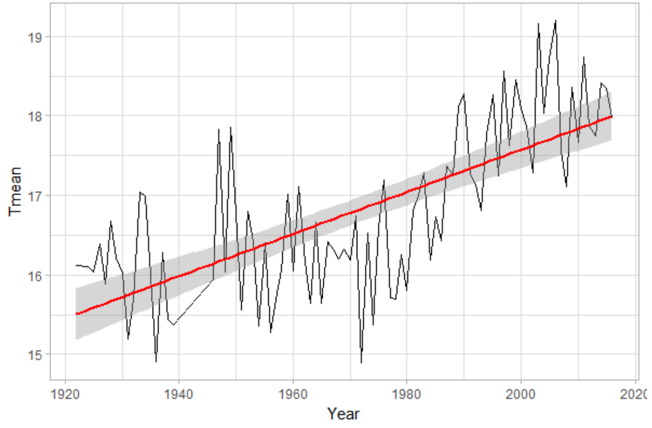


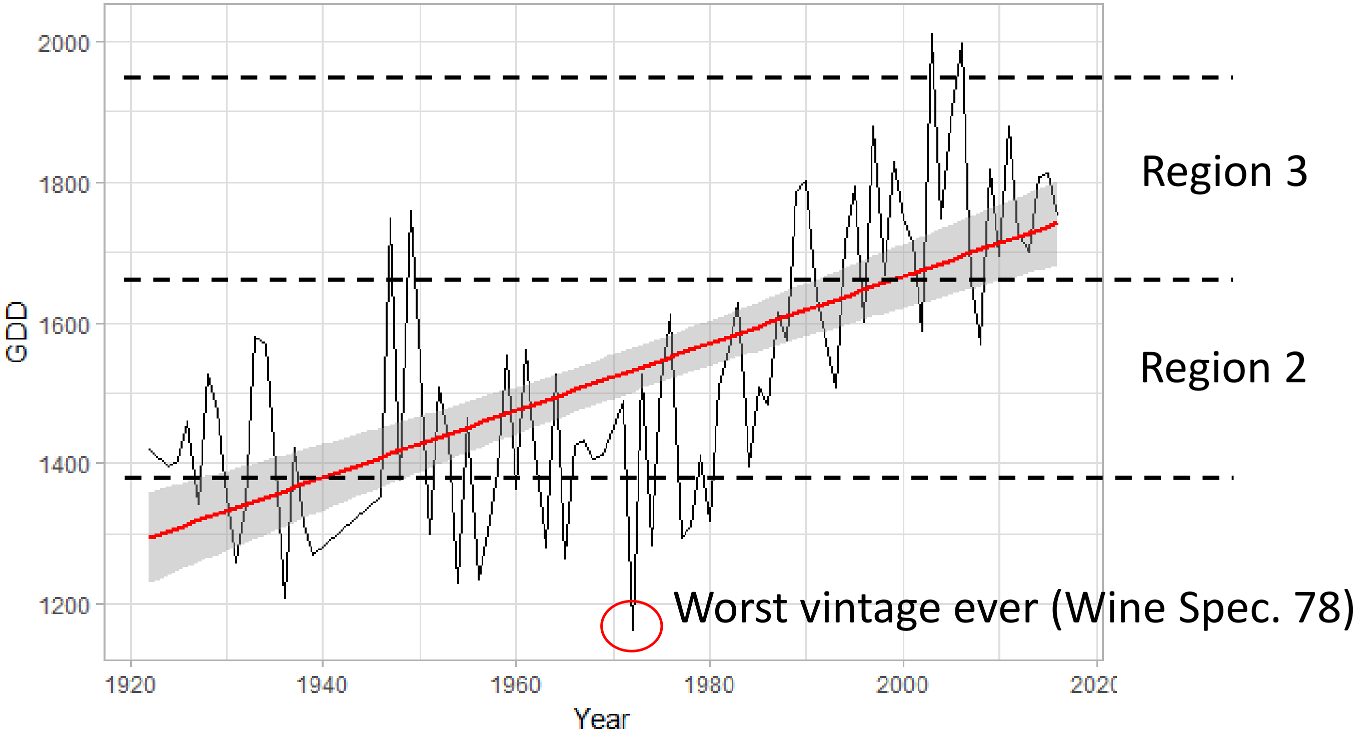
60F 61F 63F 64 F 66F 68F

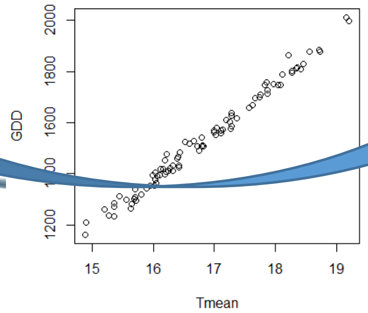
Although temperature is key for sugar. Harvest precocity can be also based on sudden events that force the decision of picking

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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Experimental Design

Pre treatment: laterals removed and vines adjusted to 22 shoots per vine in 6m

	33% of fruit kept	66% of fruit kept	100%: ~45 clusters
33%: of leaves kept			
66% of leaves kept			
100% of leaves kept			

Oakville 2018 – CS on 110R – 10 years old – 2m by 2.4 m – Relaxed VSP

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Treatment application
(~Mid June)

Peppercorn size

Laterals removed in all vines

33% of fruit

33%: 2/3 of leaves removed

100% of fruit

100% of leaves
(only laterals removed)

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Treatment application

33% of fruit

33%: 2/3 of leaves removed

100% of fruit (no secondary)

100% of leaves
(only laterals removed)

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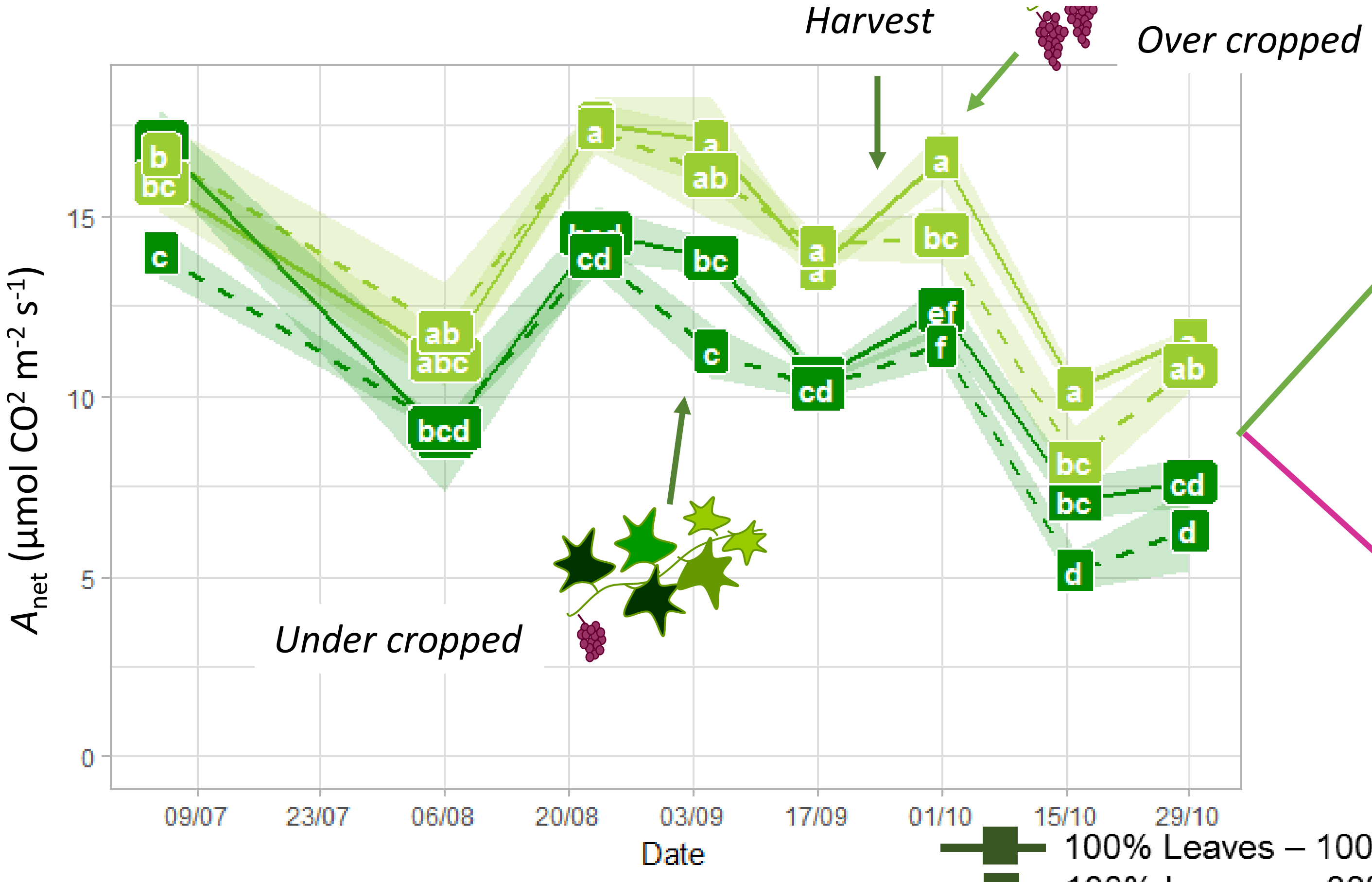
Leaf area determines carbon fixation: NOT FRUIT

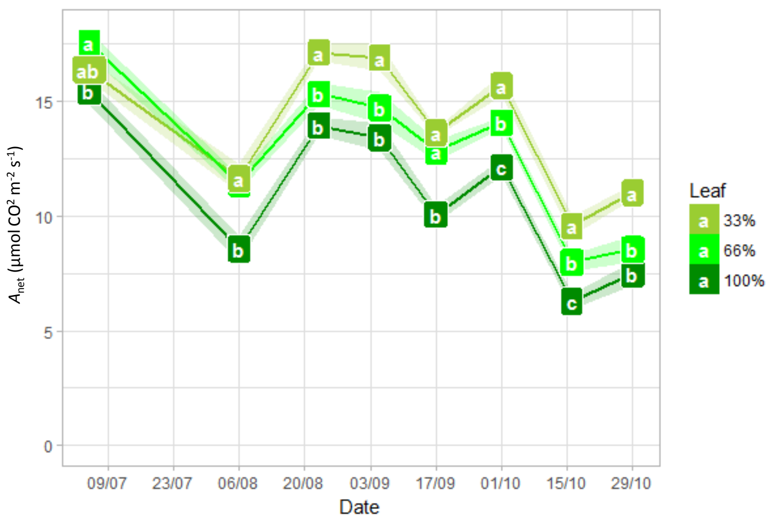
(net photosynthesis)



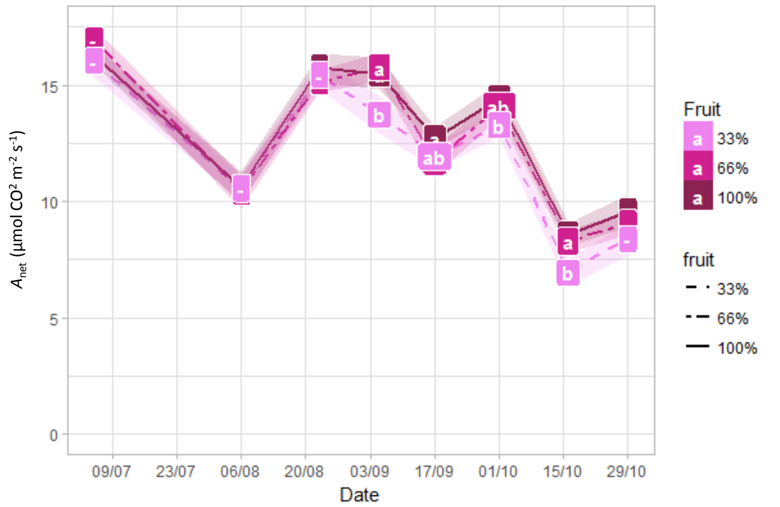
Only extreme treatments plotted

Main effects in Two-way ANOVA (post hoc)

