Kinetics of Ripening in Grape Berry

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OPTIMIZATION OF MUST COMPOSITION

SUGAR?

COLOR?

ASTRINGENCY?

ACIDITY?

WHEN I NEED TO PICK TO MAKE THE WINE I WANT?

HOW CAN WE ASSES RIPENING?

TYPICAL GRAPE DEVELOPMENT

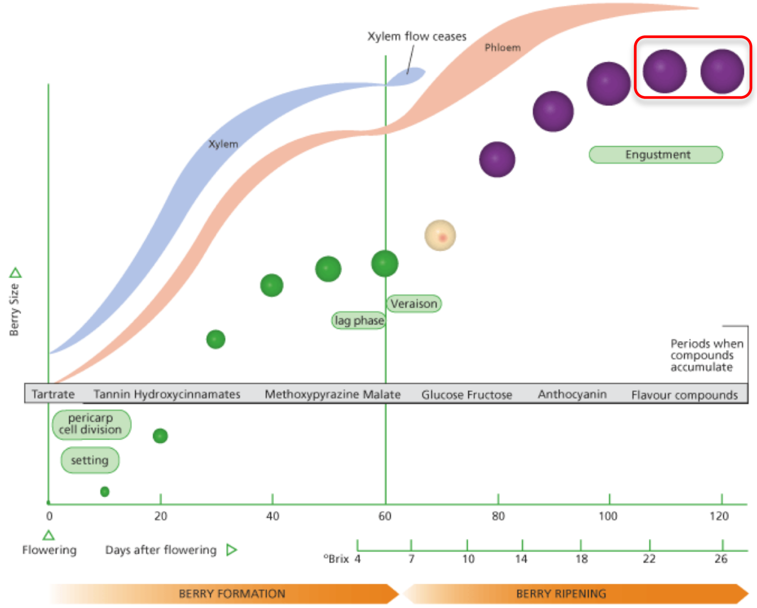
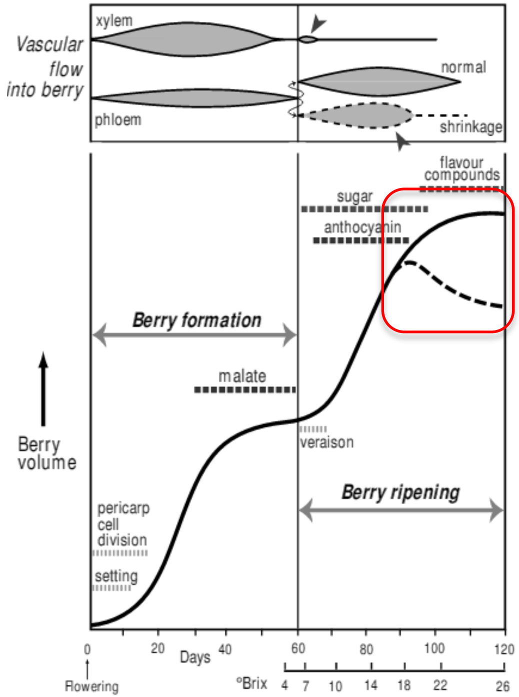


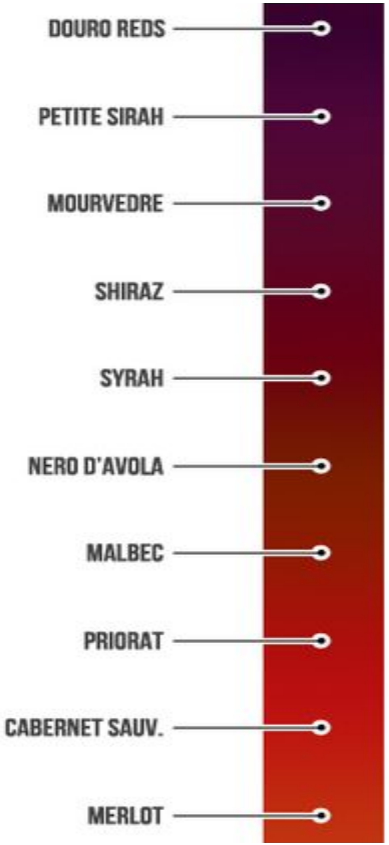
Figure 2: Diagram showing relative size and color of berries at 10-day intervals after flowering, passing through major developmental events (rounded boxes). Also shown are the periods when compounds accumulate, the levels of juice °brix, and an indication of the rate of inflow of xylem and phloem vascular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

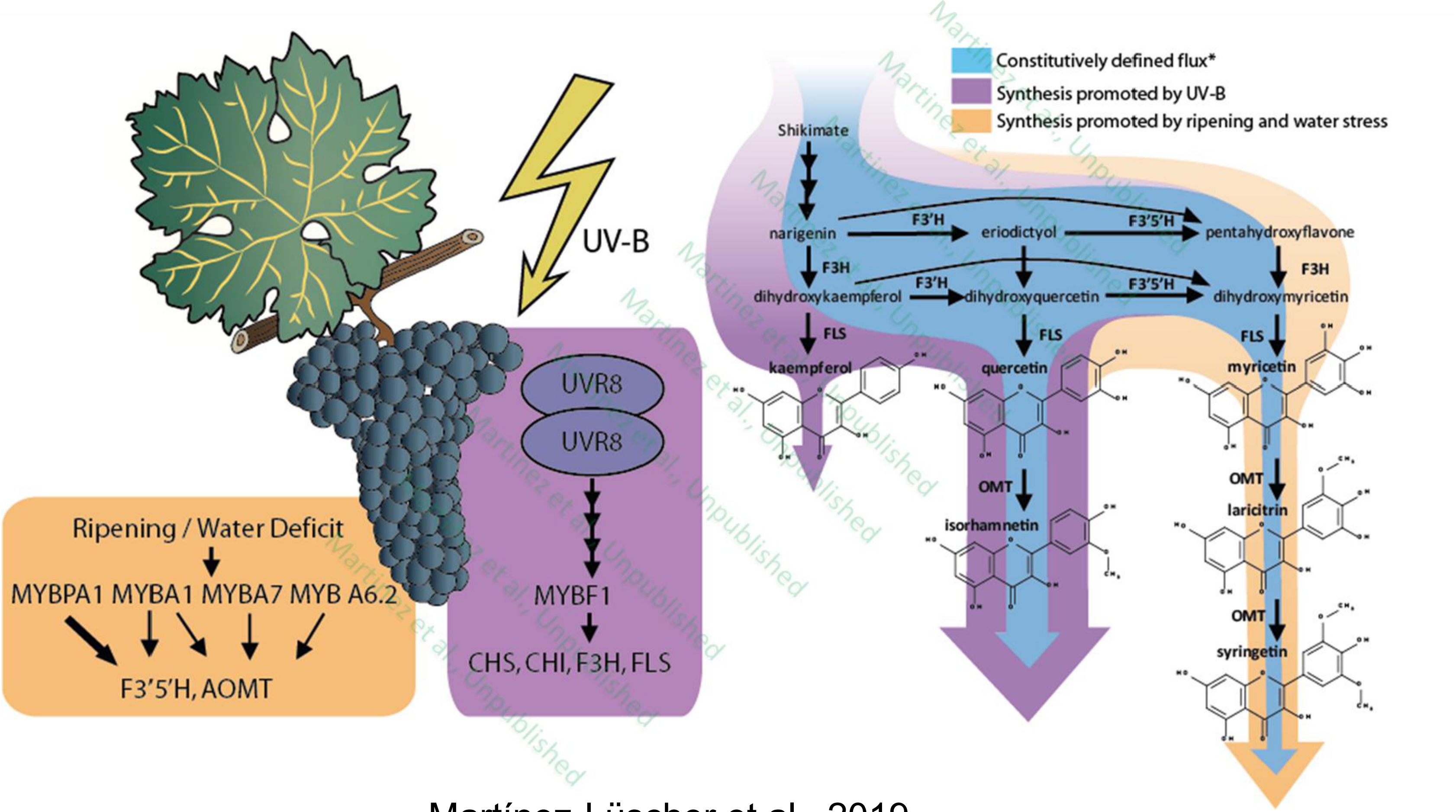


Coombe and McCarthy 2000

Phenolics in grape berry

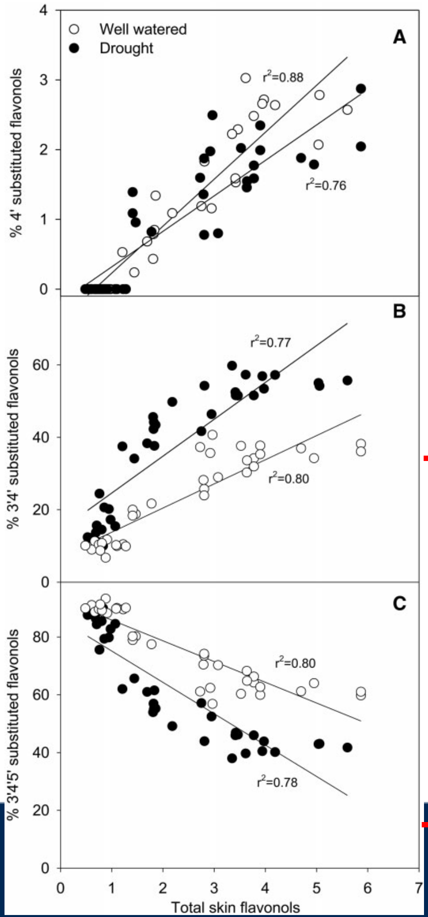
- Properties
  - Color
  - Co-pigmentation
  - Astringency (tactile)
  - Bitterness (taste)
- Health-promoting effects
- Important antioxidant capacity