Effect of defoliation

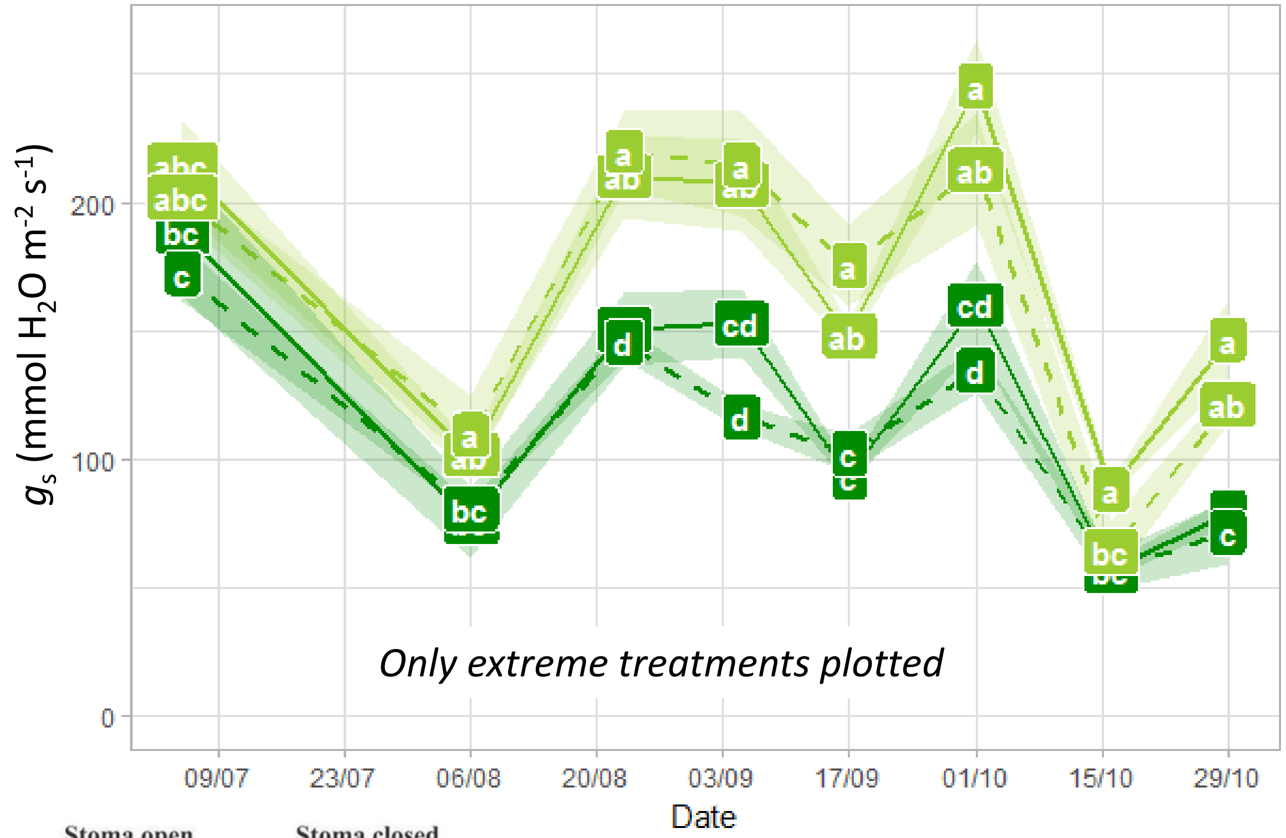


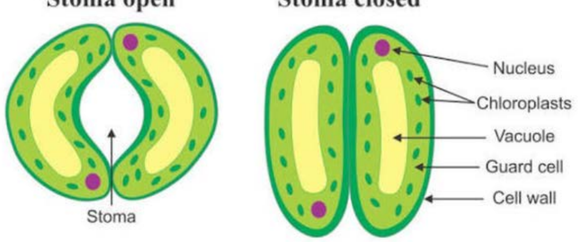
Effect of crop load



Leaf area determines plant water status NOT FRUIT

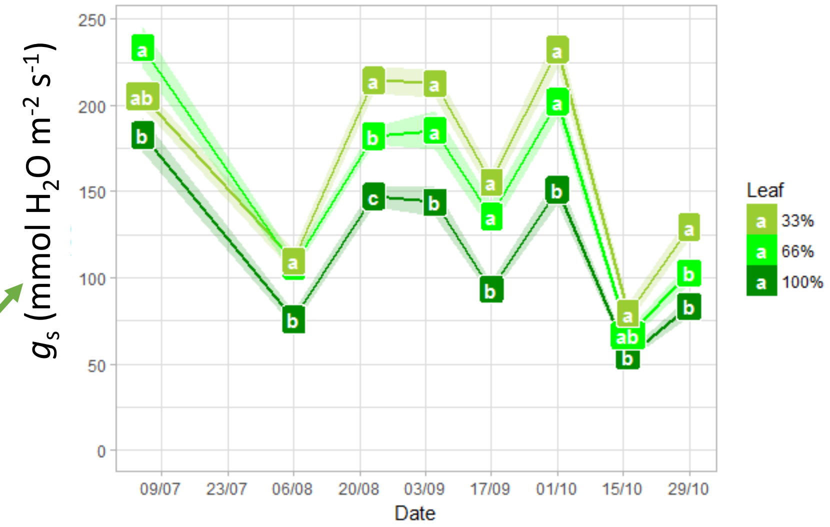
Combination treatments



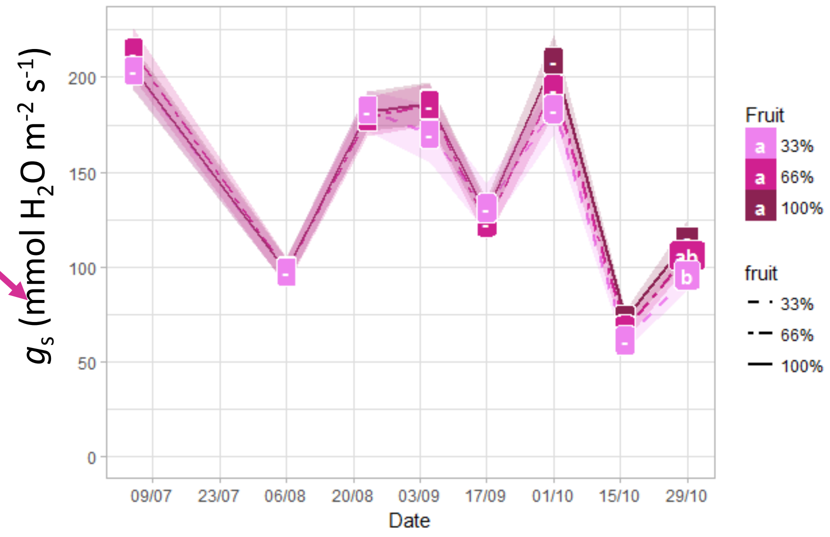


Main effects in Two-way ANOVA

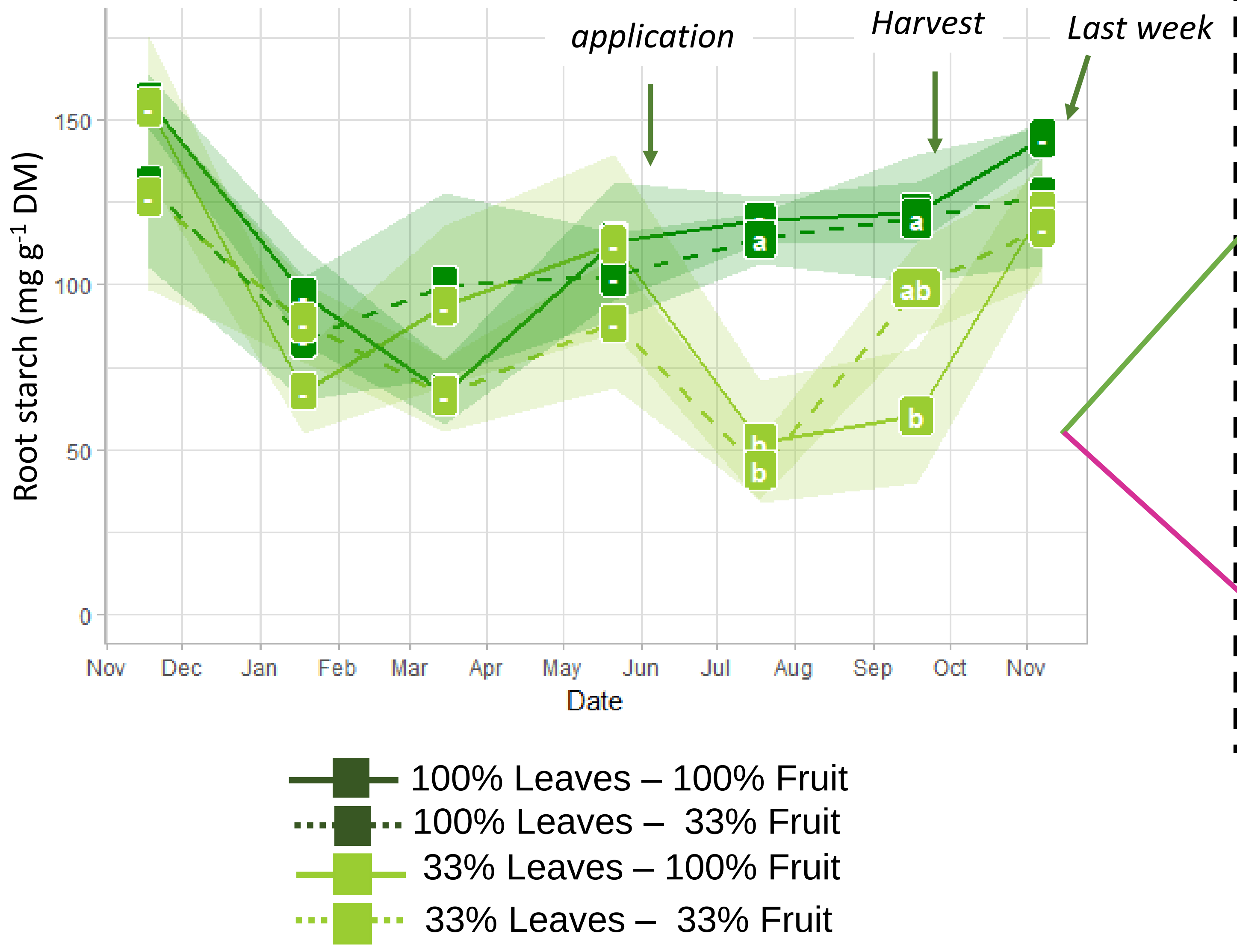
Effect of defoliation



Effect of crop load

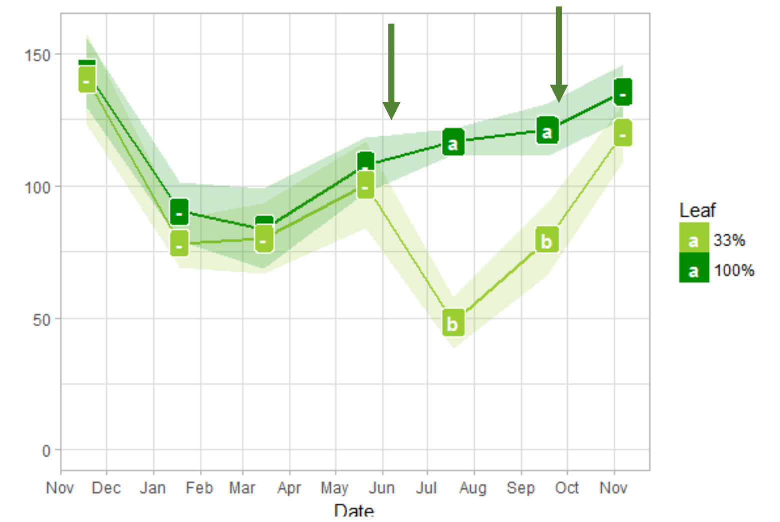


Leaf area determines plant reserves: NOT FRUIT

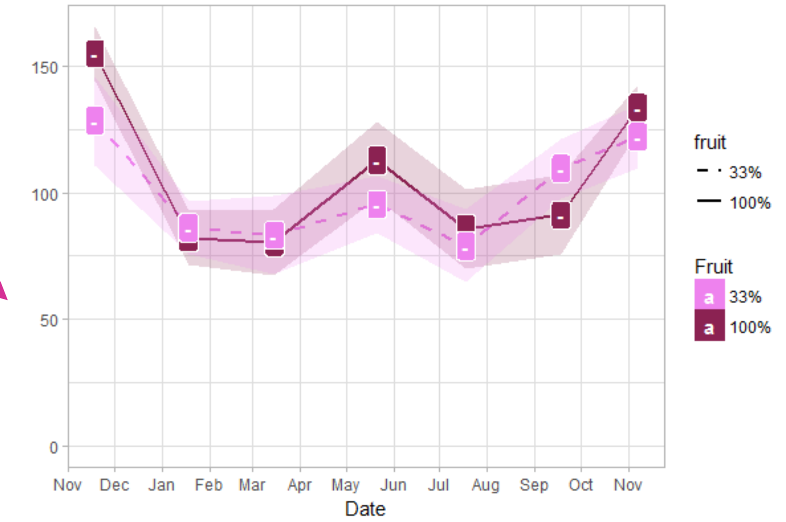


Main effects in Two-way ANOVA

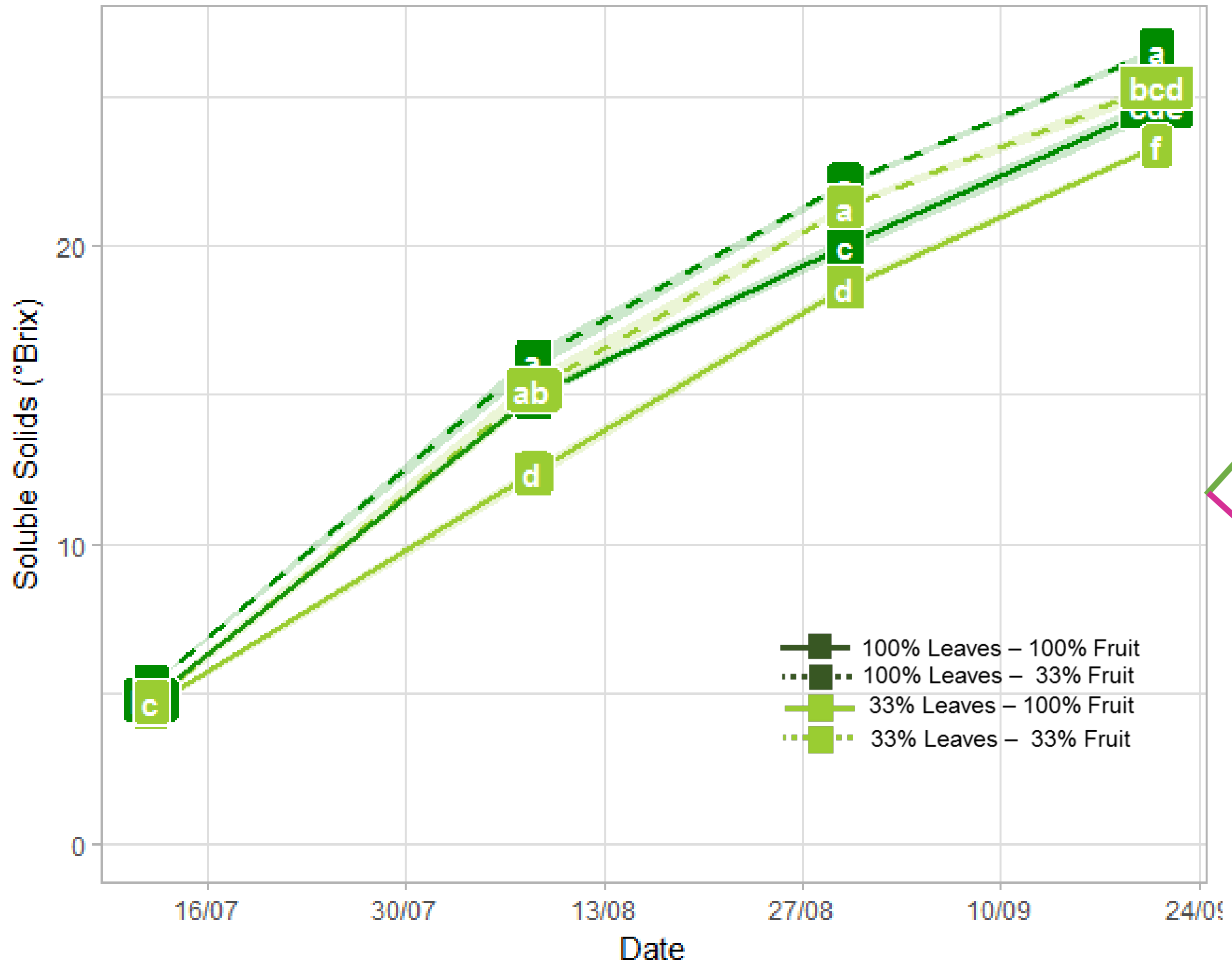
Effect of defoliation



Effect of crop load



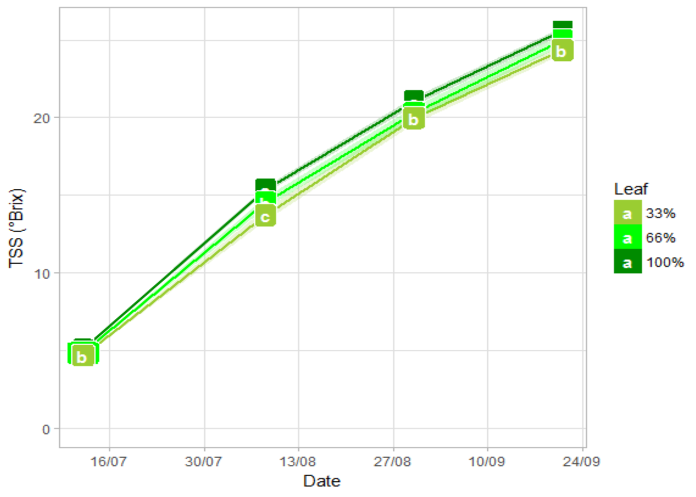
Leaf area:fruit determines speed of ripening



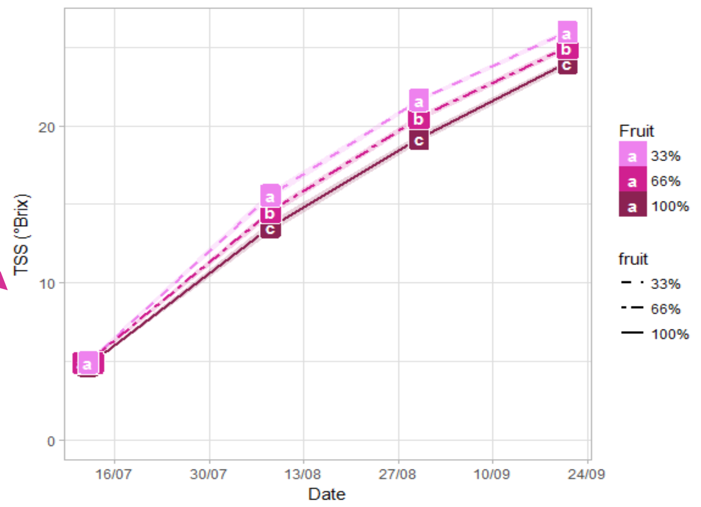
Only extreme treatments plotted

Main effects in Two-way ANOVA

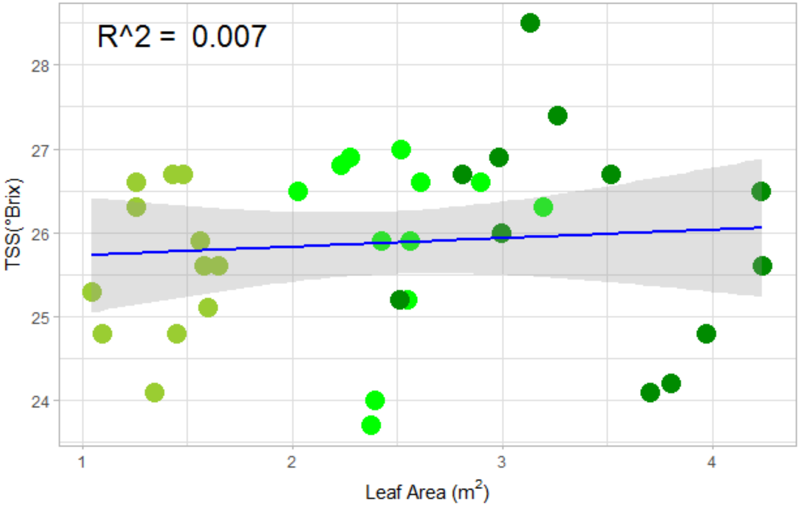
Effect of defoliation

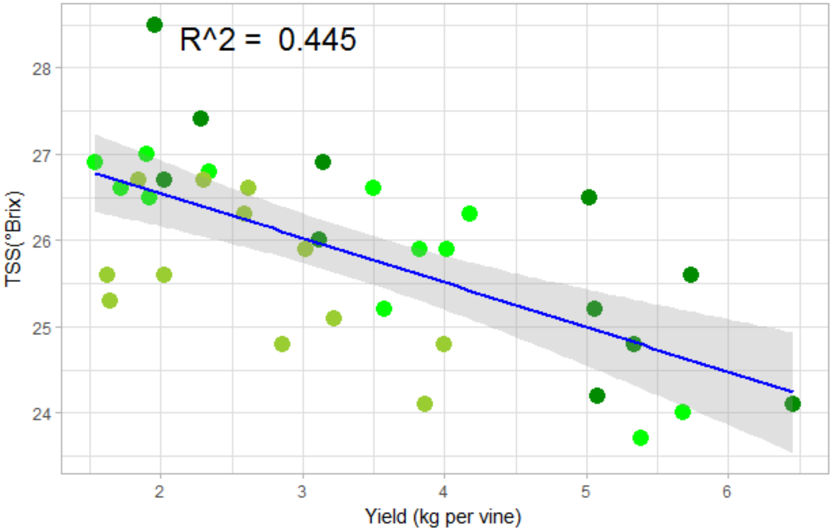


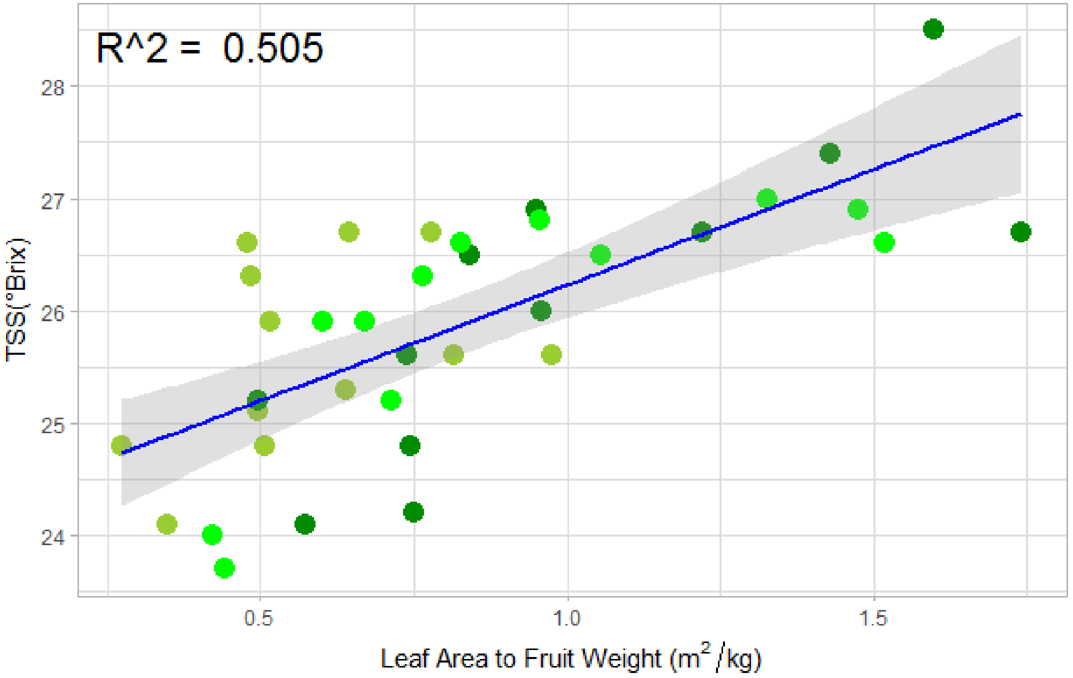
Effect of crop load

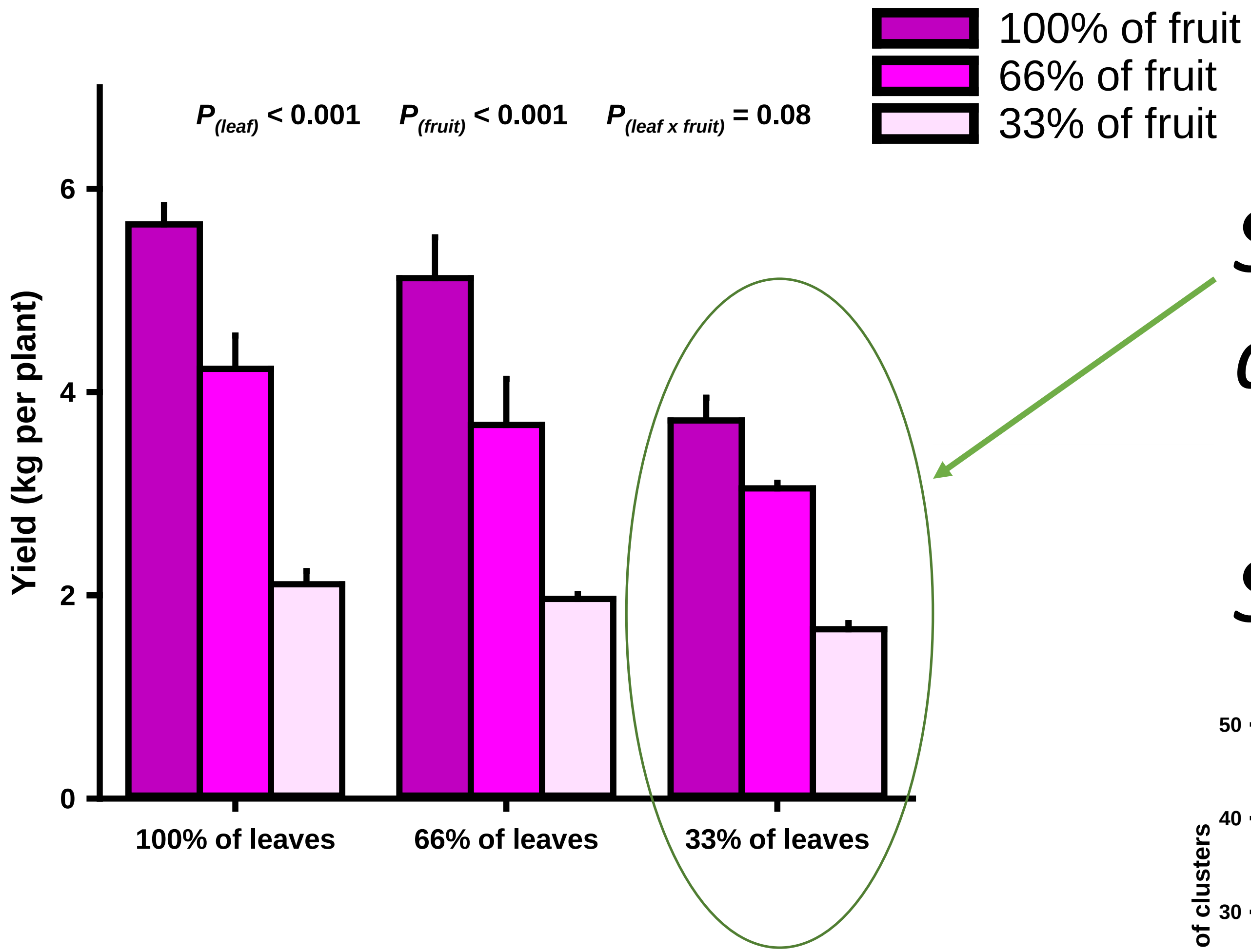


Time to reach a desired Brix: Determined by Leaf area:Fruit Ratio



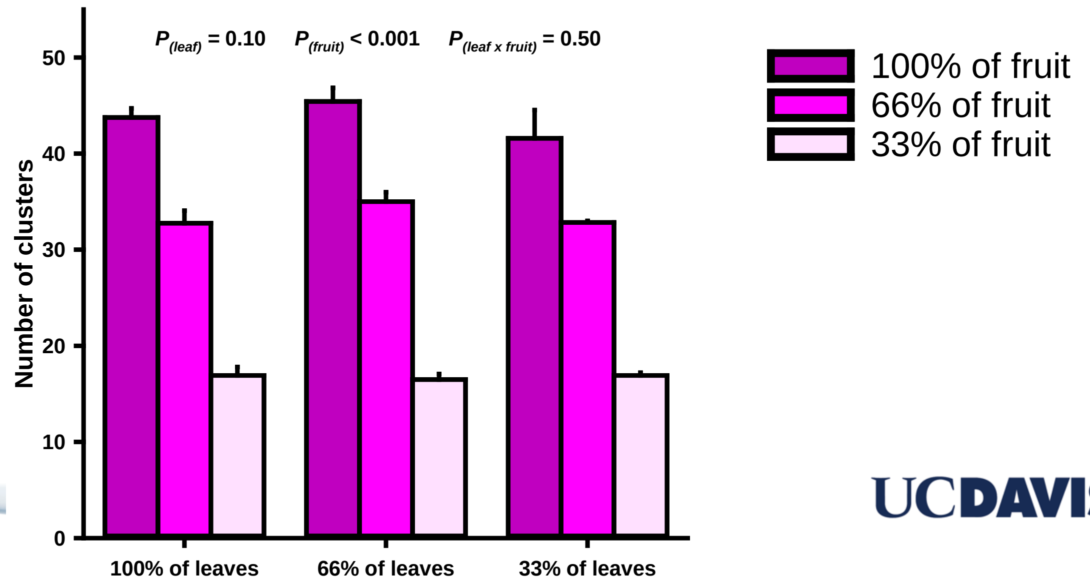




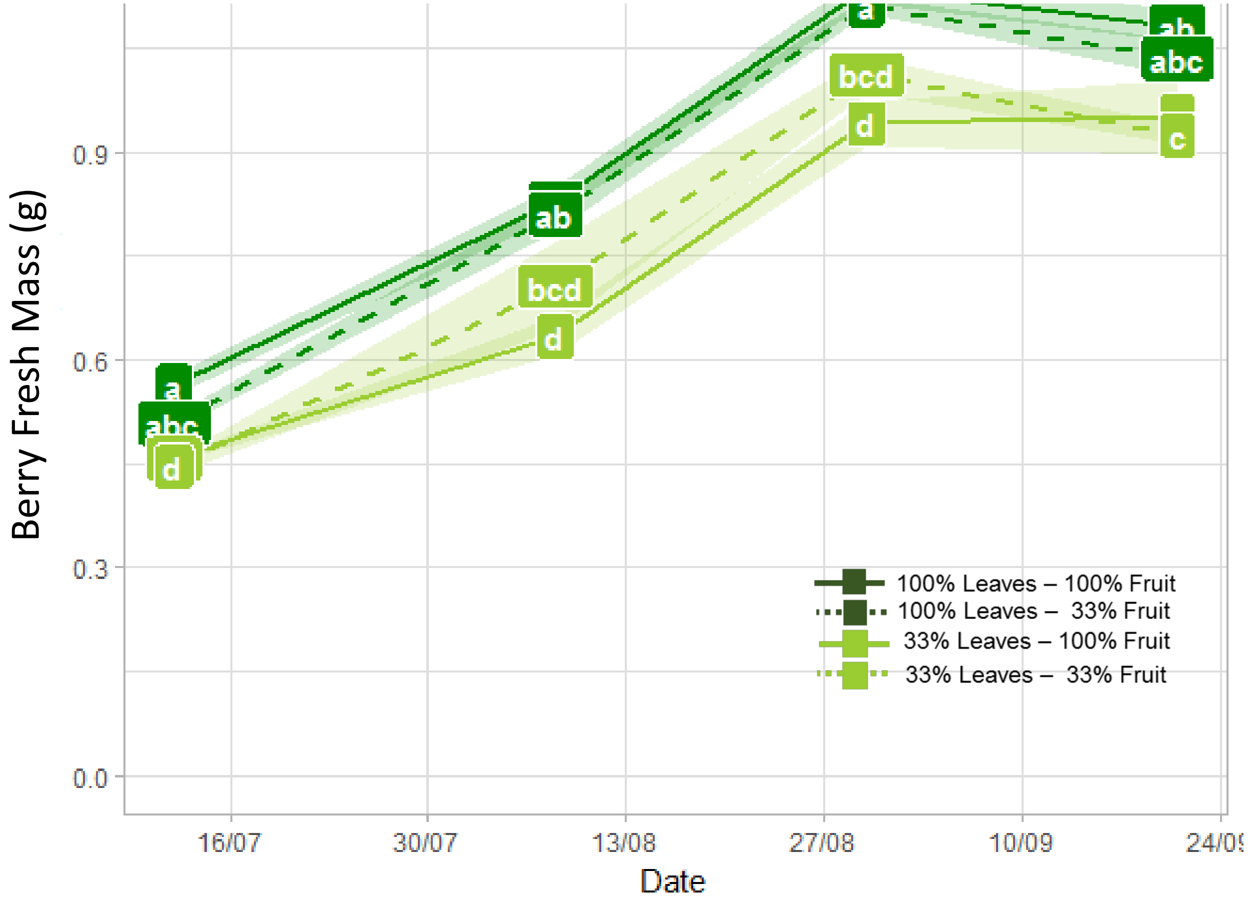


Self adjustment of yields due to “carbon starvation”

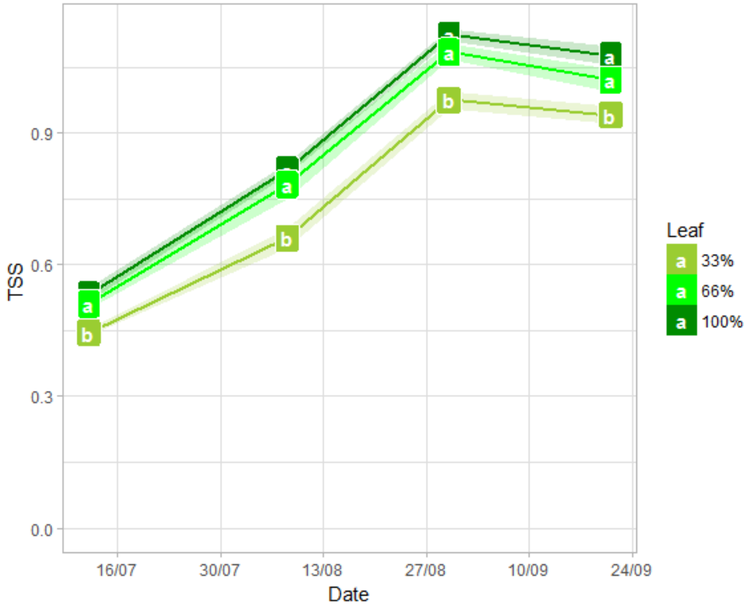
Small canopy → lower yield

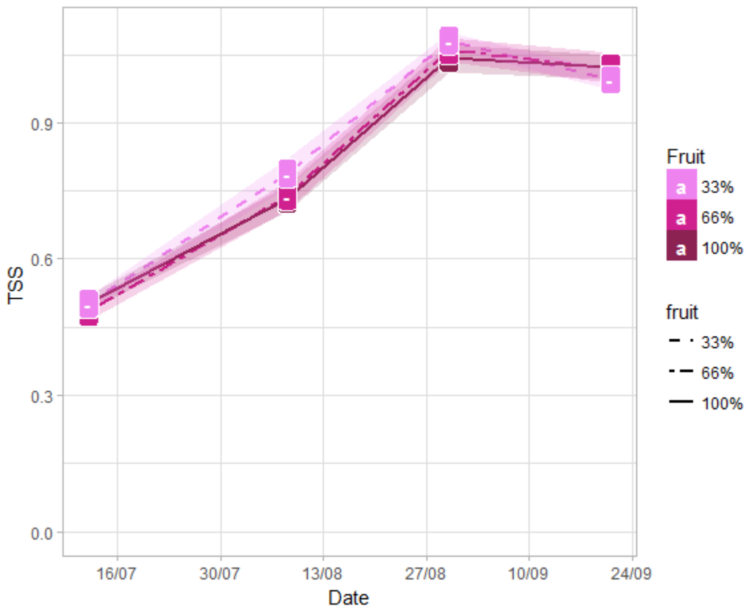


Berry size determined by leaf area: NOT FRUIT!