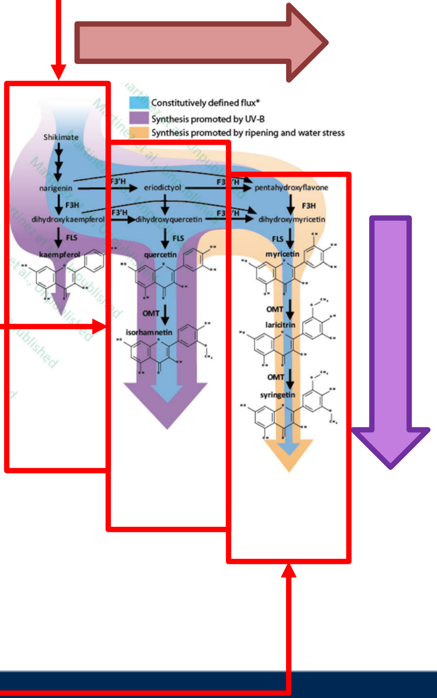


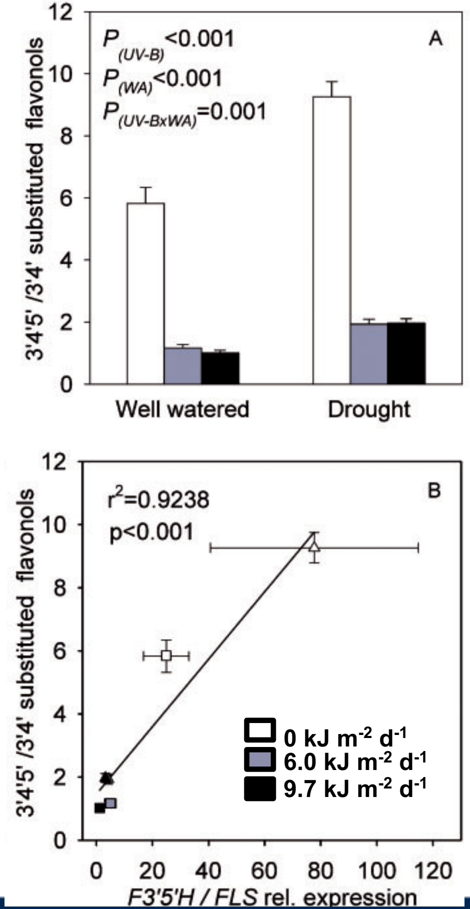


Martínez-Lüscher et al., 2019

UV-B shapes flavonoid profile







Martínez-Lüscher et al., 2014 Plant and Cell Physiology

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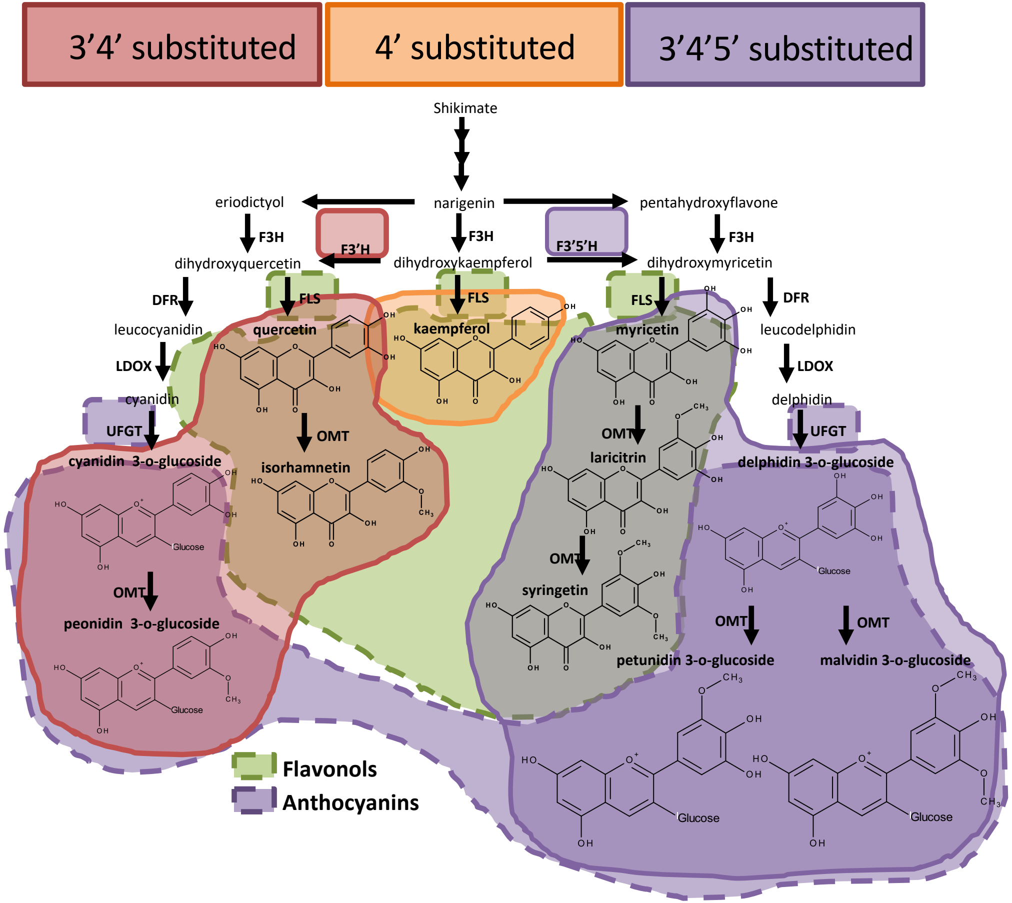
Constitution of flavonol and anthocyanin profiles



Abbreviations: F3'H: flavonoid 3'-hydroxylase; F3'5'H: flavonoid 3'5'-hydroxylase; FLS: flavonol synthase; DFR: dihydroflavonol reductase; LDOX: leucocyanidin dioxygenase; UFGT: UDP-glucose flavonoid 3-*O*-glucosyltransferase; OMT: *O*-methyltransferase

3’4’5’ substituted

Anthocyanins

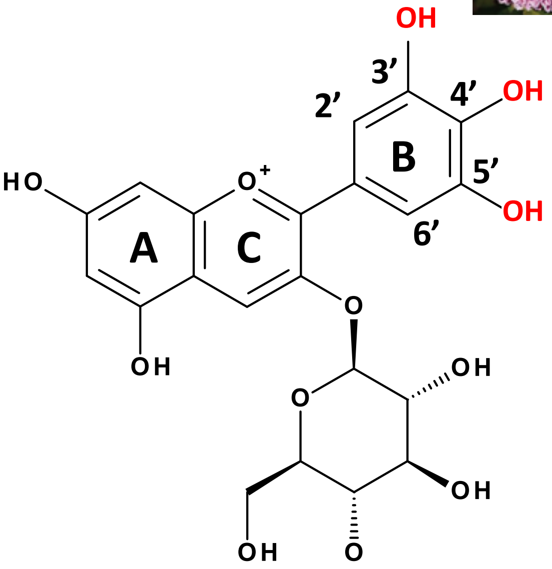
Flavonol homologues

Cyanidins F3’H Quercetins

Pelargonidins
Uncommon in *Vitis vinifera* grapes

Kaempferols

Delphidins F3’5’H Myricetins



Impact of flavonols on wine mouthfeel

Red wine *p<0.1; ** p<0.01

White wine *p<0.1; ** p<0.01

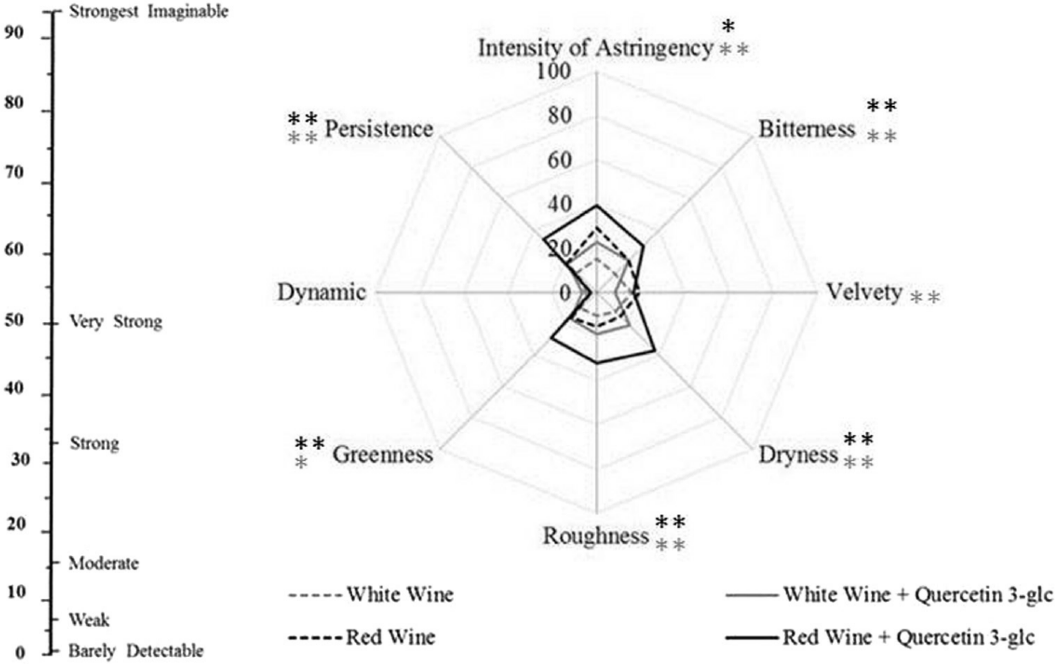


Fig. 1. Sensory analysis of white and red wines before and after the addition of quercetin 3-*O*-glucoside (2 g/L).