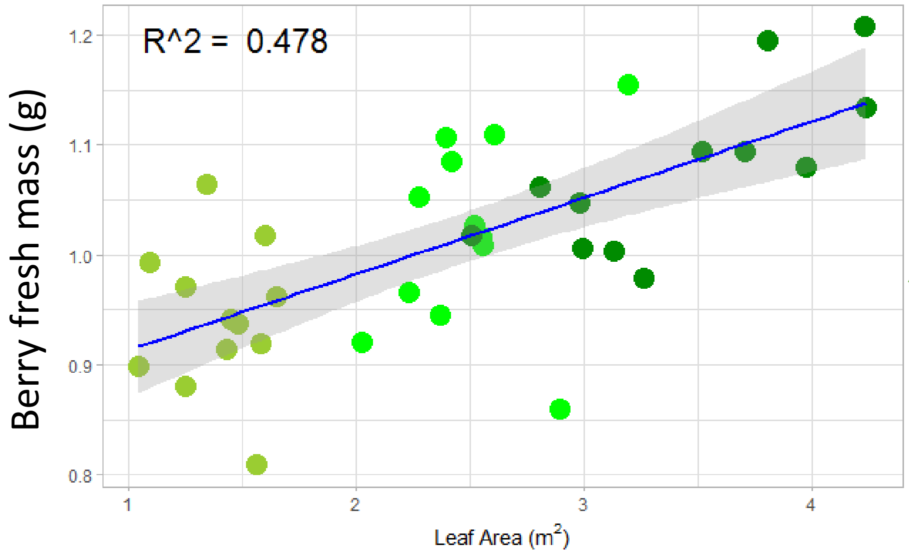
Only extreme treatments plotted

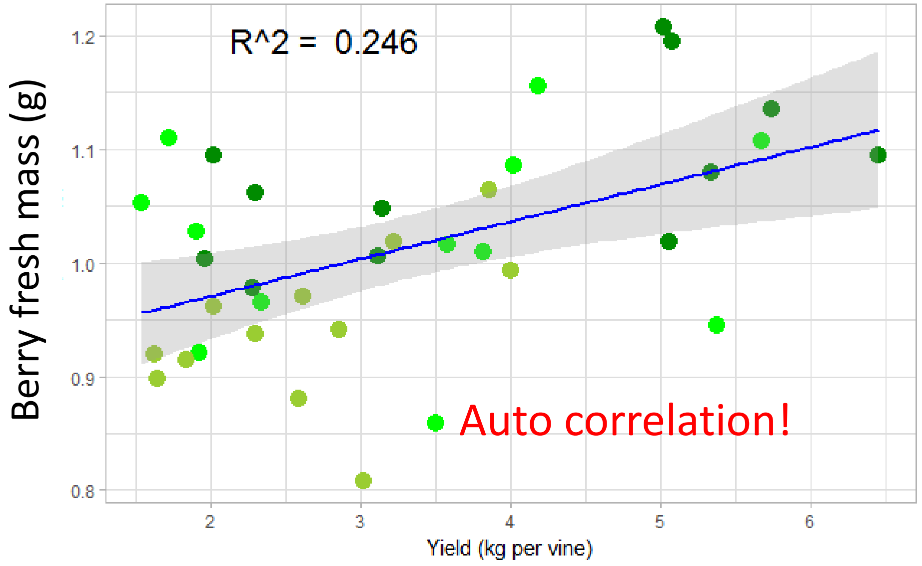


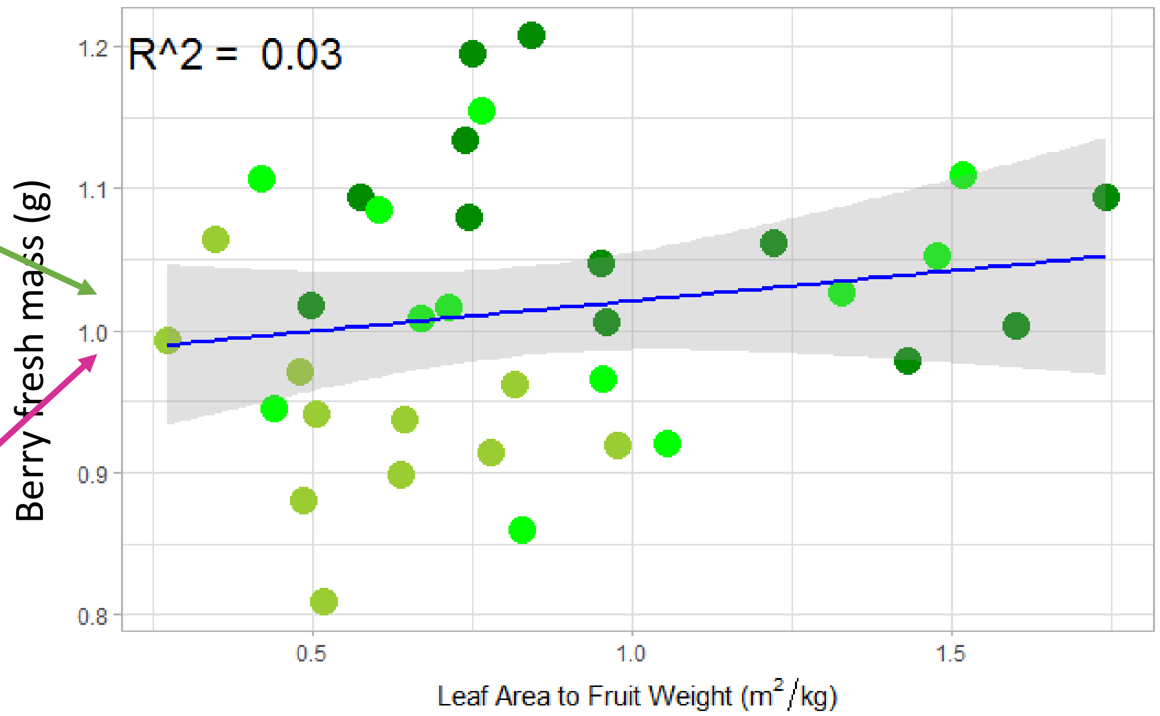


% of leaves had an effect on berry size

Berry size is determined by leaf area: NOT FRUIT

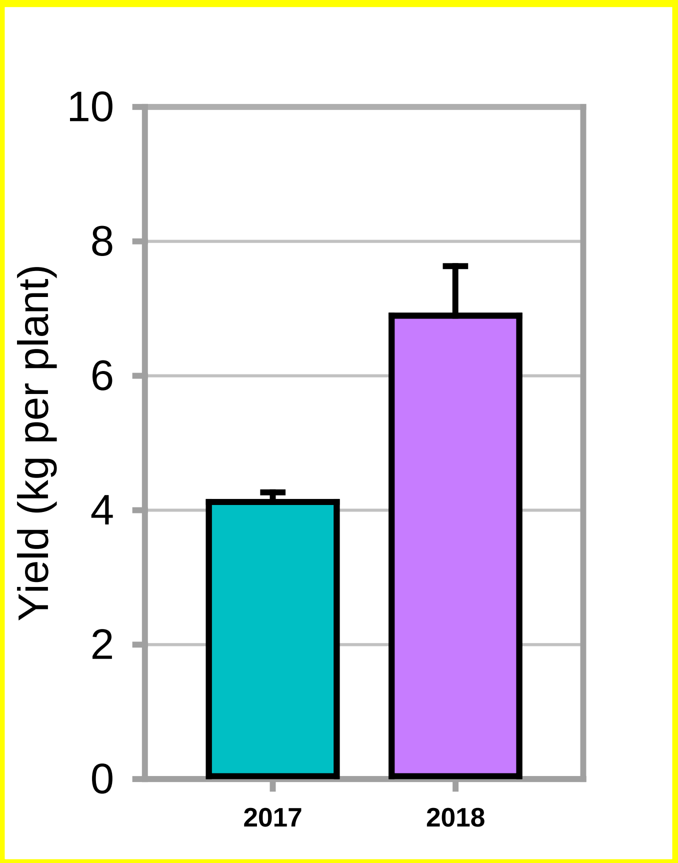






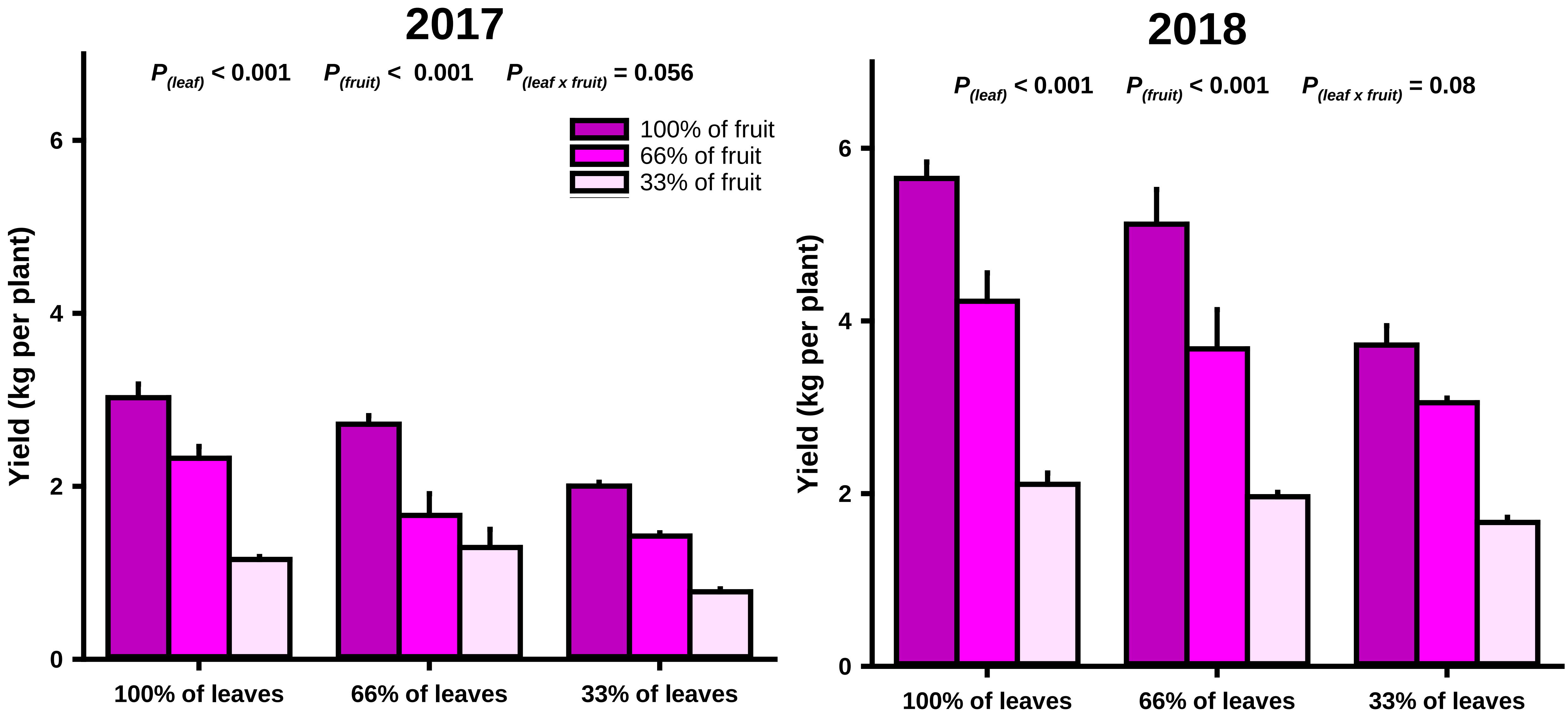
Mechanical pruning leads to smaller berries…sink competition?

Yield comparison between vintages?

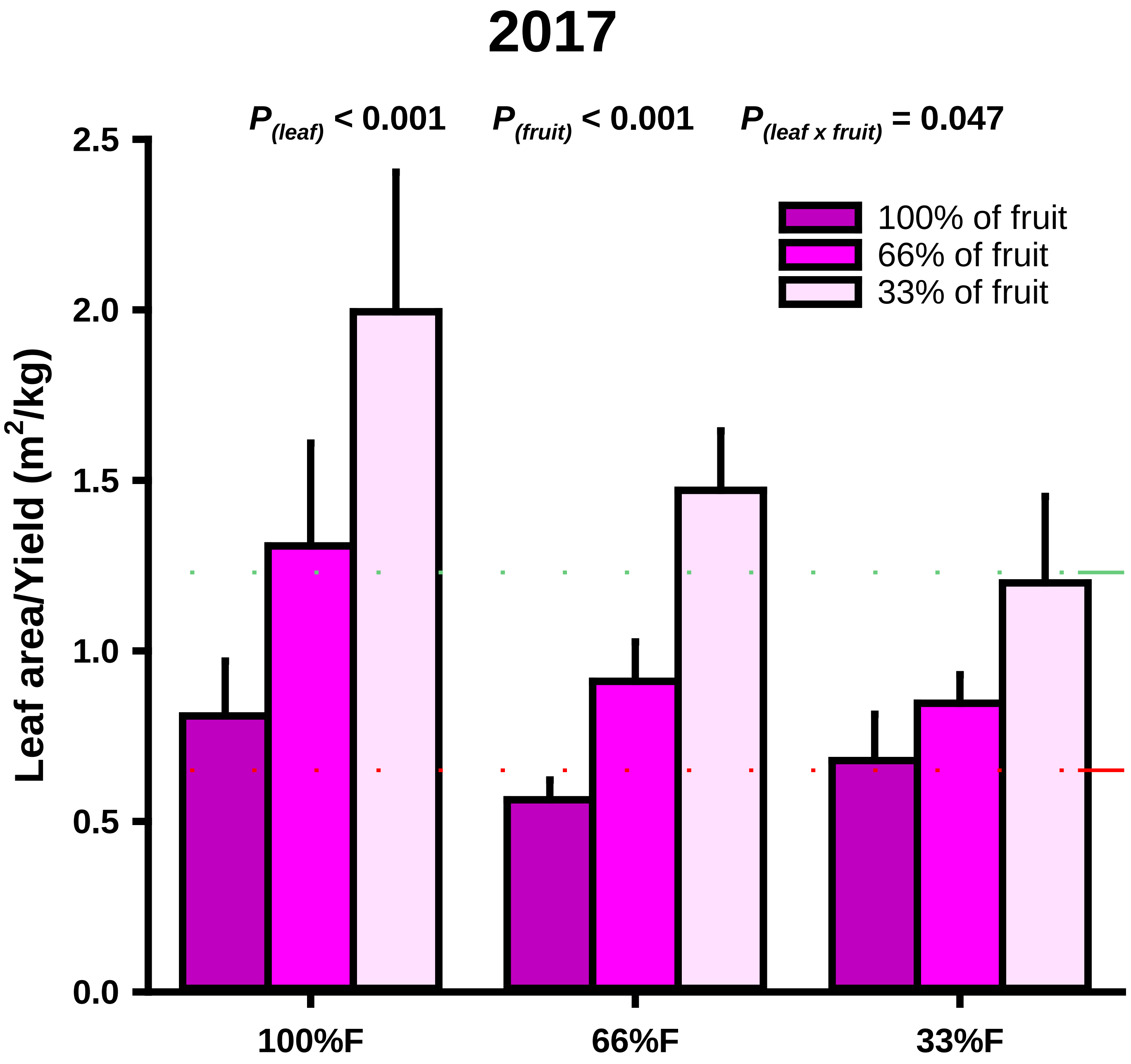


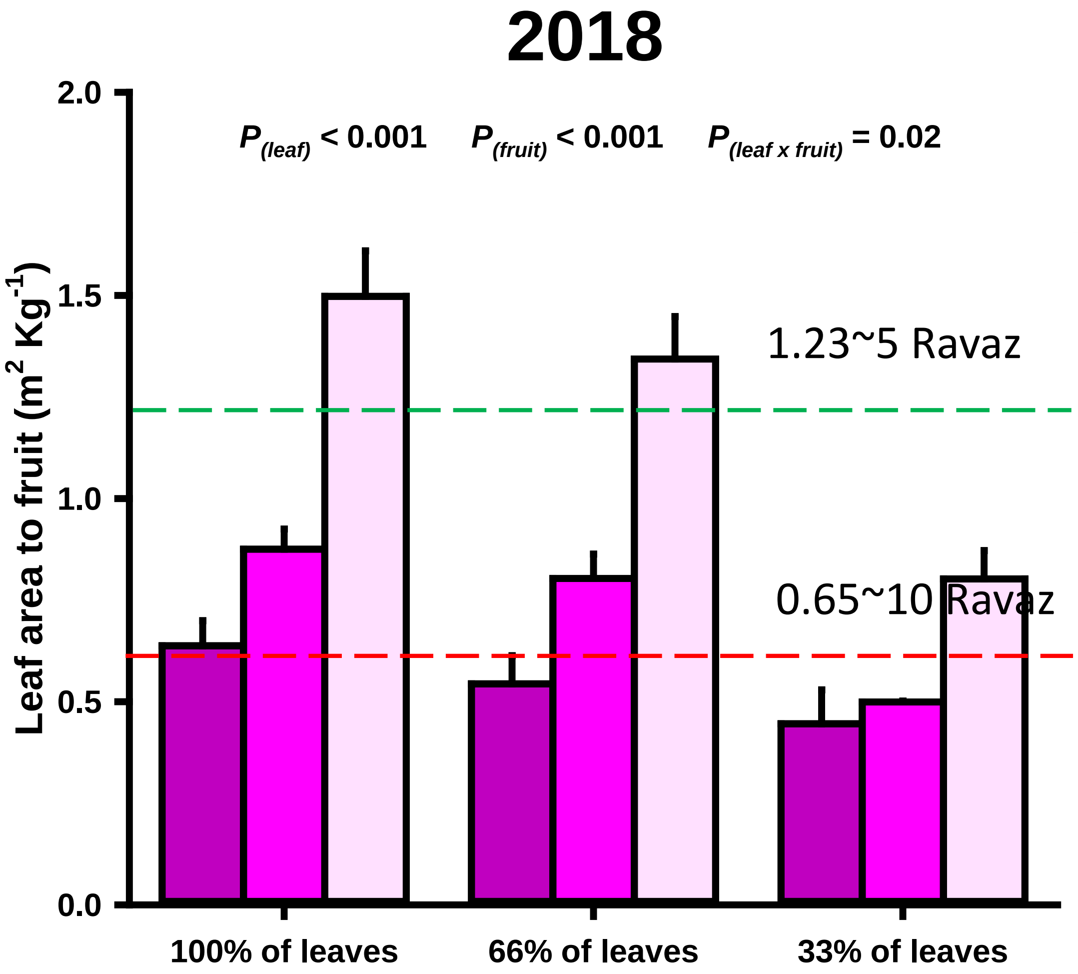
- Is this a reliable yardstick?
- There is 1.6x amount of yield in 2018

Yield comparison between vintages? Is it a reliable 'Yardstick'

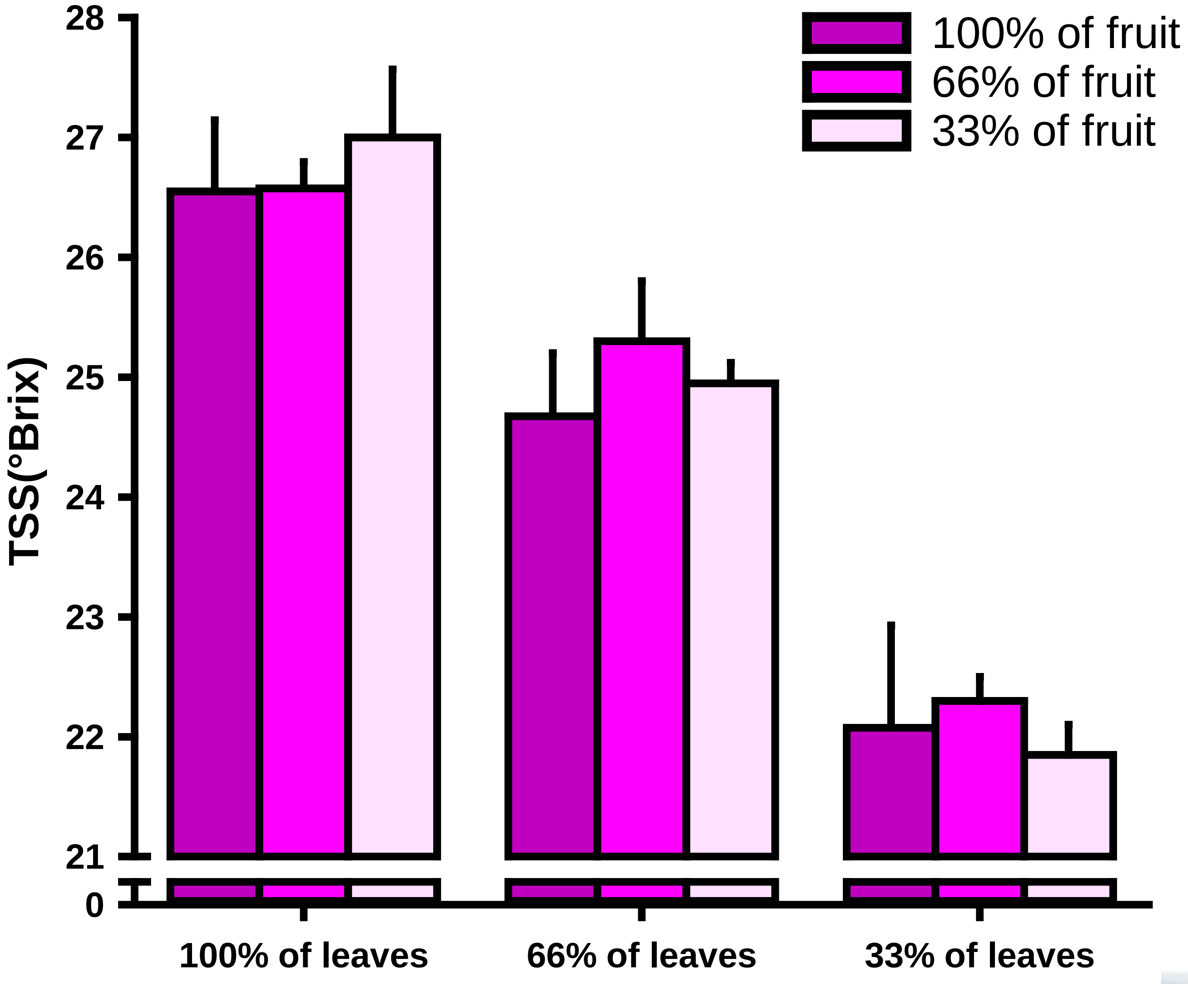


Although yields were different.
Leaf area to fruit ratio was maintained

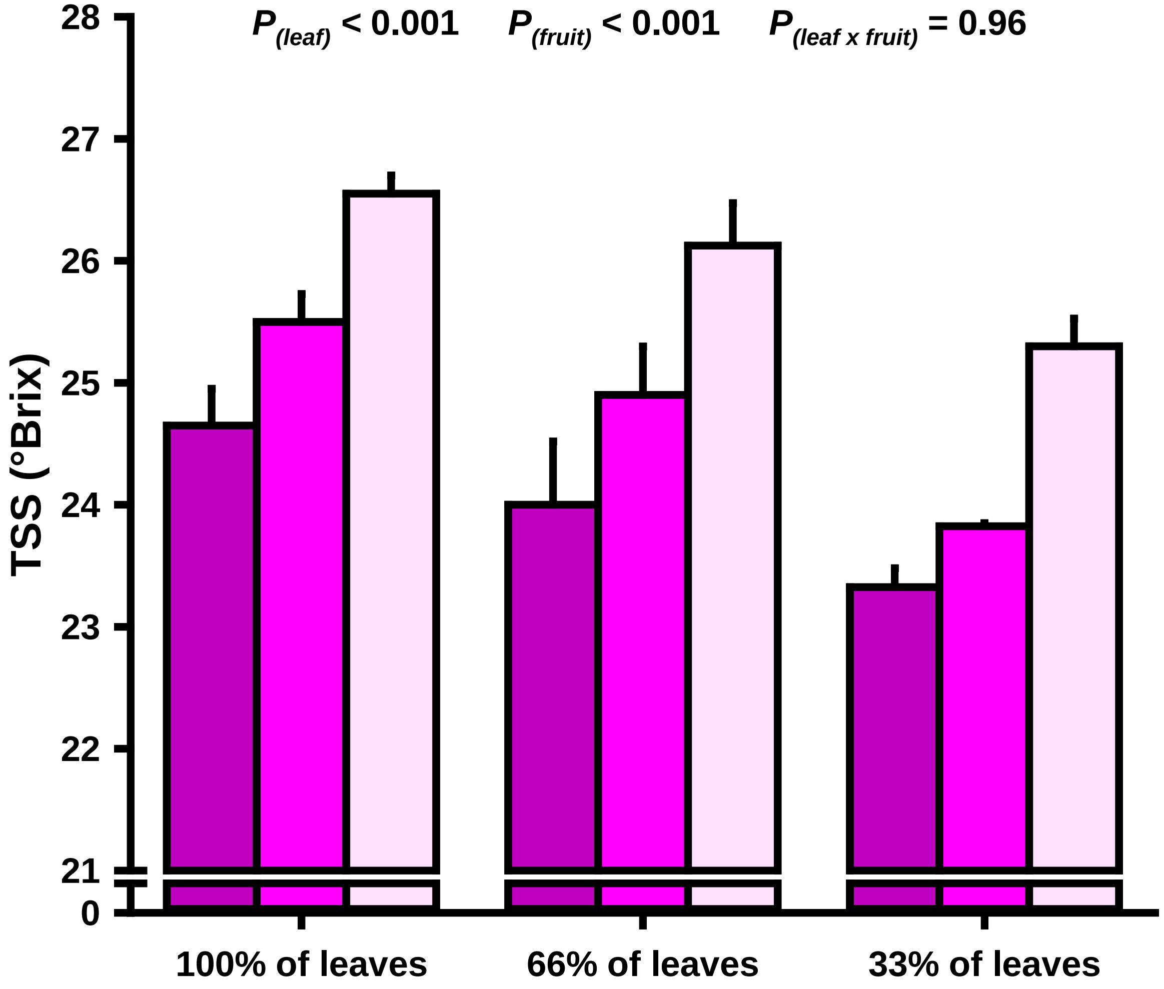




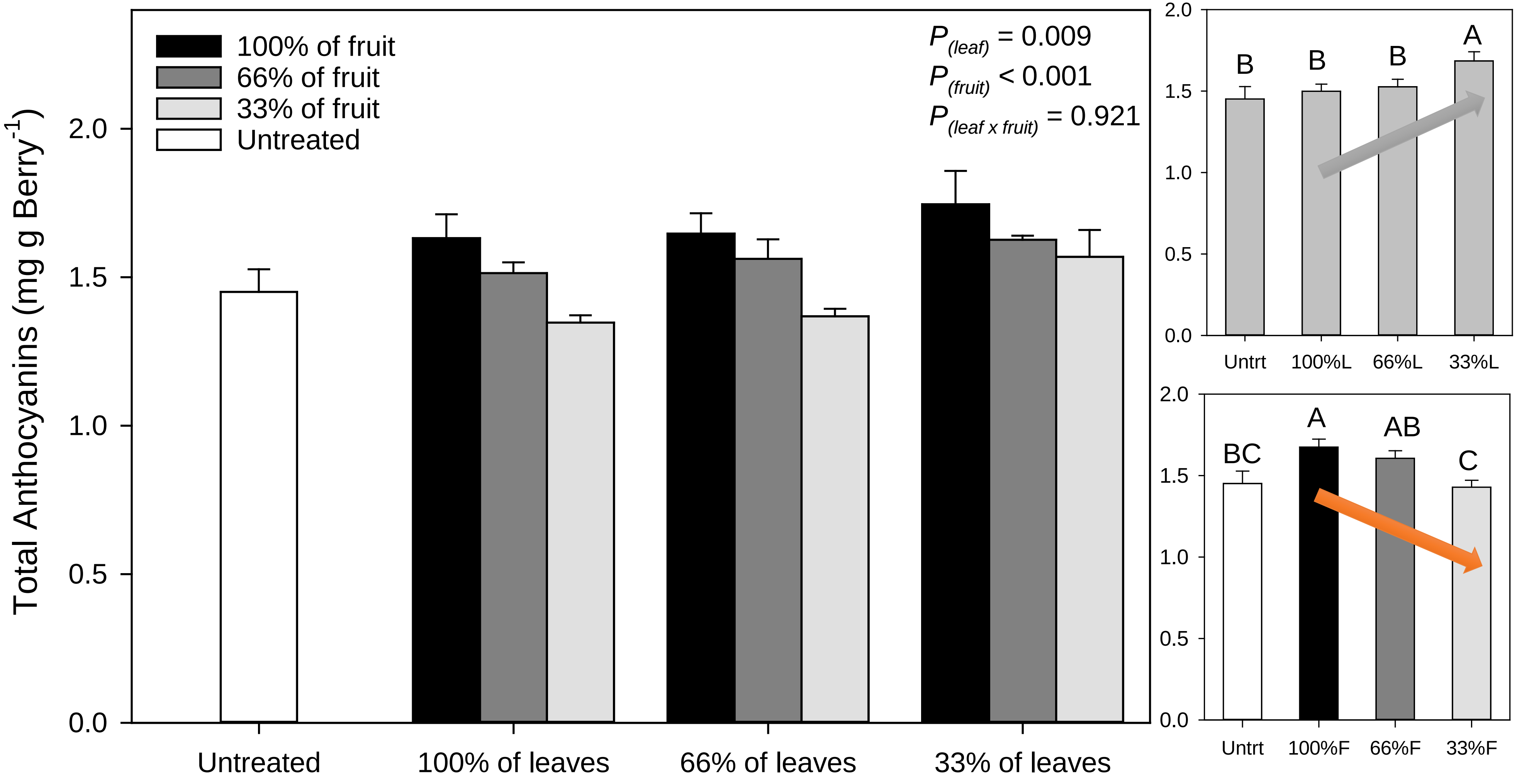
Soluble solids on 9/13/2017



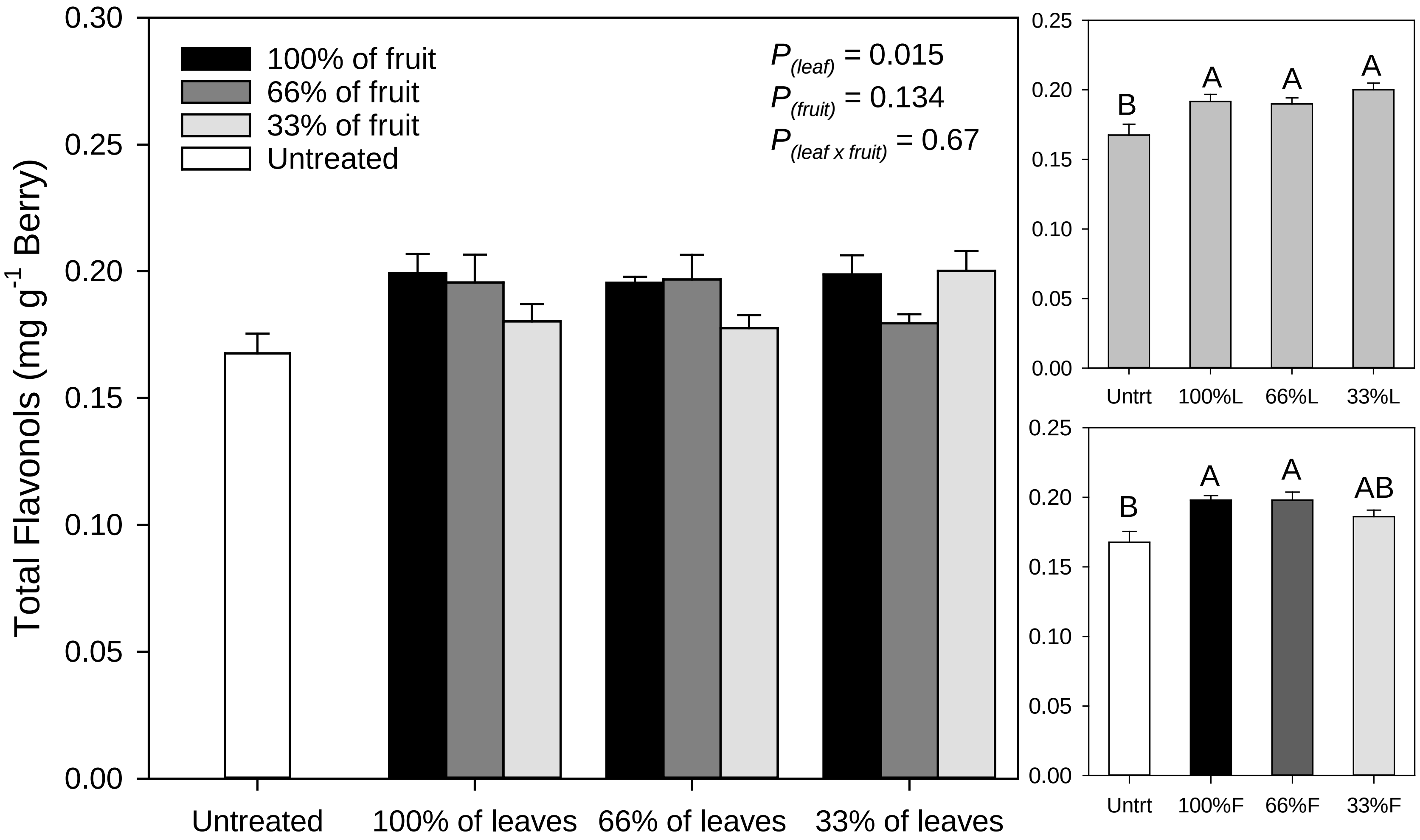
Soluble solids on 9/24/2018



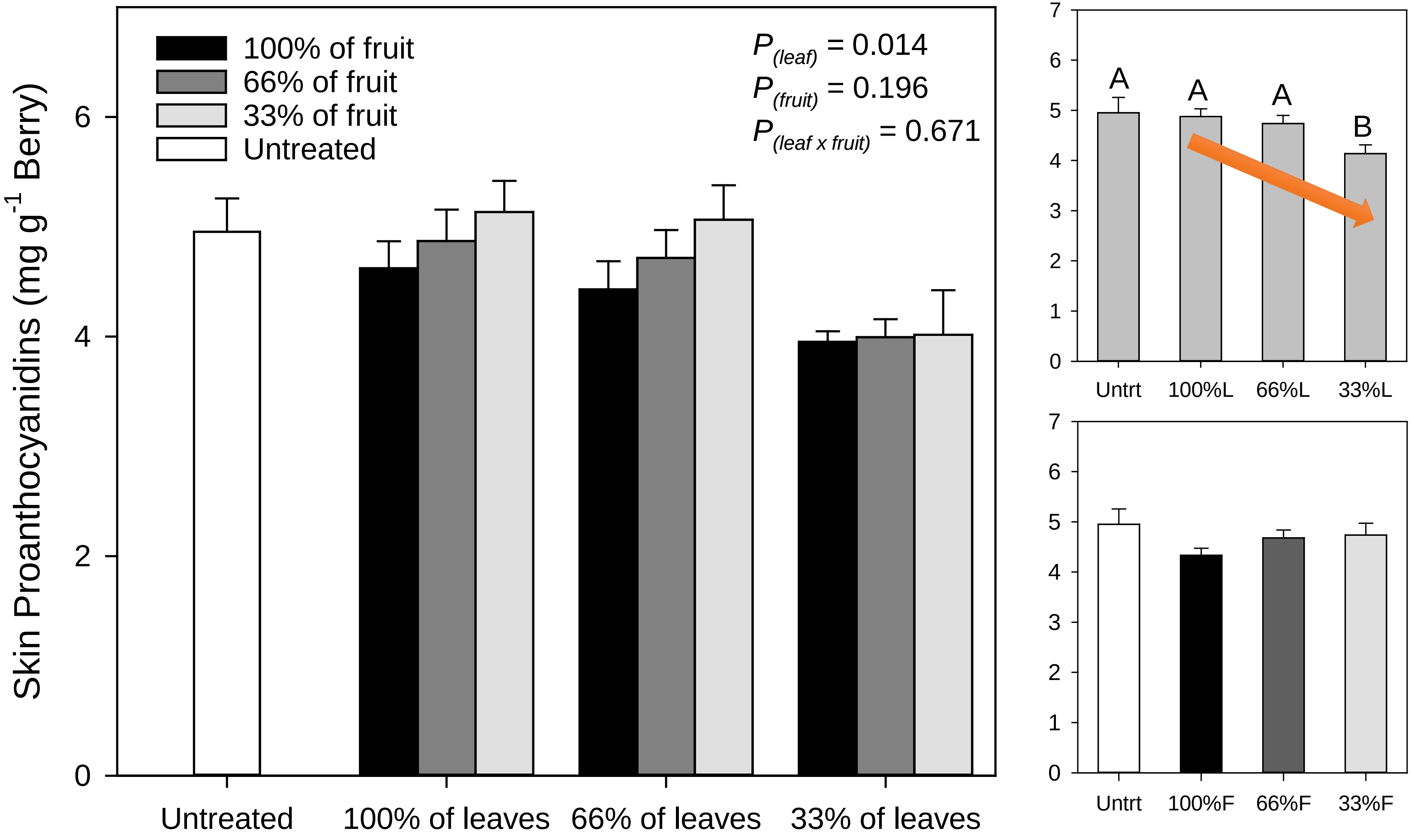
CLUSTER/BERRY THINNING DOES NOT IMPROVE ANTHOCYANIN CONTENT IN CABERNET SAUVIGNON



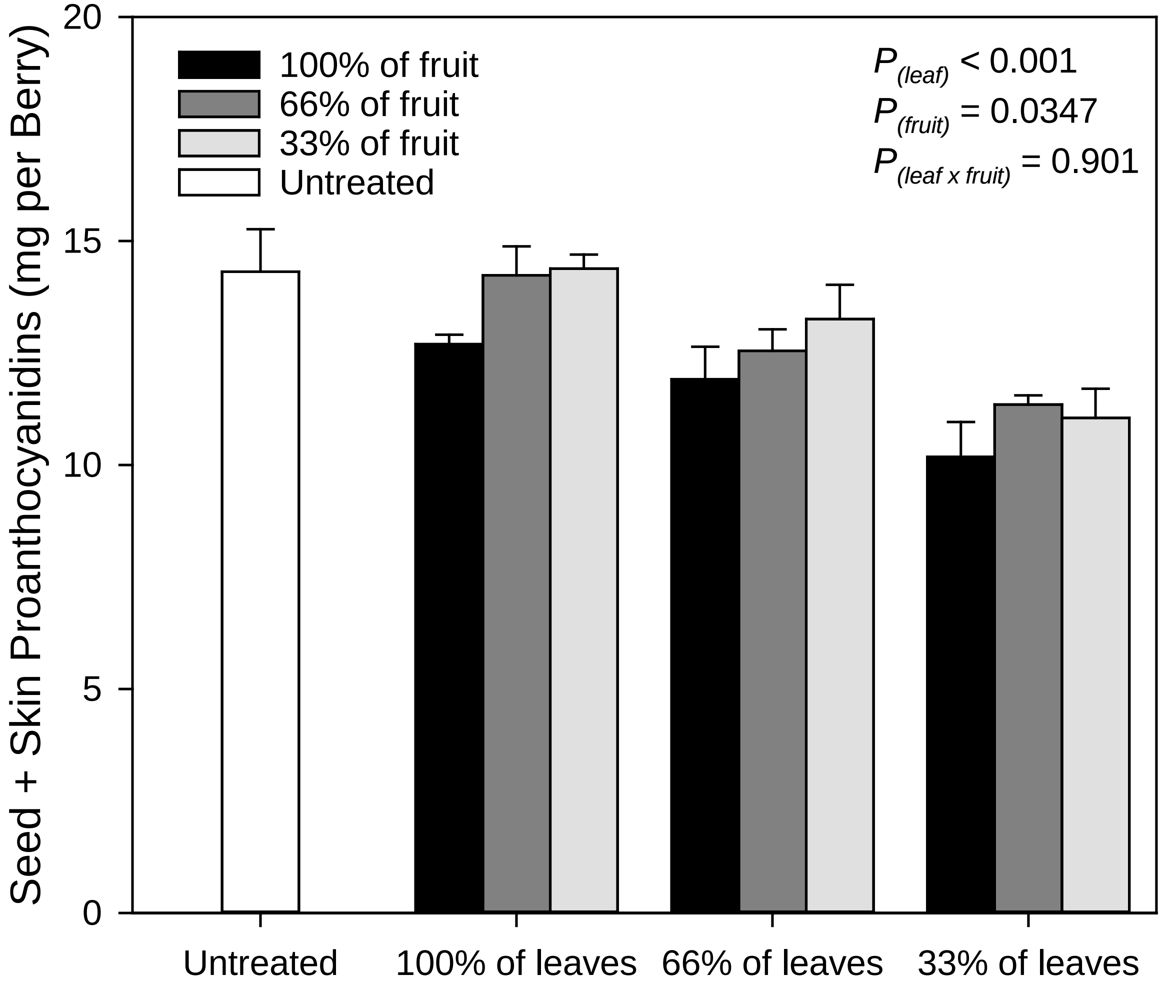
CLUSTER THINNING INTRODUCES MORE RADIATION INTO FRUIT ZONE

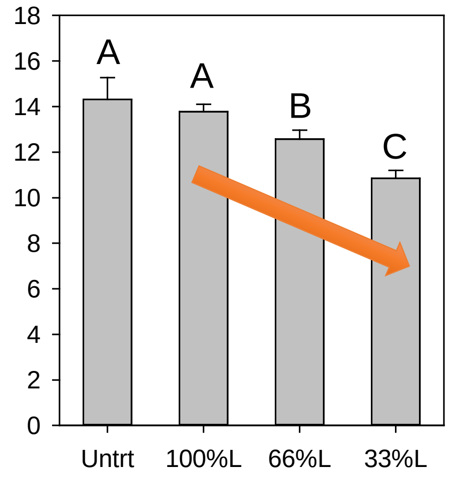


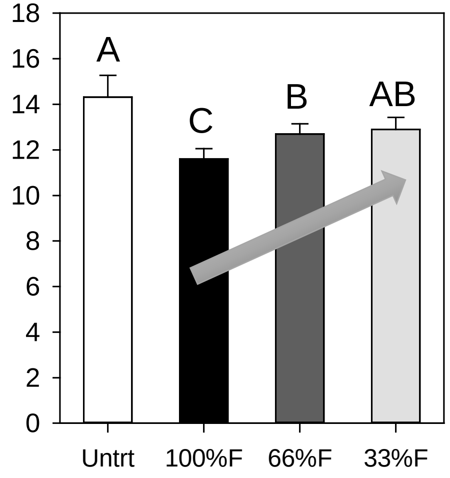
EFFECT ON SKIN PROANTHOCYANIDIN CONTENT(2017)



LEAF REMOVAL DECREASES, FRUIT REMOVAL INCREASES TANNIN CONTENT







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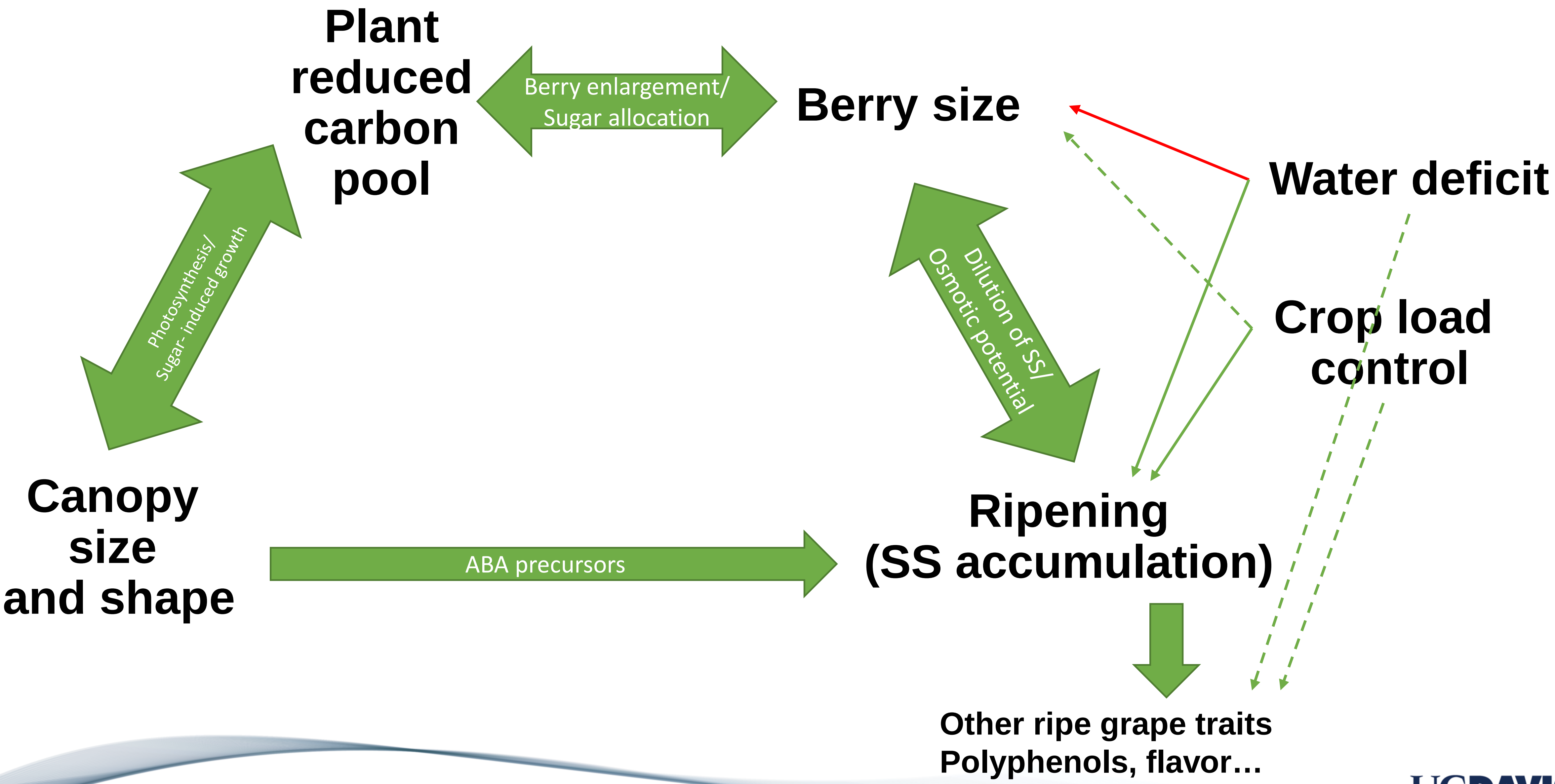

Plant reduced carbon pool
Berry enlargement/
Sugar allocation
Berry size
Water deficit
Photosynthesis/
Sugar- induced growth
Dilution of SS/
Osmotic potential
Crop load control
Canopy size and shape
ABA precursors
Ripening
(SS accumulation)
Other ripe grape traits
Polyphenols, flavor…

Main take home messages

Berry size (and thus yield) are more sensitive to canopy size more than crop load or irrigation

Small canopies are more likely reducing plant reserves (root starch) than over cropping

Challenge for increasing yields is controlling big canopies in EARLY SEASON

Main take home messages

Berry size (and thus yield) are more sensitive to canopy size more than crop load or irrigation

Small canopies are more likely reducing plant reserves (root starch) than over cropping

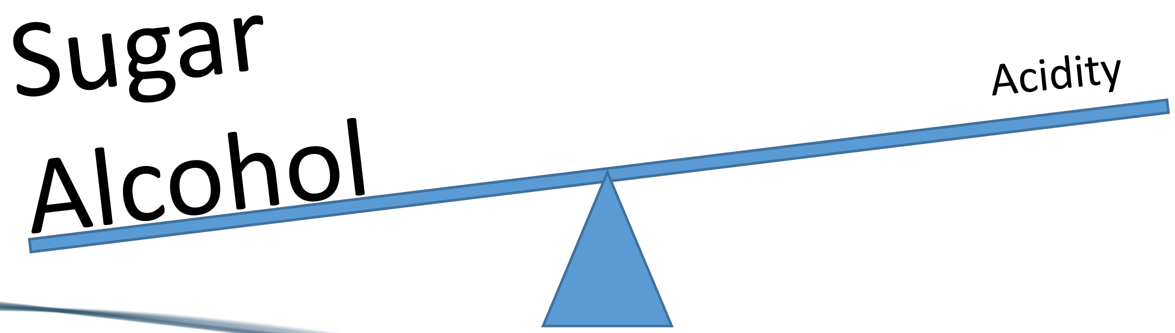
Challenge for increasing yields is controlling big canopies

Climate may be on our side…for now

Perspectives…

Heat…the more the better?