Ferrer-Gallego *et al.*, 2016

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Proanthocyanidins

Important due to their astringent properties

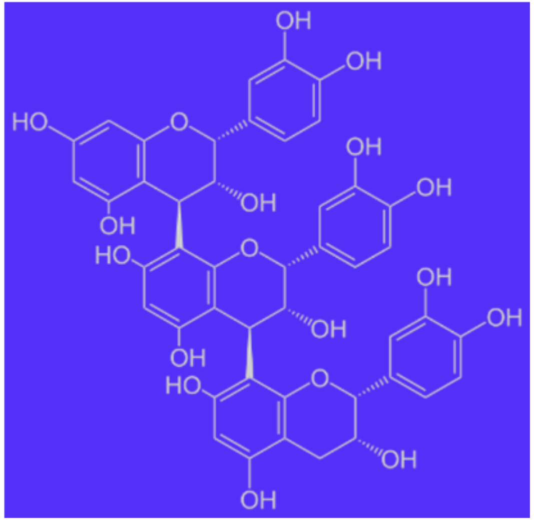
Role in long term color stability

Grape based proanthocyanidins

- (+)-catechin (C)
- (-)-epicatechin (EC)
- (-)-epicatechin-3-*O*-gallate (ECG)
- (-)-epigallocatechin (EGC)

Skin vs. seed proanthocyanidins

- Skins contain EGC
- Greater degree of polymerization
- Lower proportion of galloylated subunits



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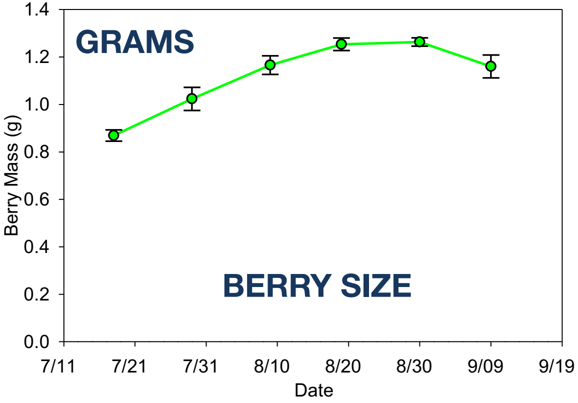
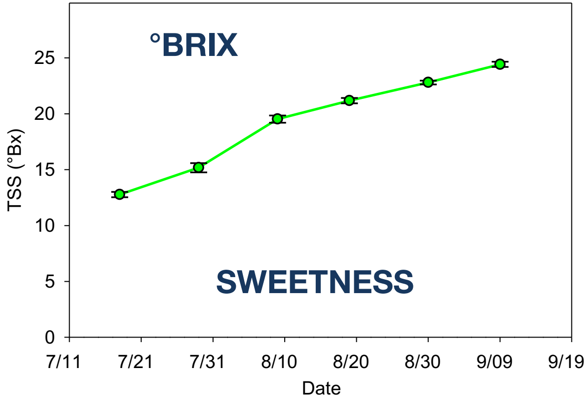
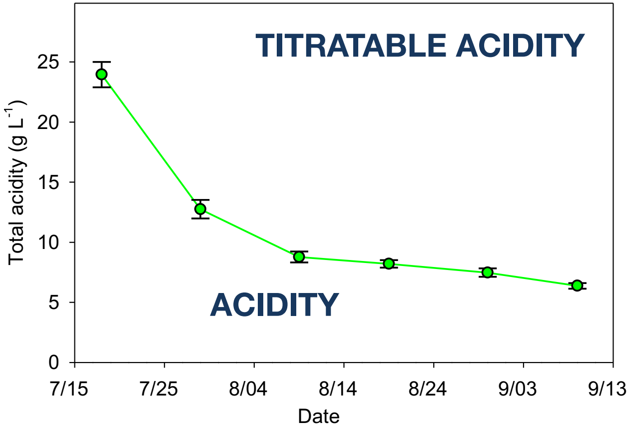
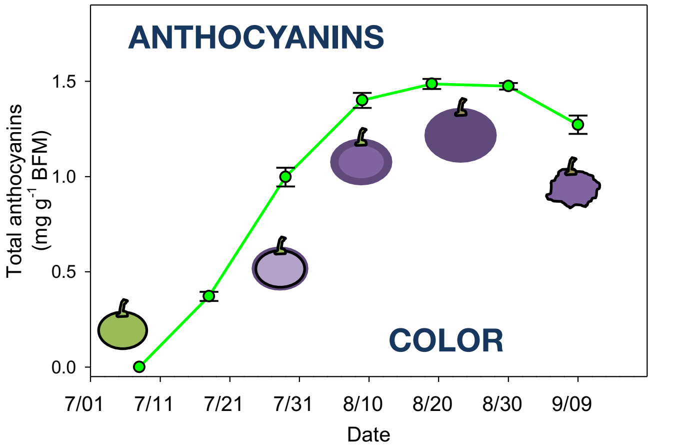
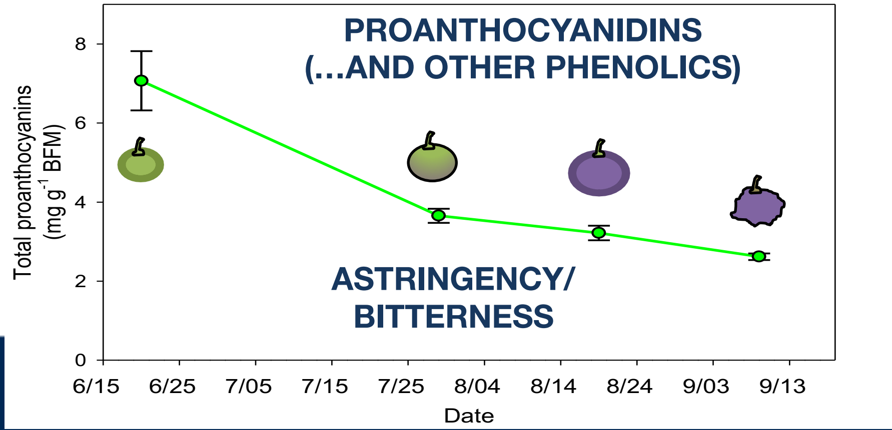
EVOLUTION OF GRAPE COMPOSITION AT OAKVILLE, CA