Polyphenols in danger

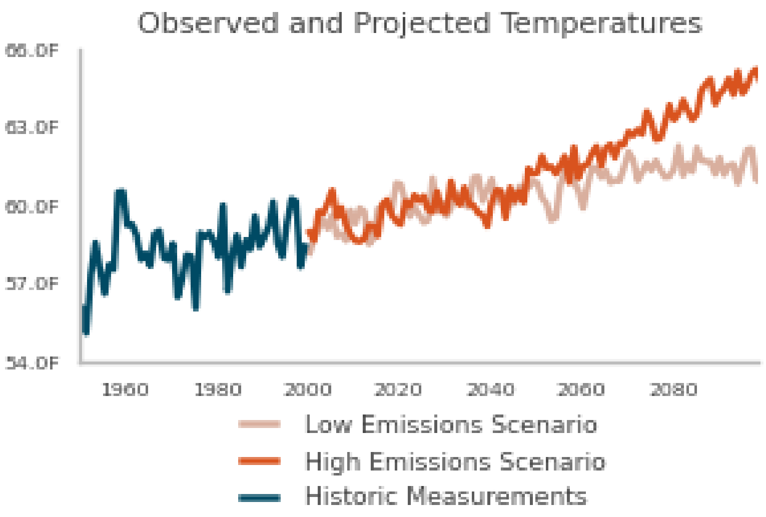


What if it gets warmer?

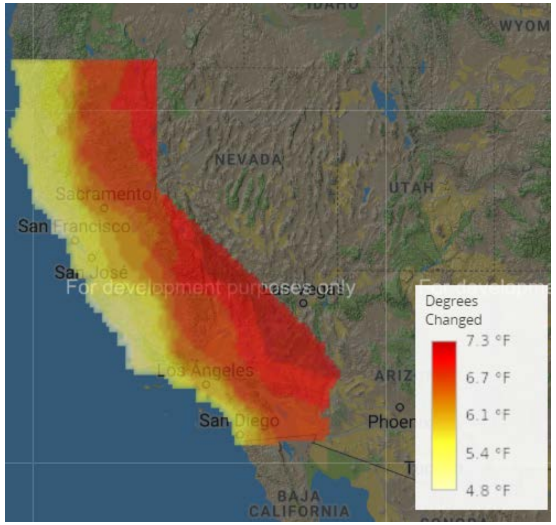
- Addition of water and tartaric
- Shade nets (kaolin applications did not work for us)
- Breeding efforts for low sugar (INRA and University Montpellier): 135-150 g/L at ripe stage (max berry vol.)
- IPCC projections:
    - 77% increase of surface burned annually by the end of the century

Can you breed a variety to produce cold weather wine in hot climate?

Projections Sta. Helena



Source: cal-adapt.org
SCRIPPS



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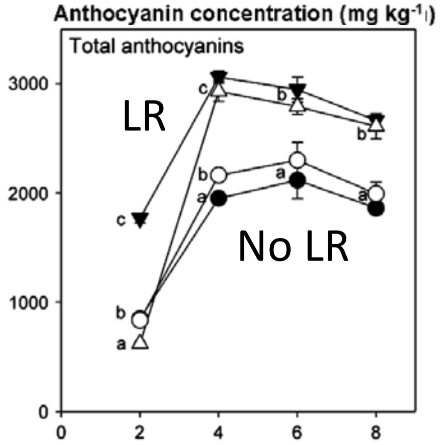
Typical grapevine trellis -> Fruit -zone

Exposure – Good to induce ripening (remove herbal characters)



Over exposure – Grapes can take a lot but at some point damage appears

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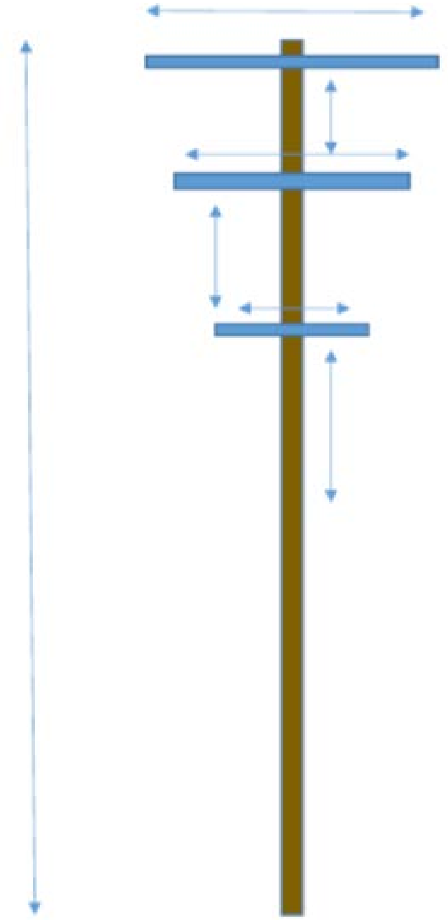
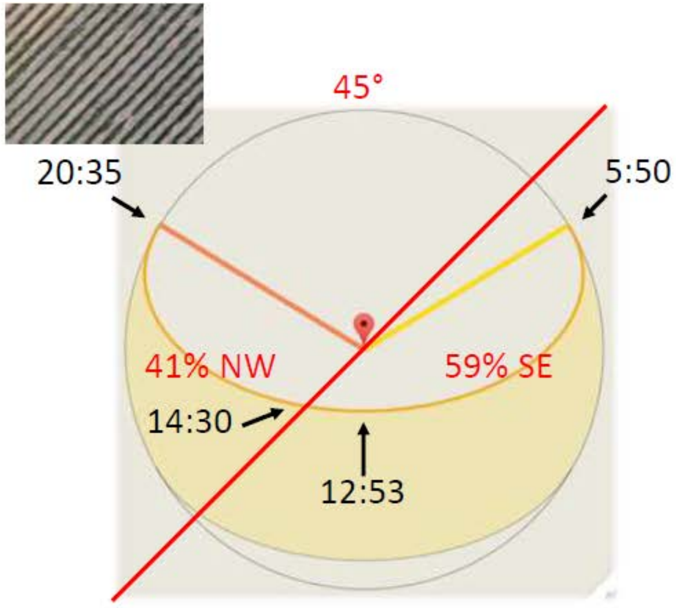
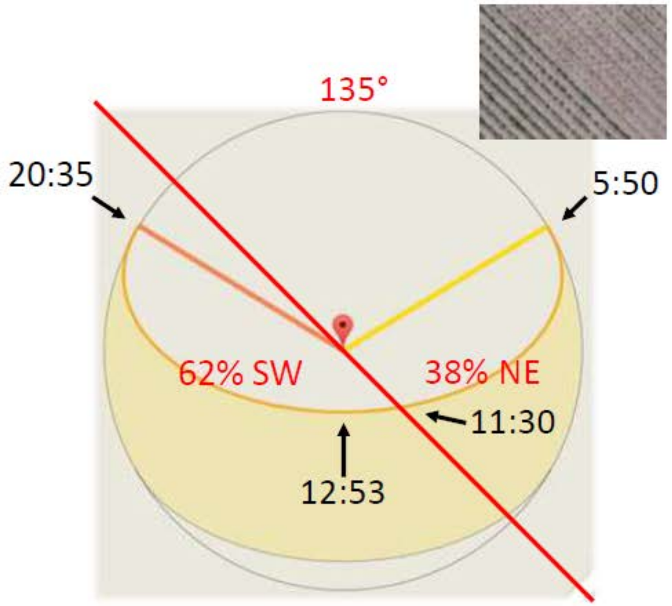
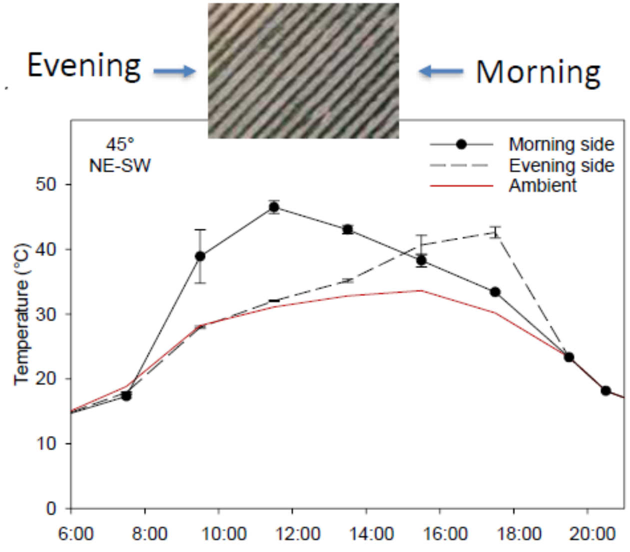
Shift towards positioned and sprawling systems

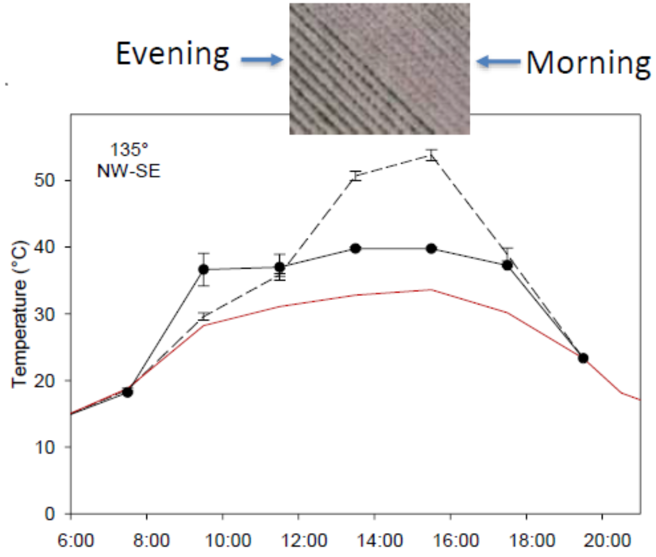
The UCDavis30 Trellis











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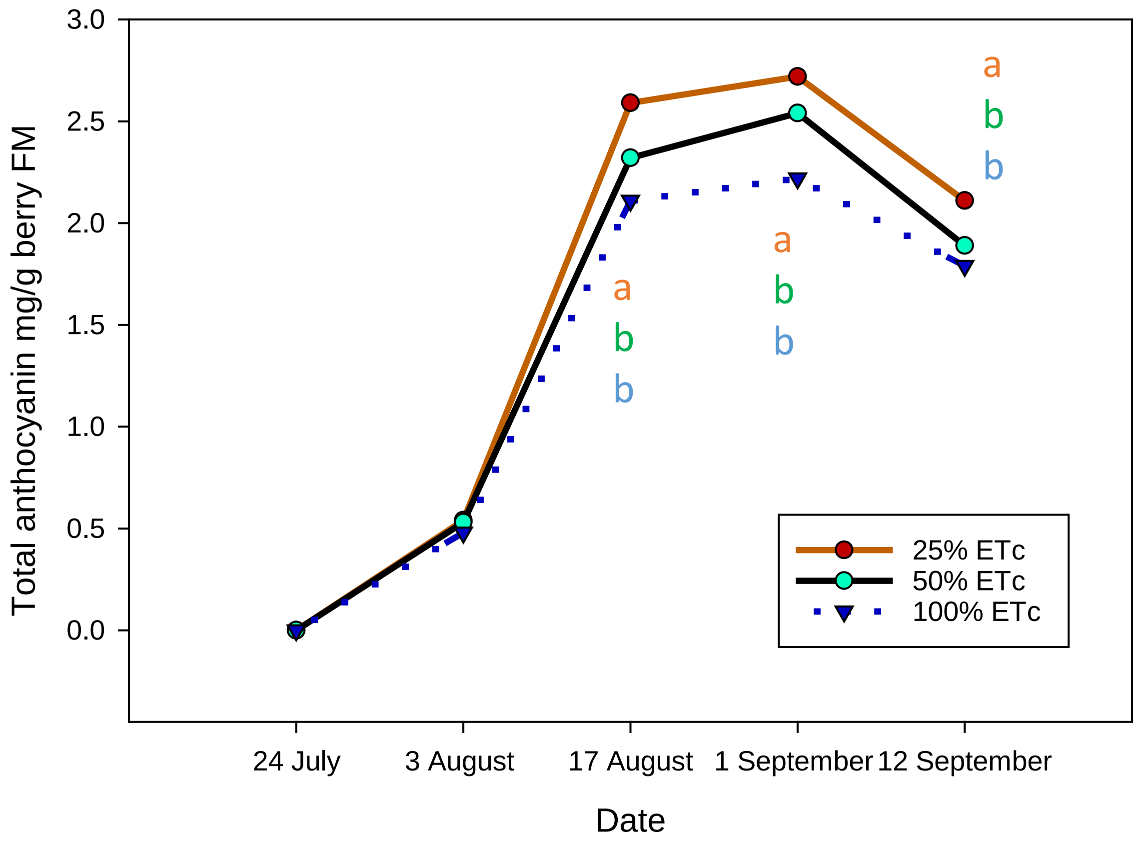
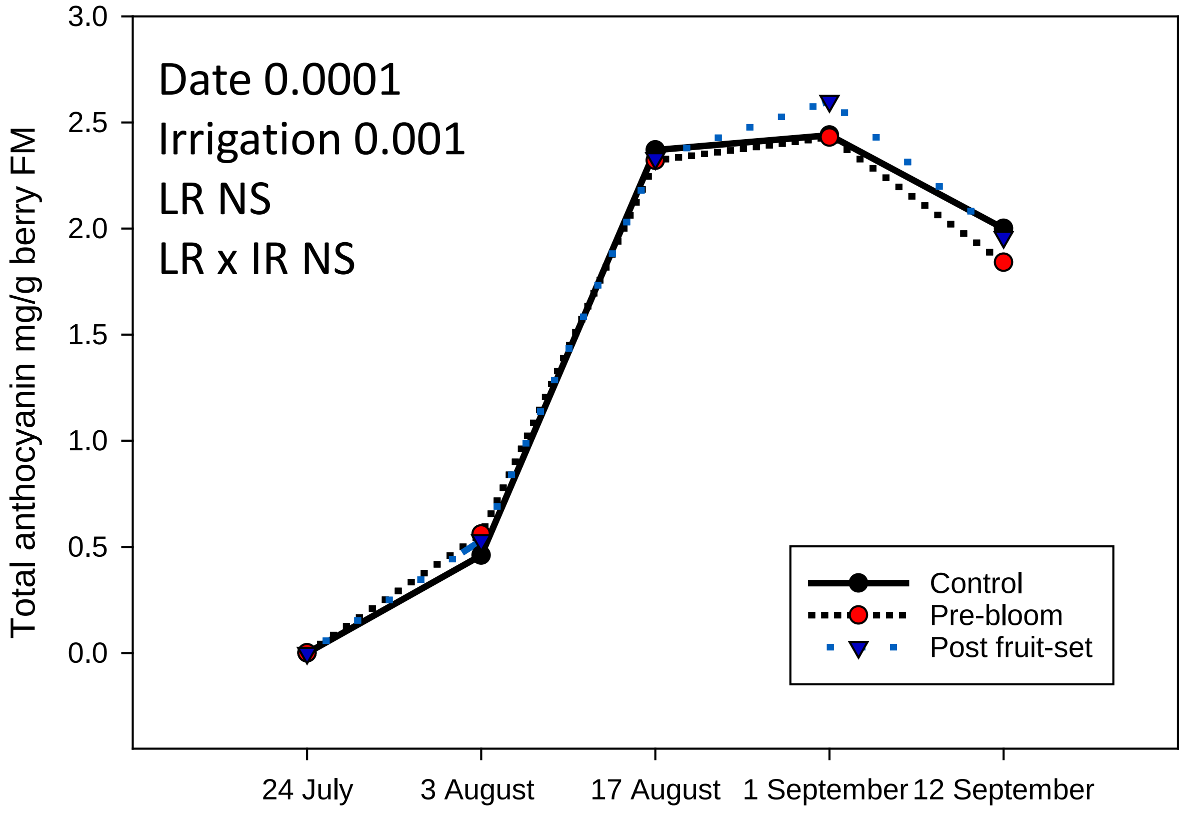
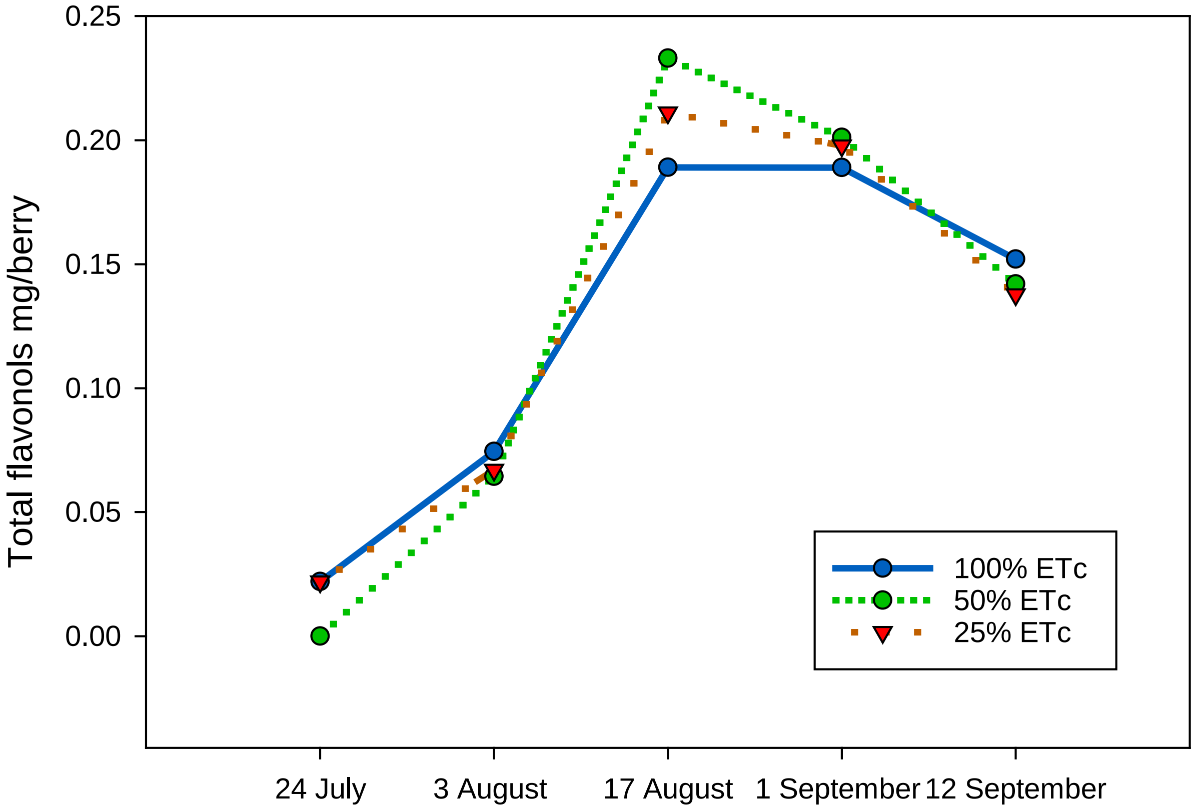
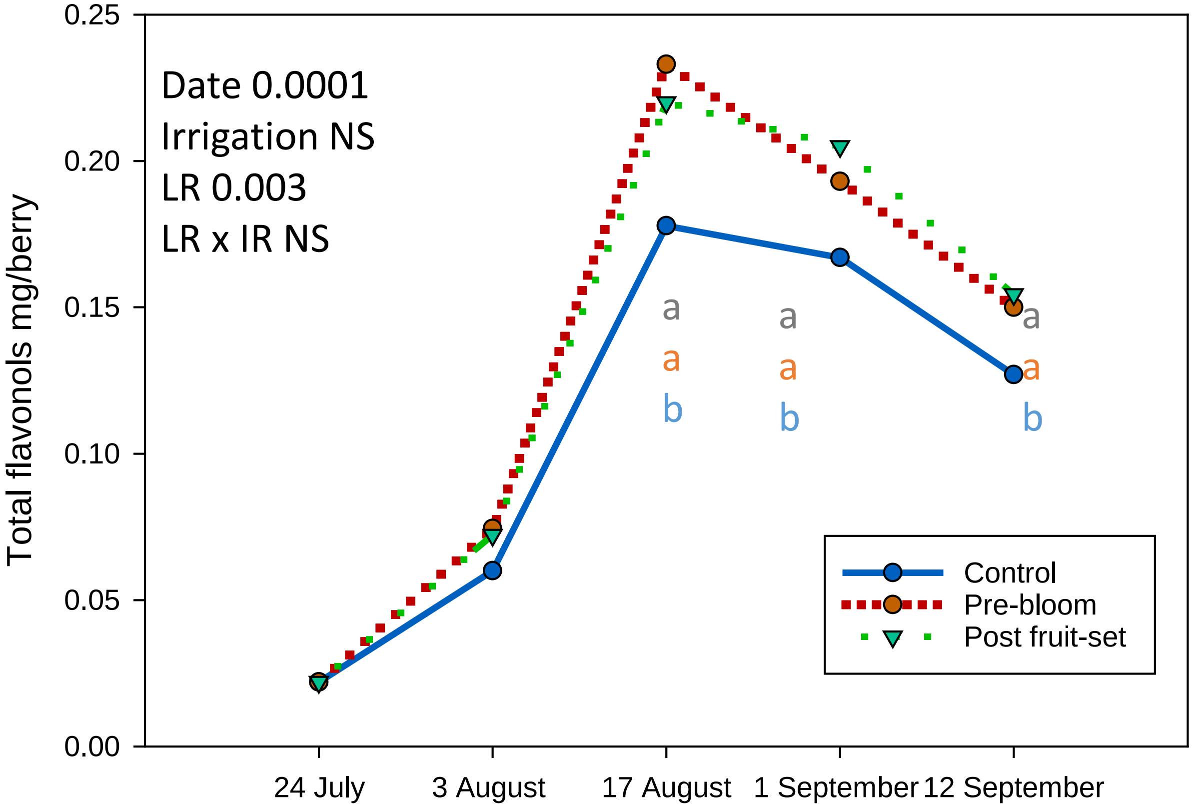
Kinetic development of total anthocyanin concentration