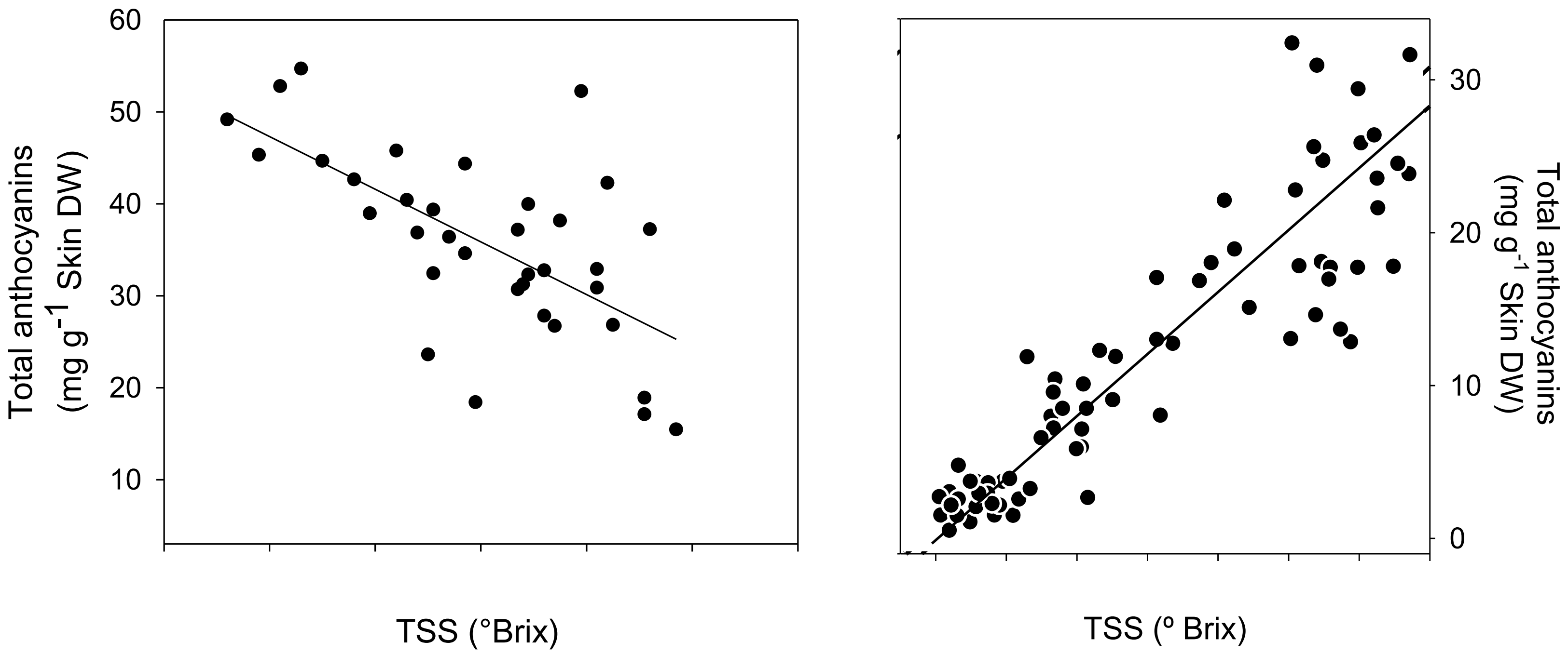






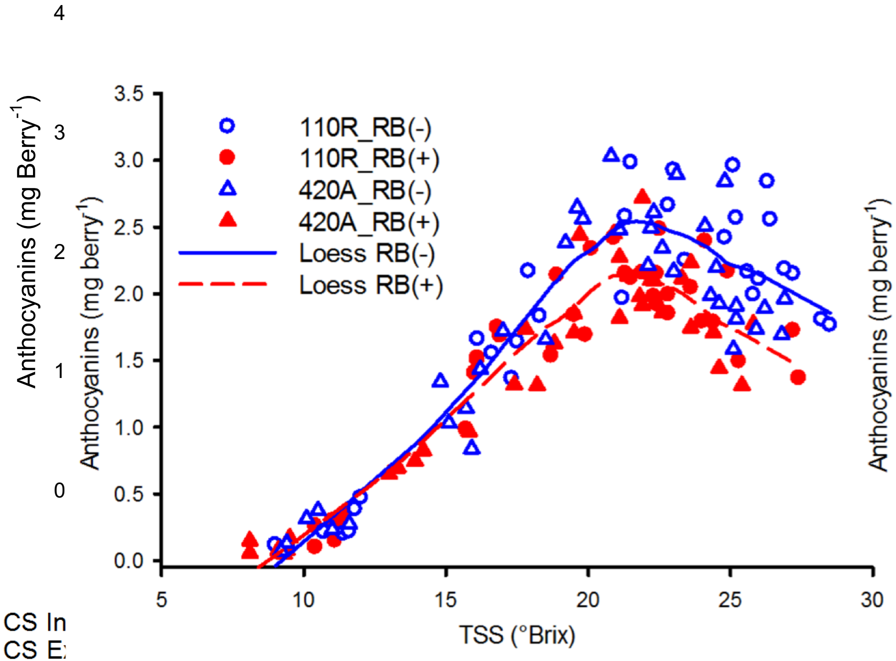


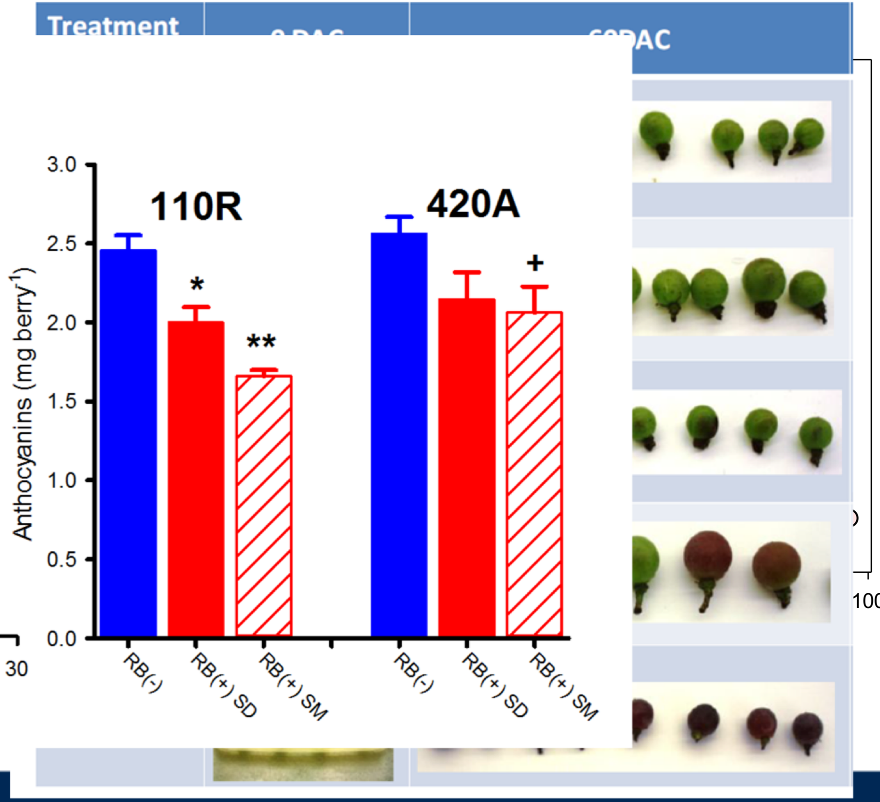
RELATIONSHIP BETWEEN TSS AND COLOR

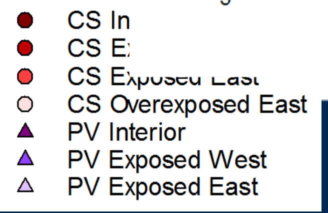


SHRIVELING VS RIPENING IN C. SAUVIGNON

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







Martínez-Lüscher et al., 2019

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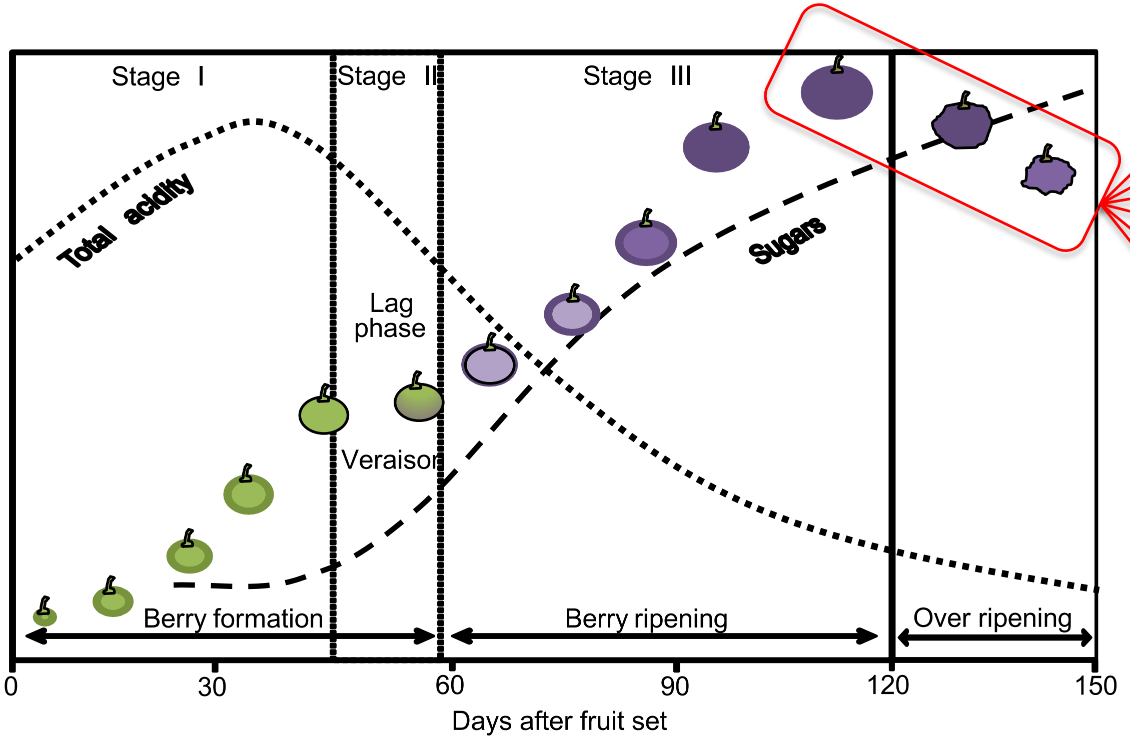


LOSS OF WATER

LOSS OF ACIDITY

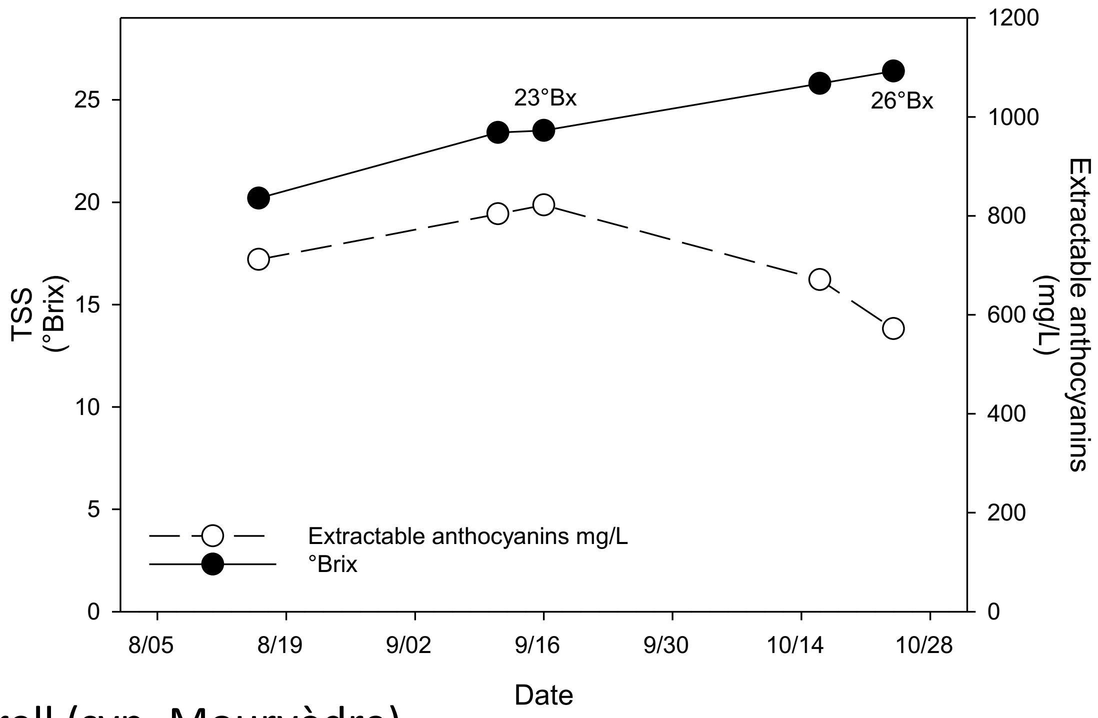
LOSS OF COLOR

LOSS OF ASTRINGENCY

AROMA/FLAVOR CHANGE

CONSISTENCY CHANGE

RIPENING STAGE AND COLOR



Region IV Monastrell (syn. Mourvèdre)

Bautista-Ortin et al. 2013

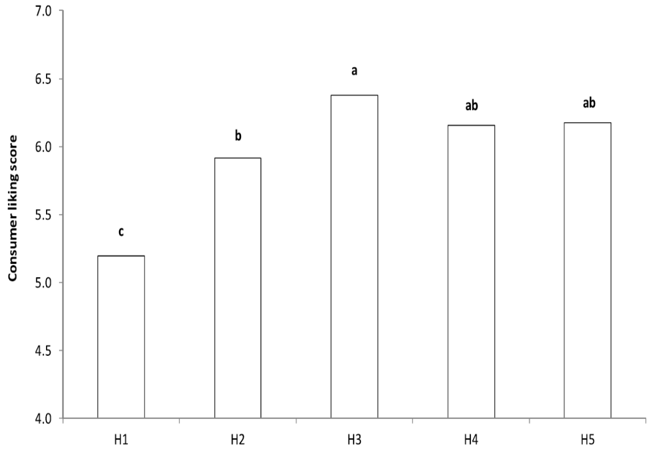
RIPENING STAGE AND WINEMAKING

Table 1

General compositional analysis, non-volatile compounds and isobutyl methoxypyrazine in grape juice and solids from different harvest points in 2010 where H1 was the earliest (16th February) and H5 the latest (17th March) sampling date.

	H1	H2	H3	H4	H5
Juice composition					
Soluble sugar [°Brix][f]	20.3 ± 0.12[a]	22.1 ± 0.12[b]	23.1 ± 0.15[c]	24.1 ± 0.1[d]	26.0 ± 0.0[e]
pH	3.18 ± 0.01[a]	3.18 ± 0.02[a]	3.33 ± 0.01[b]	3.33 ± 0.01[b]	3.48 ± 0.01[c]
Titratable acidity pH 7.0 [g/L][g]	8.3 ± 0.2[a]	6.9 ± 0.3[b]	6.5 ± 0.05[b]	5.7 ± 0.21[c]	5.3 ± 0.25[c]
Grape solids composition					
Anthocyanin [mg/g][j]	1.37 ± 0.06[a]	1.44 ± 0.05[ab]	1.61 ± 0.09[bc]	1.67 ± 0.02[c]	1.87 ± 0.04[d]
Total tannin [mg/g][k]	4.15 ± 0.10[a]	3.76 ± 0.15[ab]	3.63 ± 0.01[bc]	3.48 ± 0.16[bc]	3.26 ± 0.14[c]

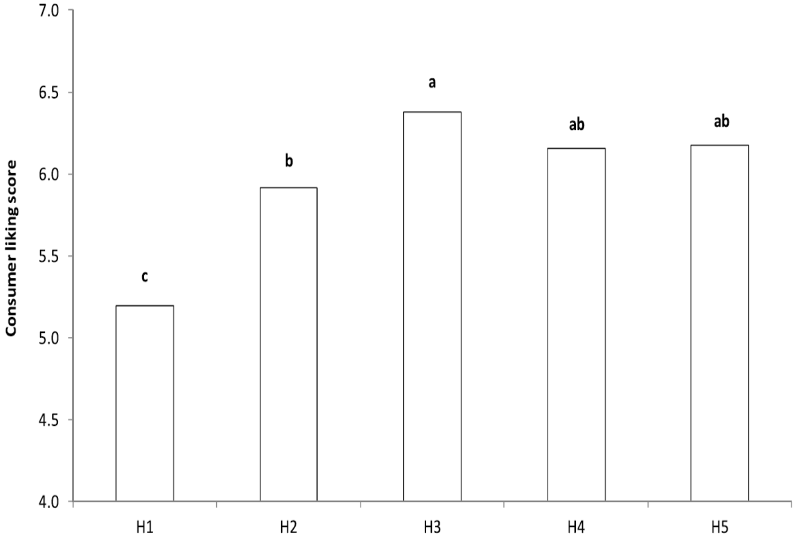
Values as mean ± standard error, significant differences between treatments are indicated by different letters in superscript determined by ANOVA, post hoc Student's *t*-test, *n* = 15.



Region IV Cabernet

Bindon et al. 2013

RIPENING STAGE AND WINEMAKING



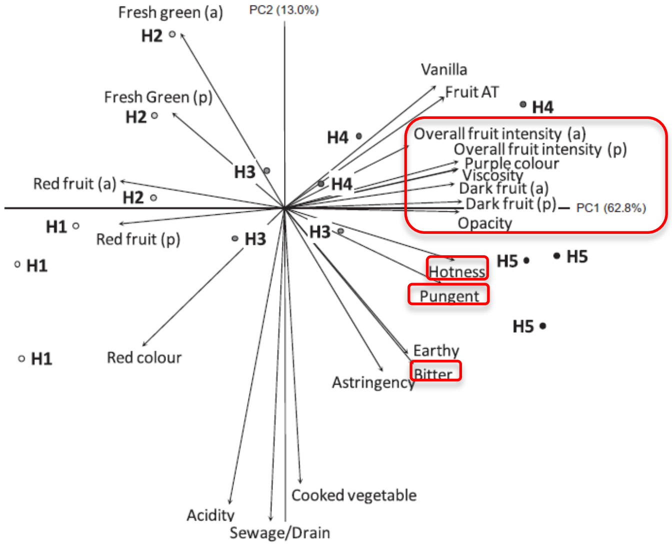


Fig. 1. Principal component (PC) analysis biplot of the mean scores of the significant ($P < 0.05$) sensory descriptive analysis data for the 15 wines (H1–H5: harvest 1–5, and their individual fermentation triplicates). Vectors for the sensory attributes and the circle symbols for the wines are shown, calculated from scores of 10 judges × 3 presentation replicates. AT, aftertaste; a, aroma; p, palate.

OVERRIPE BERRIES HAVE LESS PENALIZATION
BALANCED WINES WERE THE MOST LIKED, FROM 23°BX (13.5% ALC) BERRIES

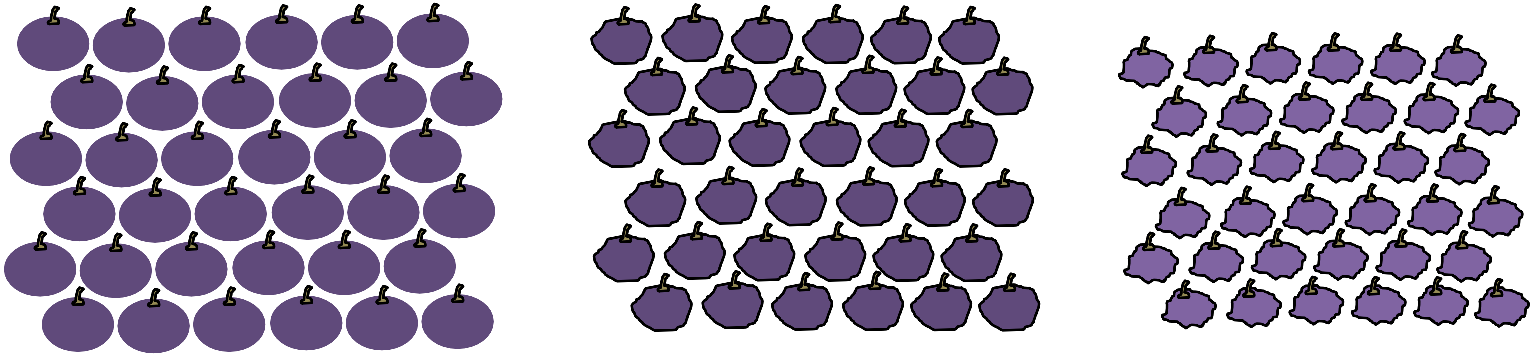
Bindon et al. 2013

WHAT IS THE OPTIMAL MATURITY?

Vegetation ⋯⋯► Herbaceousness ⋯⋯► Unripe fruit ⋯⋯► Red fruit ⋯⋯► Black fruit ⋯⋯► Jam

Vegetation	Herbaceousness	Unripe fruit	Red fruit	Black fruit	Jam
(Plant matter)	(Straw, herb, vegetal, tobacco)	(Green apple, citrus rind)	(Cherry, strawberry, raspberry, cranberry)	(Plum, blackberry, black cherry)	(Prune, date, raisin)