Kinetic development of total flavonol content





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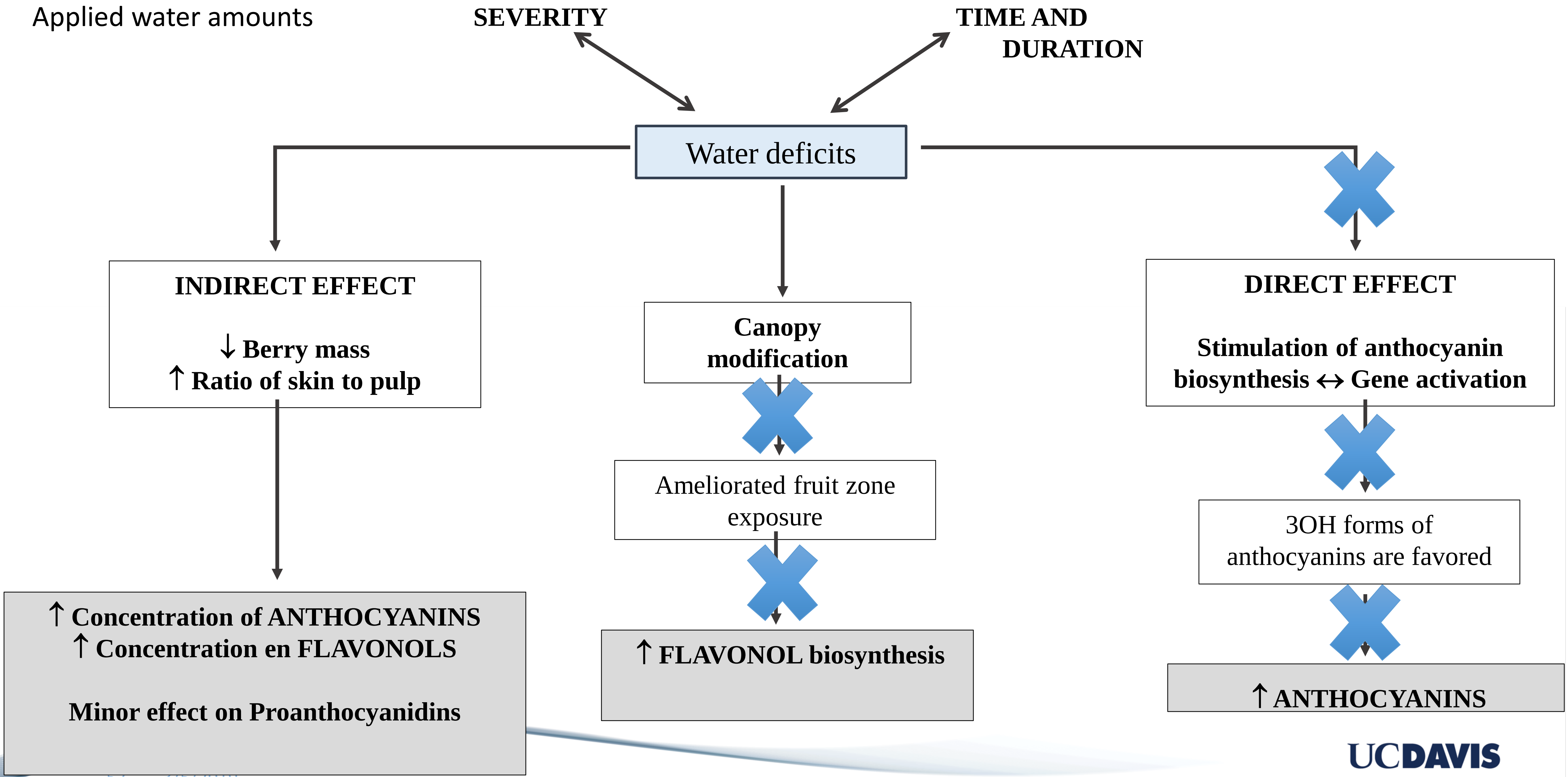
Applied water amounts



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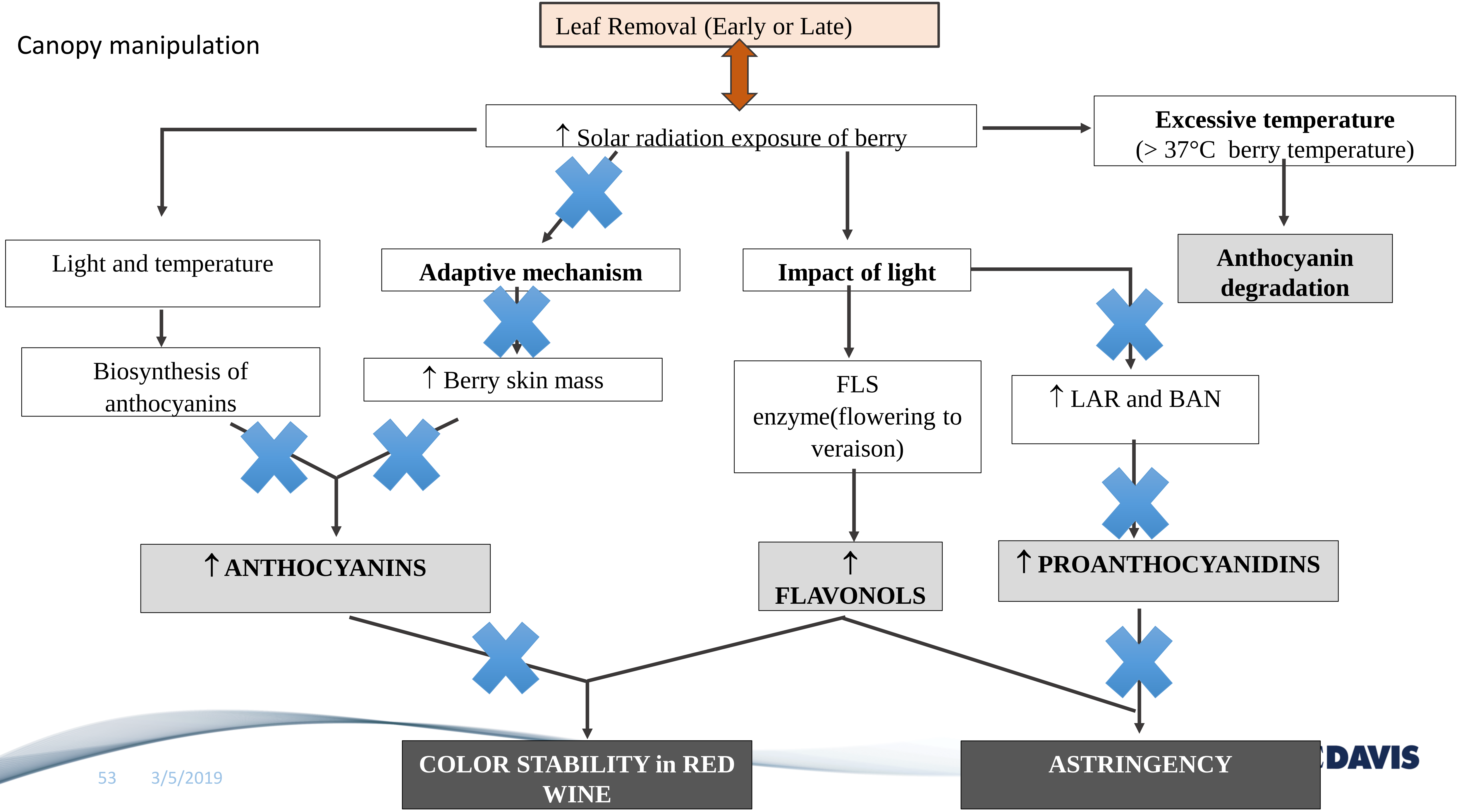
Canopy manipulation



Thanks for your attention!

- Johann Martinez PhD
- Luca Brillante, PhD
- Christopher Chen
- Runze “Cliff” Yu
- Cassandra Plank, PhD
- Marshall Pierce
- Constance Cunty
- Andrew Bebee
- August D’Amato
- Wei-Chao Cheng
- Katie Rouse
- Longjiao Zhang
- Vincenzo Messana

Research funded by

American Vineyard Foundation

Groth Vineyards & Winery Rooted in Oakville

- Cameron Parry
- Mary Stump

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Department of Viticulture and Enology

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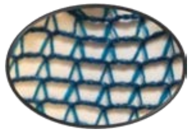
Experiment 1: Colored Shade Net Trial

- Control: Uncovered
- 20% shading factor – White 
- 40% Shading factor - Black 
- 40% Shading factor – Blue 
- 40% Shading factor - Aluminet 

n=4 (3 vines per rep)
Cabernet Sauvignon on VSP
Oakville (Napa)
NE to SW row orientation

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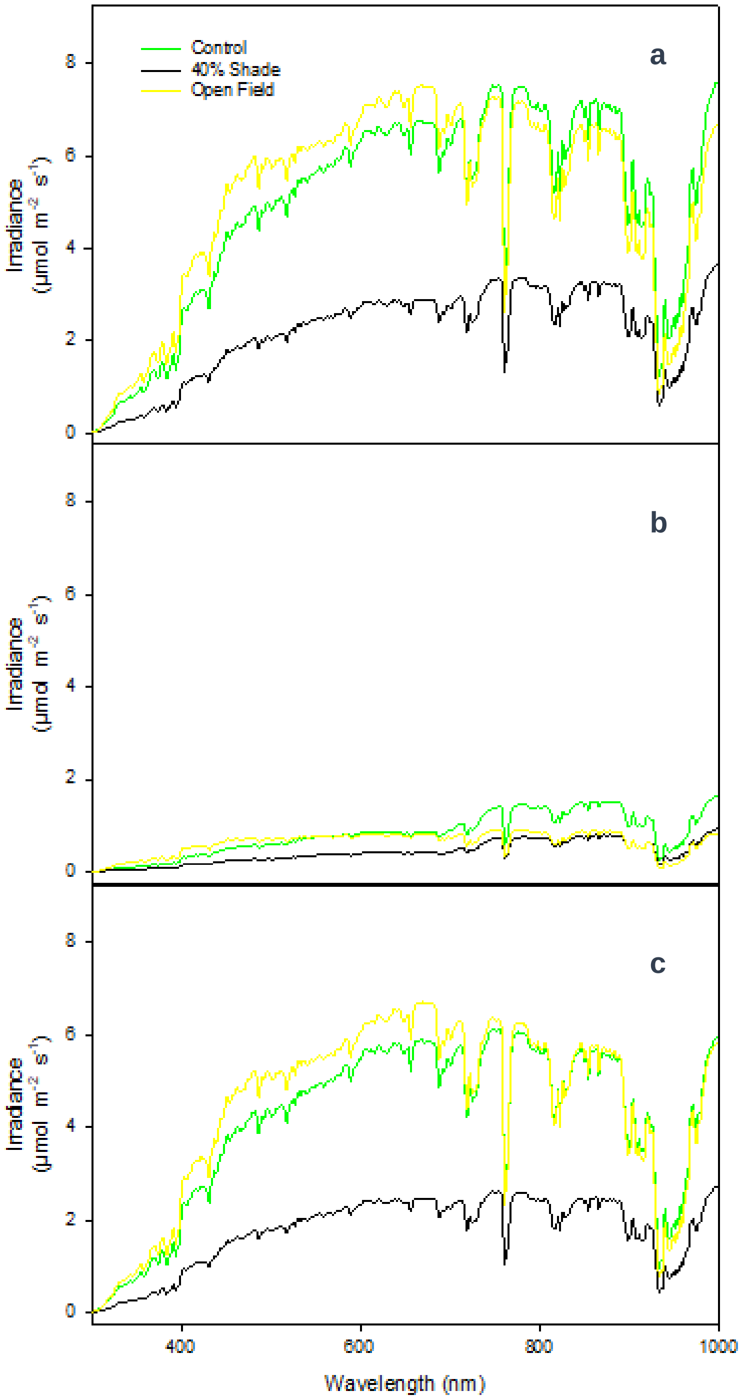
Fruit-Zone Light Conditions

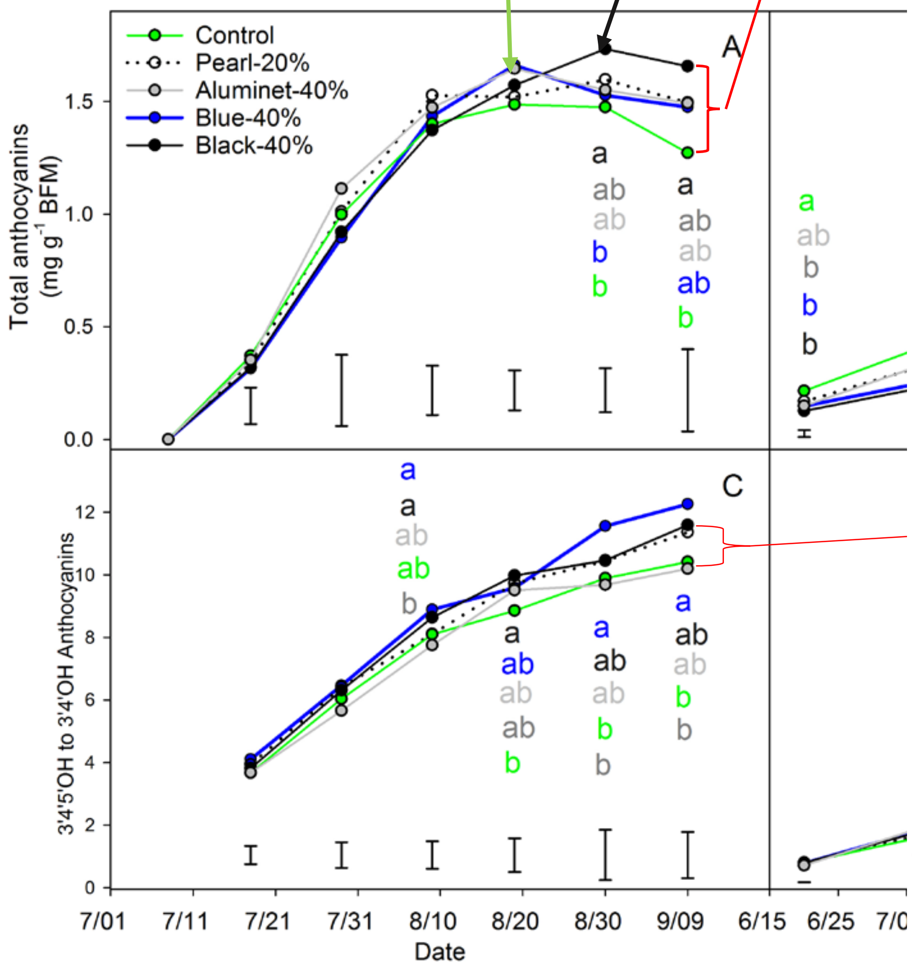
- Spectral radiation wavelengths in the fruiting zone
  - Quantified using a spectrometer with a cosine-corrected head for net treatments, controls, and in an open field at solar noon (~15:00 h PDT).
- Total Irradiance (Fig. a)
  - The sum of direct and diffuse irradiance ($\mu mol\ m^{-2}\ s^{-1}$)
  - Shows that shade nets worked particularly well in reducing irradiance from within the visible range (410-700 nm).
    - Reduction of up to 60% of irradiance
  - Infrared wavelengths (>700 nm) were reduced greatly as well.
- Diffuse Irradiance (Fig. b)
  - Although diffuse radiation makes up <20% of the total radiation received in the fruit-zone, it contributes.
  - Diffuse irradiance was mostly modulated by the canopy itself, with nets having little influence outside of the visible range.
- Direct Irradiance (Fig. c)
  - Making up the majority of radiation the fruit zone receives, direct irradiance was drastically reduced by the application of a shade net.
  - Few differences were observed between controls and an open field, save for the decrease in green, yellow, and orange wavelengths. Possibly due to leaf interference.