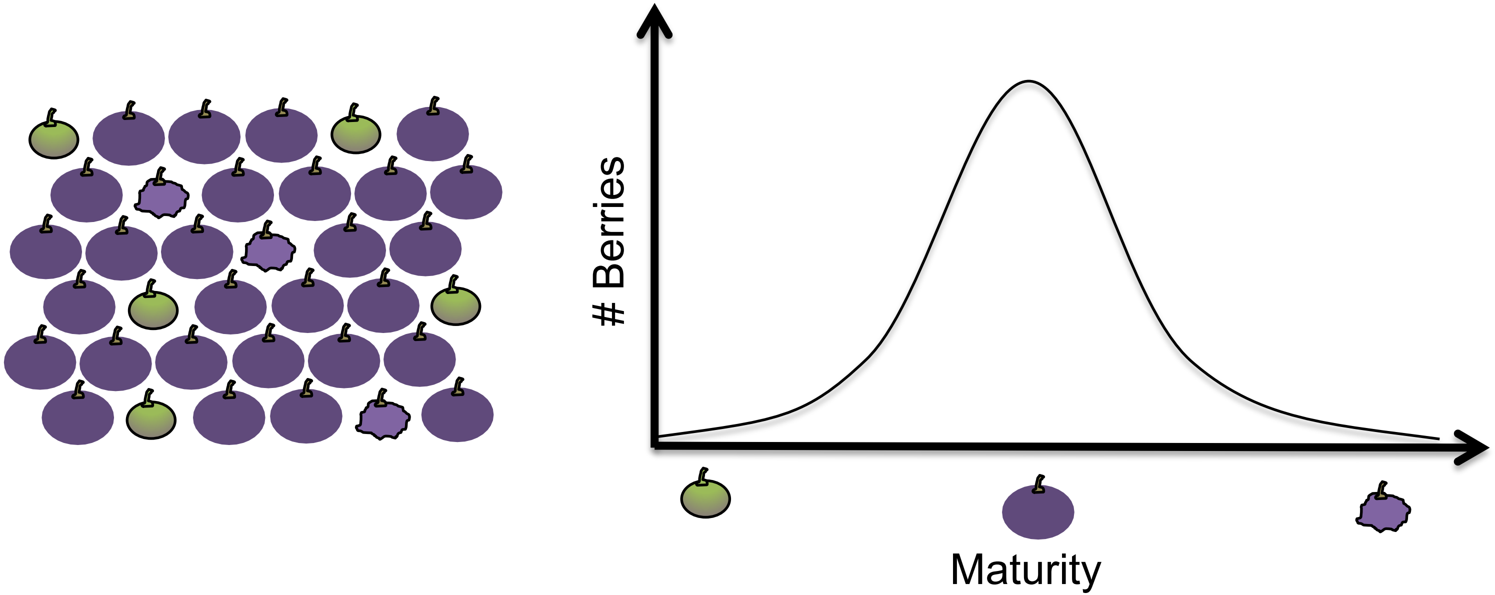
Figure 5: Evolution of flavorants in Cabernet Sauvignon



Bisson, 2001

THE QUEST OF THE PERFECT MATURITY STAGE

NORMAL DISTRIBUTION



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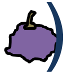
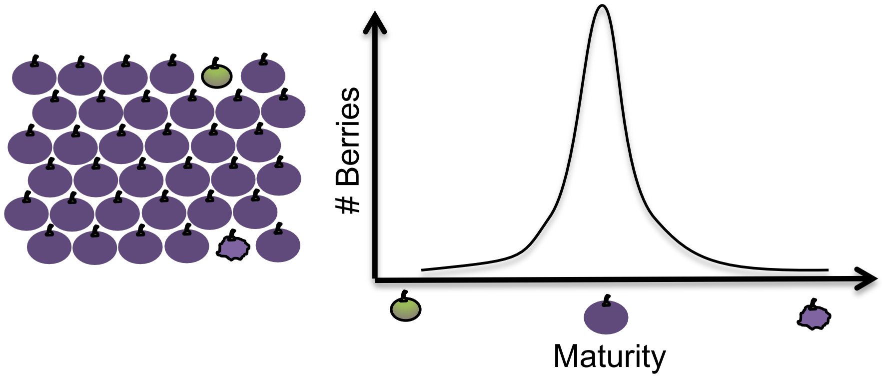
WINE IS THE RESULT OF THE COMBINATION ALL GRAPES

Mean (20 , 28) = 24°Brix

Mean ( , ) = ?

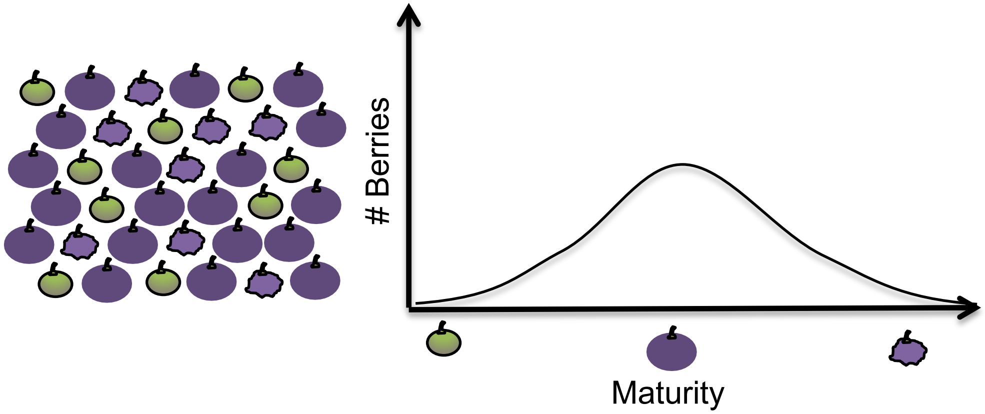
COMBINING TWO BAD THINGS RARELY MAKES A GOOD ONE!