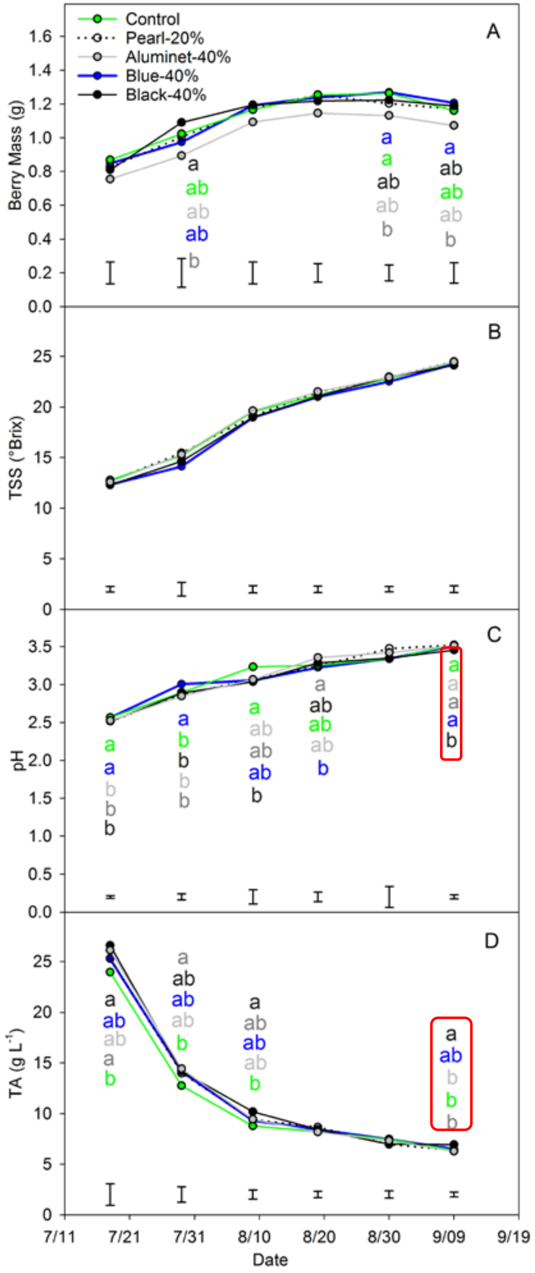


Results

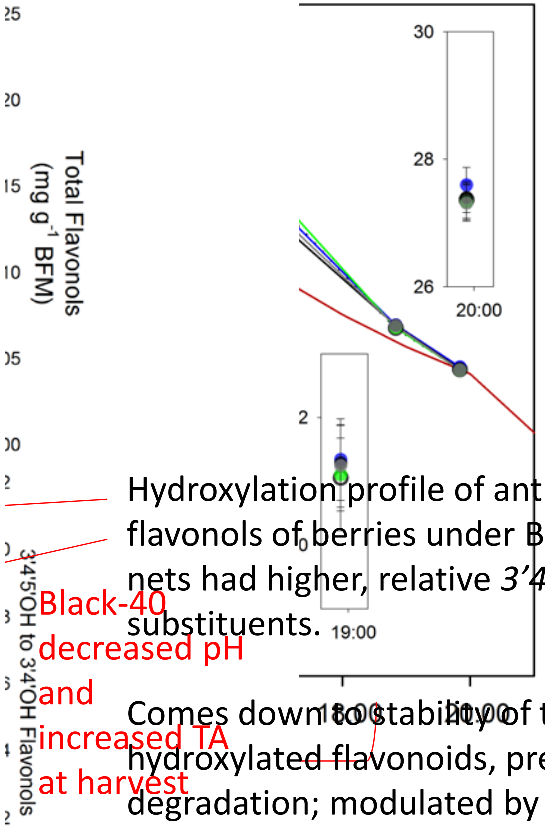
Peak content
control &
Black-40

Degradati
control >
Black-40





of flavonols in
rol, but less
s well.



Hydroxylation profile of anthocyanins and flavonols of berries under Black-40 shade nets had higher, relative *3'4'5'OH* substituents.

Black-40 decreased pH and increased TA at harvest

Comes down to stability of tri-hydroxylated flavonoids, preventing rapid degradation; modulated by partial shading.

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Conclusions

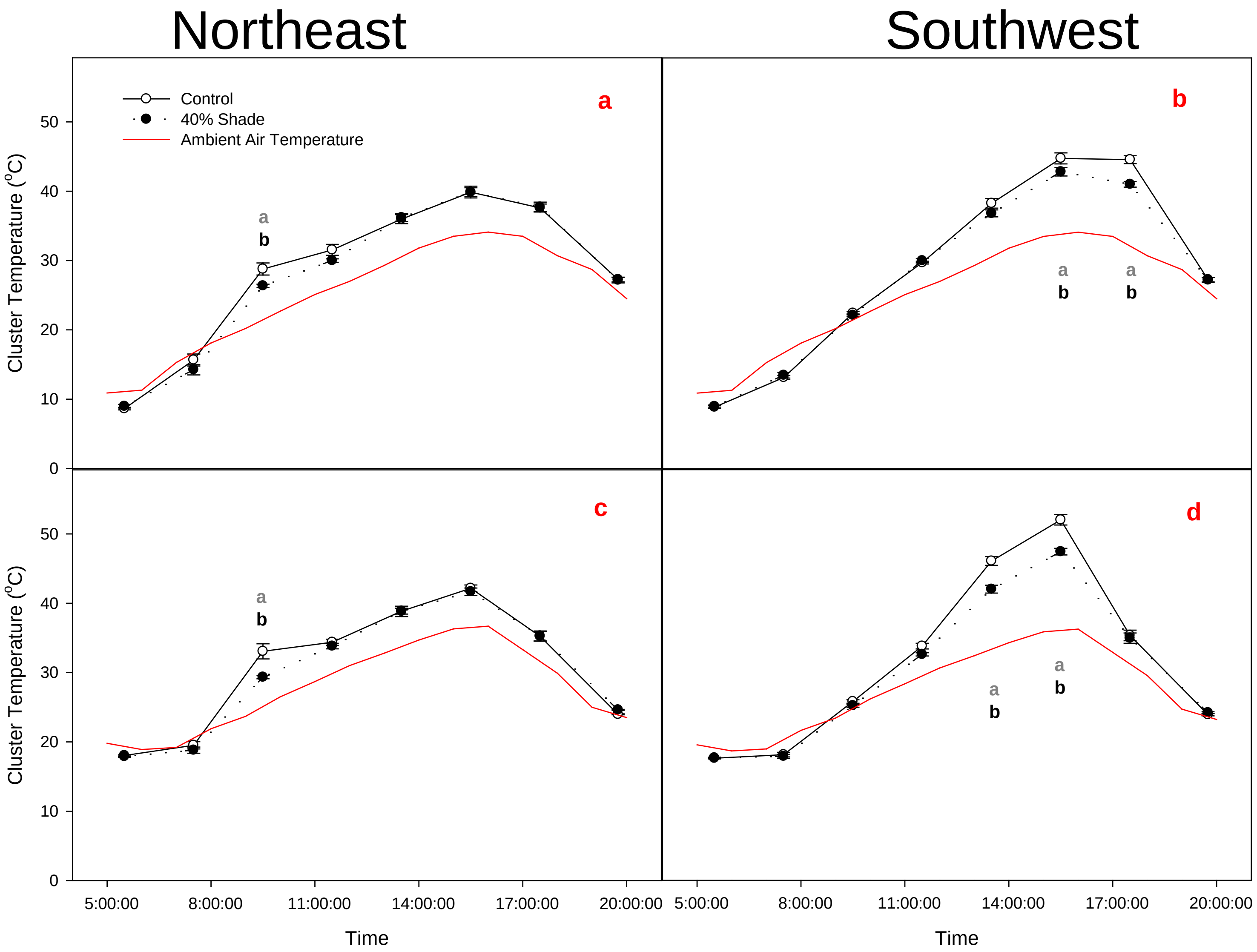
	Partial solar radiation exclusion	
	Uncovered	**Black 40%**
Yield (kg/vine)	No influence	No influence
Berry mass (g)	No influence	No influence
Berry temperature	↑	↓
TSS (Brix)	No influence	No influence
TA (g/L)	↓	↑
pH	↑	↓
Σ Anthocyanins	↓	↑
Anthocyanin 3’4’5’ hydroxylase forms	↓	↑
Σ flavonols	No influence	No influence
Flavonol 3’4’5’ hydroxylase forms	↓	↑

Primary and secondary metabolism response to partial solar radiation exclusion

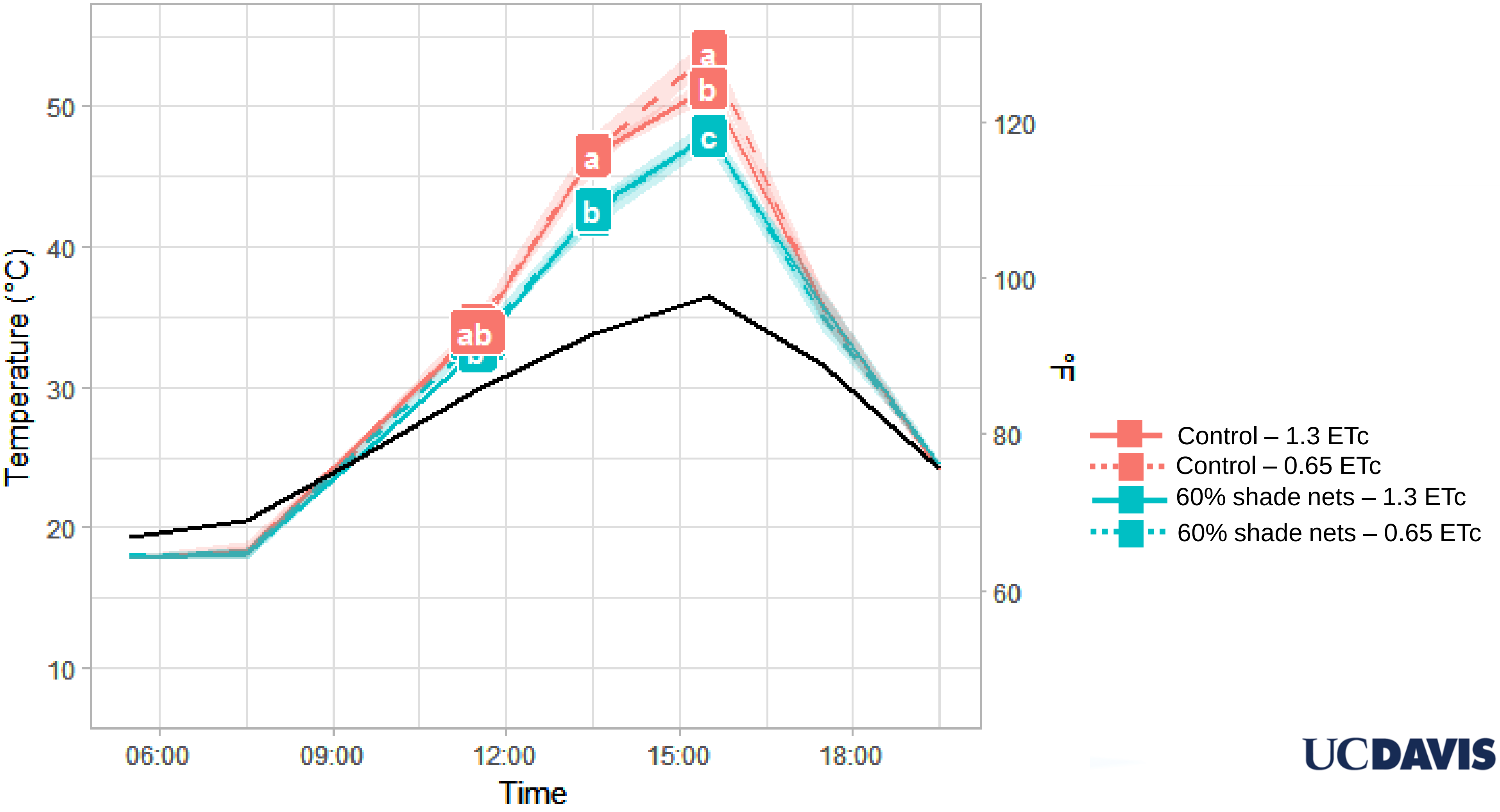
Cluster Temperatures

Diurnal-Cluster temperature evolution were measured using a portable infrared thermometer on both sides of the canopy on two dates (a) July-29-East; (b) July-29-West; (c) Sep-11-East; (d) Sep-11-West

- Shade nets appear to mitigate cluster temperature accumulation when solar radiation is directly on the cluster.
- Particularly on the western side of the canopy (Fig. b and Fig. d)
- Shading reduced berry temperatures by 3-4°C



Key finding: Ripe Fruit in SW side reaches 53°C…with shade nets 48°C



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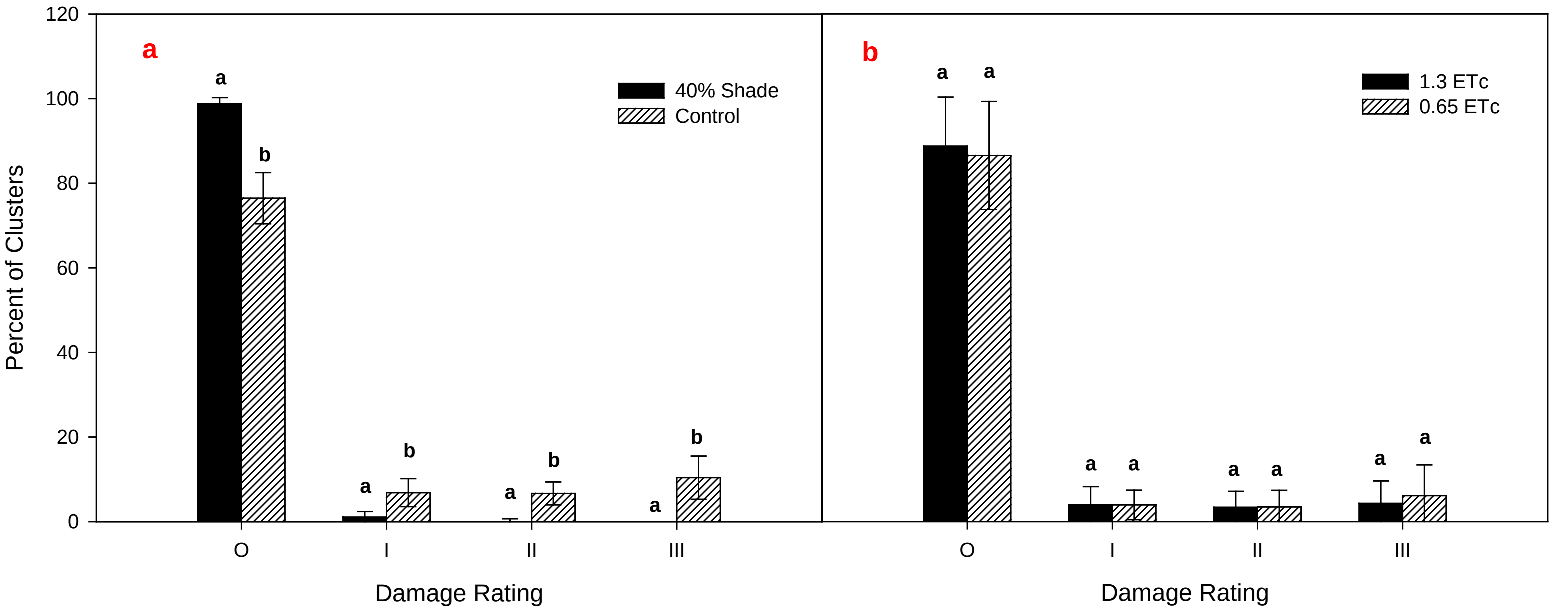
Visible Damage

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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Conclusions

	Partial solar radiation exclusion			
	Uncovered	**Black 40%**	**1.3 ETc**	**0.65 ETc**
Damaged clusters (%)	↑	↓	No influence	No influence
Berry mass (g)	No influence	No influence	↑	↓
Berry temperature	↑	↓	No influence	No influence
TSS (Brix)	No influence	No influence	↓	↑
TA (g/L)	No influence	No influence	No influence	No influence
pH	No influence	No influence	No influence	No influence
Σ Anthocyanins	↓	↑	No influence	No influence
Anthocyanin 3’4’5’ hydroxylase forms	↓	↑	No influence	No influence
Σ flavonols	↑	↓	No influence	No influence
Flavonol 3’4’5’ hydroxylase forms	↓	↑	No influence	No influence

Conclusions

- Climate is changing
  - Napa has increased annual, accumulated GDDs over past five decades
  - More frequent and intense heat spikes.
- Light (solar radiation) is not limiting in California
  - Damage occurs at low PAR exposure >20% of light intercepted in the fruit zone (Brillante et al. 2017; Cook et al. 2015; Dokoozlian & Kliewer, 1994; Martinez et al. 2017; Yu et al. 2016)
- Greater applied water amounts do not relieve stress from solar radiation
- Shade nets can be used to decrease incidence of solar radiation in fruit zones
  - Decreases in visible damage associated with shade net application
- Shade nets modulate the anthocyanin and flavonol profiles favoring lower rates of flavonoid degradation and higher, relative *3'4'5'-hydroxylated* substituents.
- Shade nets can be considered a short-term response to increasing temperatures

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