THE QUEST OF THE PERFECT MATURITY STAGE

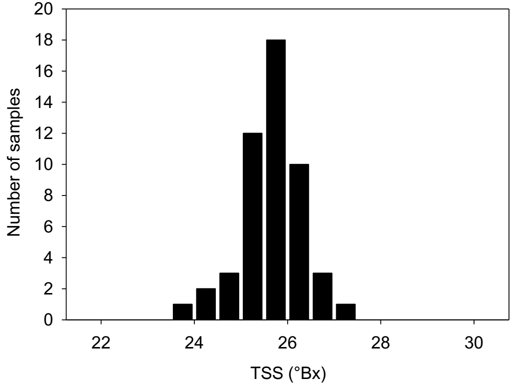


SYNCHRONOUS

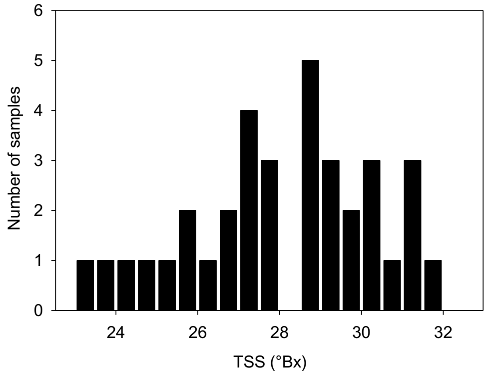
ASYNCHRONOUS



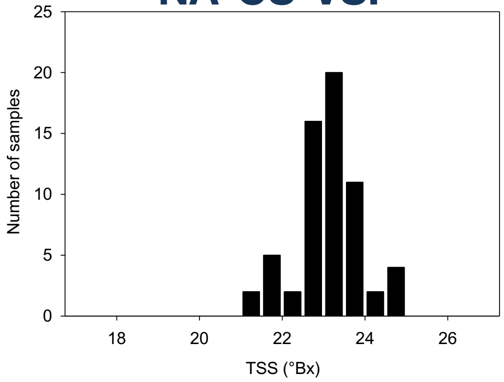
LO-CS-QUA



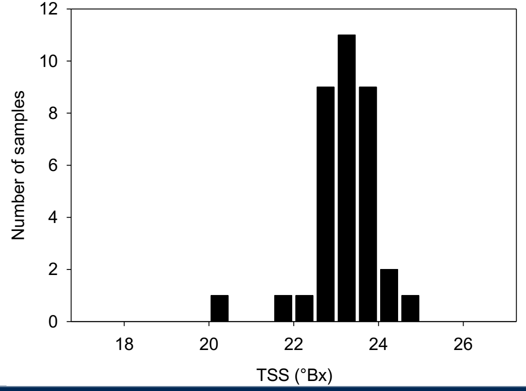
SO-CS-QUA



NA-CS-VSP

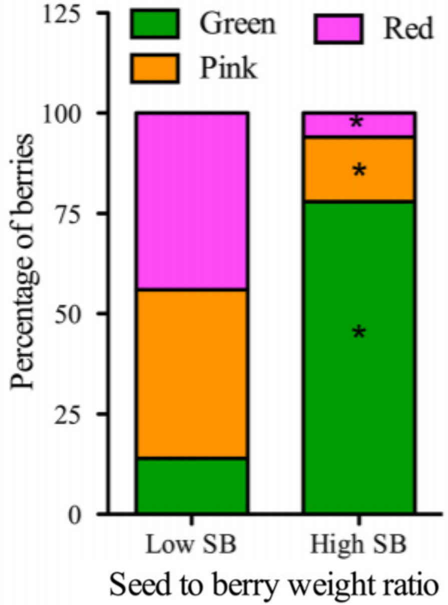


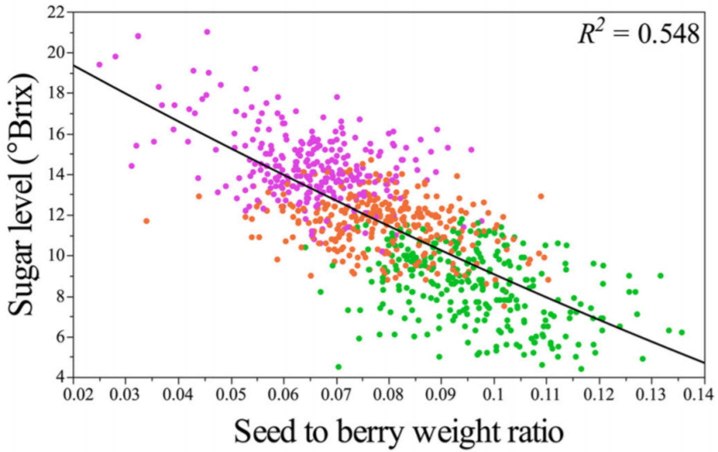
PR-ME-VSP



1 sample= 55 berries from 3 plants

ROLE OF SEED-TO-BERRY RATIO ON RIPENING ASYNCHRONY





Gouthu and Deluc 2015

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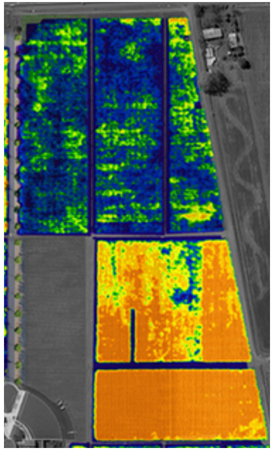
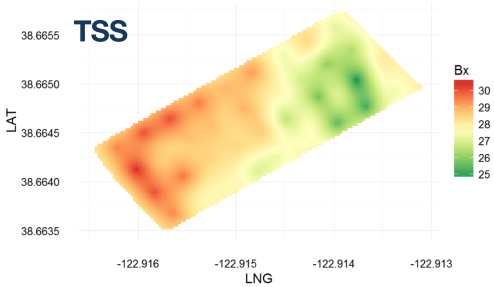
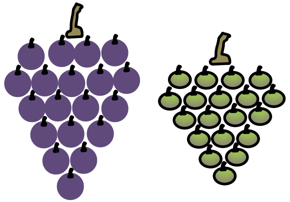
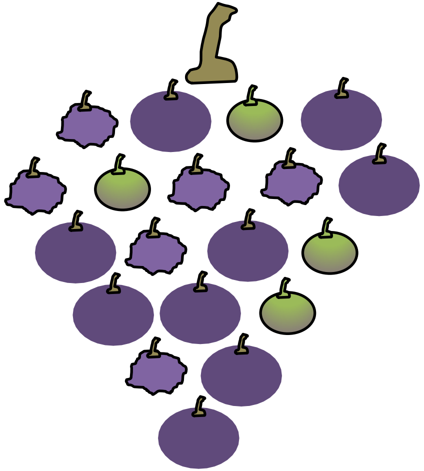
LEVELS OF VARIABILITY

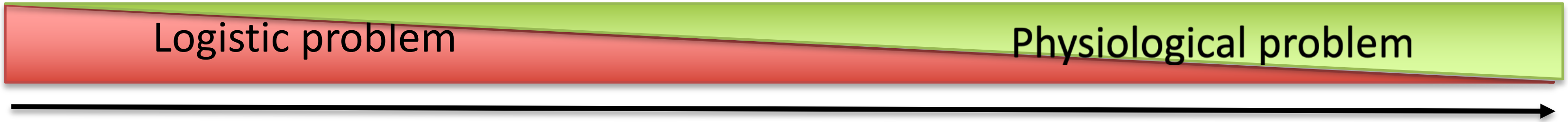
BETWEEN PLOTS - WITHIN A PLOT - WITHIN A PLANT - WITHIN A CLUSTER

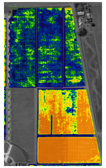












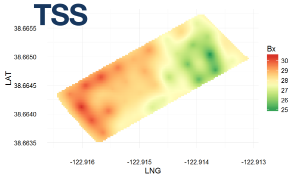
VARIABILITY “BETWEEN PLOTS”

CAUSES:

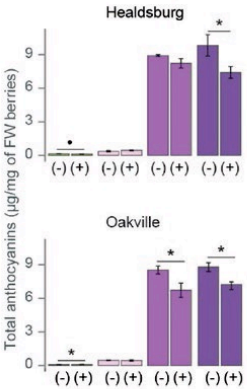
- GENETIC: DIFF CLONES OR VARIETIES
- MICROCLIMATE
- SOIL
- TERRAIN
- CULTURAL PRACTICES
- …

MANAGEMENT:

- HARVEST SCHEDULING



VARIABILITY "WITHIN PLOT"



CAUSES:

- DIFFERENT CLONES
- SOIL
- MICROCLIMATE
- TERRAIN
- DISEASES

MANAGEMENT:

- DIFFERENTIAL HARVEST... BUT
  - Several passes
  - Only for continuous patterns
  - Requires certain knowledge of each plot
  - strawberry picking approach not possible
- INDIVIDUAL VARIABLE MANAGEMENT
  - Requires great knowledge of the field structure (if any)
- STANDARDIZATION
  - May mean give up on some yield for no reason (Shoot or fruit thinning)

Blanco-Ulate et al. 2016

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VARIABILITY “WITHIN PLANT”

CAUSES:

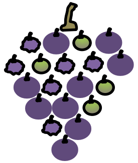
- DISEASES
- LOW LEAF-TO-FRUIT RATIO
- SUN EXPOSURE/ORIENTATION

	Berry mass (g/berry)	Soluble solids (%)	TA (%)[a]	pH	Total color (AU/mL)[b]
Cluster position					
East exposed	1.47a	23.2a	0.61b	3.61b	18.0a
Shaded	1.35a	22.4b	0.76a	3.55c	13.2b
West exposed	1.30a	22.7ab	0.52c	3.71a	13.7b

MANAGEMENT:

- INDIVIDUAL VARIABLE MANAGEMENT
  - Requires great knowledge of the field structure (if any)
- STANDARDIZATION (L:F ADJUSTMENTS)
  - May mean give up on some yield for no reason (Shoot or fruit thinning)
- BERRY SELECTION IN THE CELLAR
- TEND TO OVERRIPE (LESS PENALIZATION)

Spayd et al. 2002



VARIABILITY “WITHIN CLUSTER”

CAUSES:

- DISEASES
- LOW LEAF-TO-FRUIT RATIO
- SUN EXPOSURE
- UNEVEN FRUIT SET

MANAGEMENT:

- DIFFERENTIAL HARVEST... BUT
    - Several passes
    - Only for continuous patterns
    - Requires certain knowledge of each plot
- INDIVIDUAL VARIABLE MANAGEMENT
    - Requires great knowledge of the field structure (if any)
- STANDARDIZATION (L:F ADJUSTMENTS)
    - May mean give up on some yield for no reason (Shoot or fruit thinning)

ROLE OF CARBON FIXATION IN BERRY RIPENING

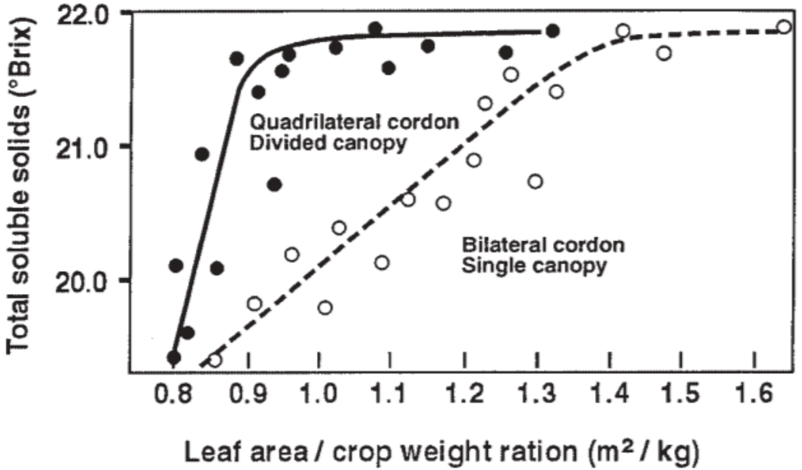
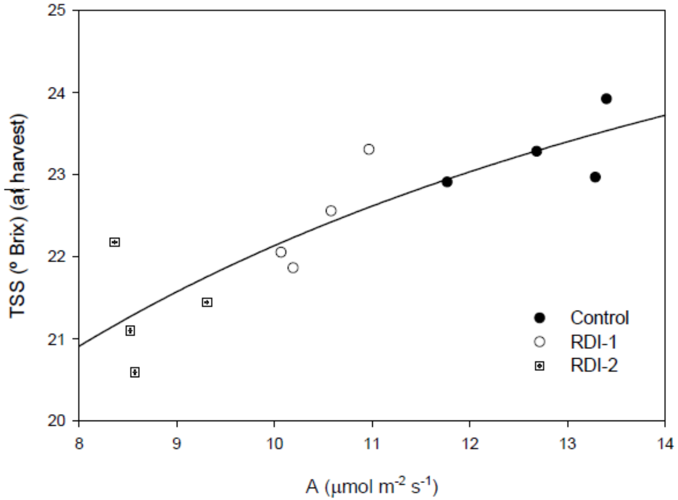


Figure 14 Regressions of total soluble solids (Brix) of Cabernet Sauvignon berry juice at harvest on leaf area per unit crop weight (m^2/kg) of vines trained to either single-canopy or divided-canopy systems.



Carbon fixation rate

Azorin et al. (2012); Kliewer and Dokoozlian (2005) AJEV

CONTROL OF RIPENING: MINIMAL PRUNING

Table 2 Effects of minimal pruning (MP) and conventional hand pruning (CHP) on must composition and berry anthocyanins in Tempranillo in 2014 and 2015.

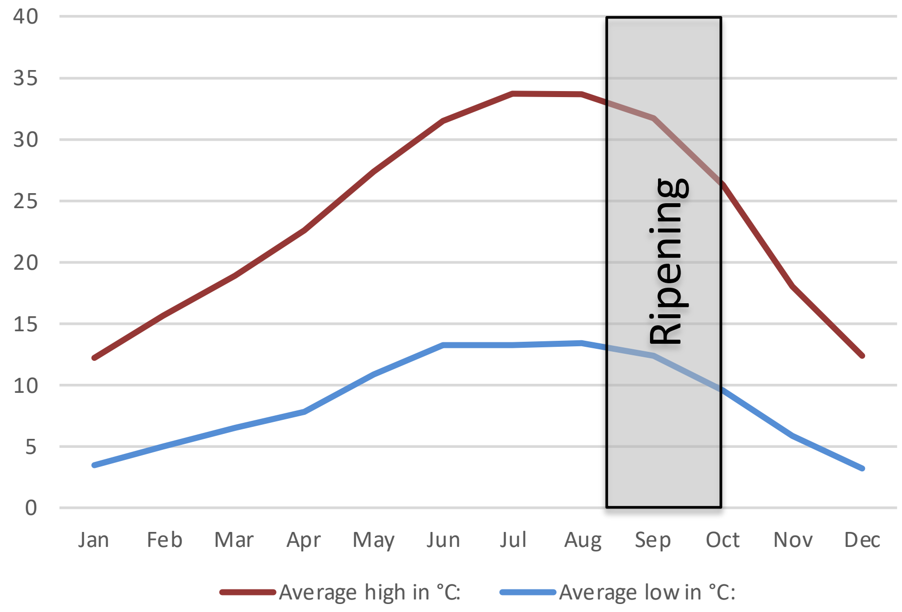
Pruning treatment	Date of fruit maturation (22 Brix)	Titratable acidity (g/L)	pH	Tartaric acid (g/L)	Malic acid (g/L)	Total anthocyanins (mg/g)[a]	Anthocyanins (mg/cm² skin surface)[a]
2014							
CHP	1 Oct	3.85	3.41	4.4	3.1	1.31	0.37
MP	21 Oct	5.30	3.60	4.9	2.7	1.53	0.39
Significance[b]		**	***	***	**	*	ns
2015							
CHP	15 Sept	7.55	3.39	–[c]	3.2	0.96	0.25
MP	28 Sept	6.34	3.23	5.3	3.5	1.16	0.25
Significance		***	***	–[c]	ns	*	ns

[a]Measured at 22 Brix.
[b]Differences between treatments were assessed with independent-samples *t*-tests; *, **, ***, ns: significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, or not significant, respectively.
[c]Missing data.

Delayed ripening

- Higher acidity
- Higher color density
- Over cropping risk managed by trimming

LATER RIPENING MAY DECREASE TEMPERATURE



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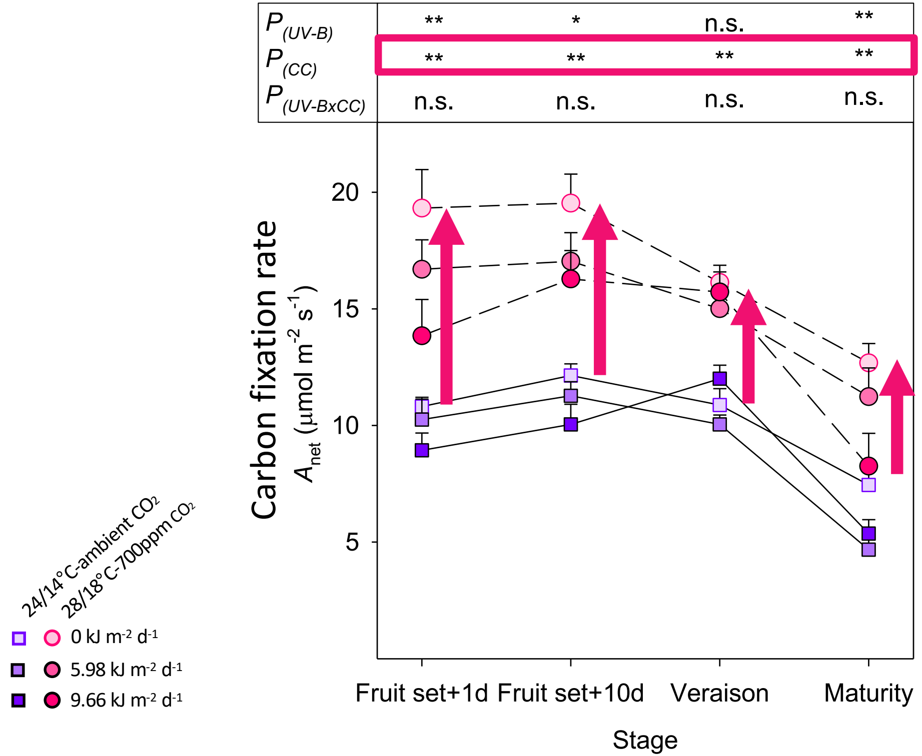
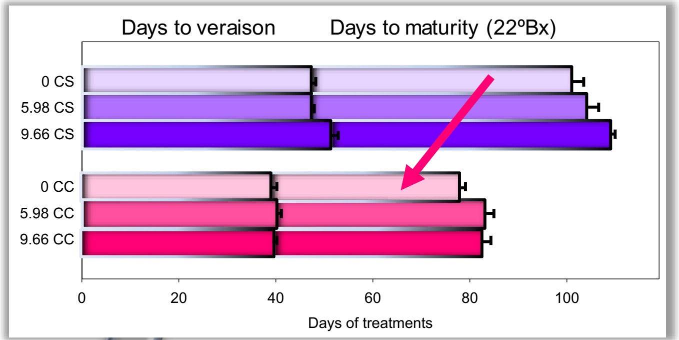
Elevated CO_2 can double photosynthesis

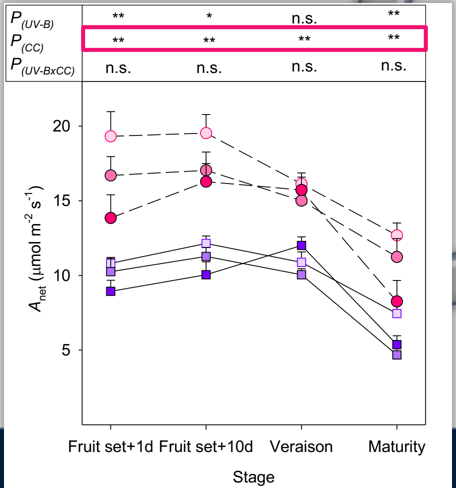


Martínez-Lüscher et al. 2016 Plant Science

UCDAVIS

Faster berry development associated to higher carbon fixation



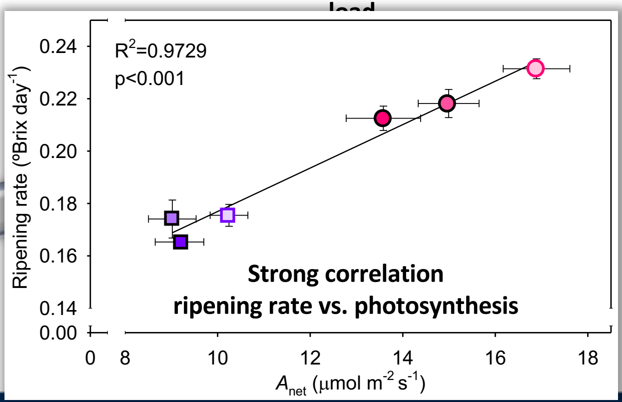


24/14°C-ambient CO_2

28/18°C-700ppm CO_2

- 0 kJ m-2 d-1
- 5.98 kJ m-2 d-1
- 9.66 kJ m-2 d-1

Constant leaf area and crop load



Martínez-Lüscher et al., 2015 Plant Science

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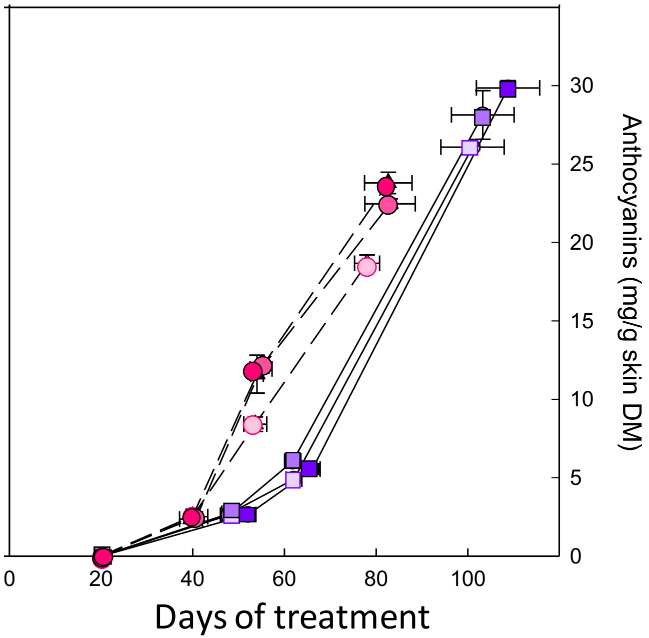
FASTER RIPENING LED TO LOWER ANTHOYCANIN CONCENTRATION

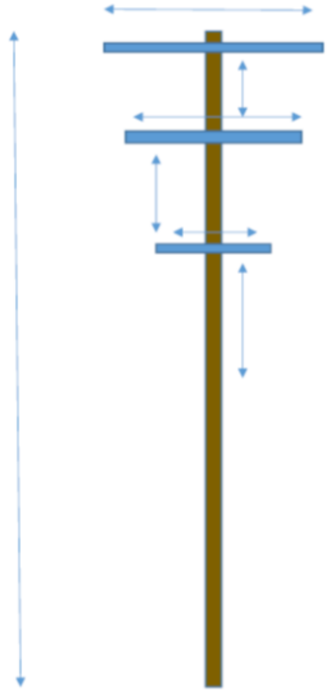


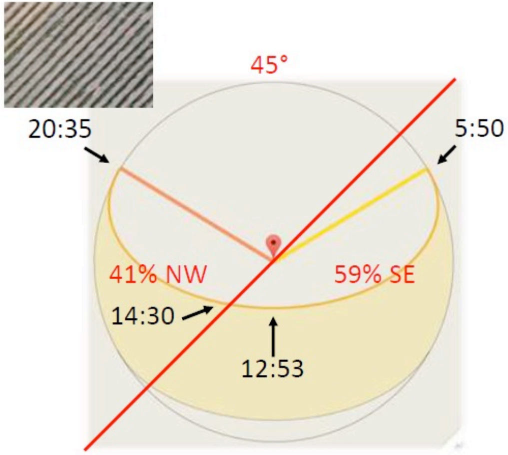
Martínez-Lüscher et al., 2015 AJGWR

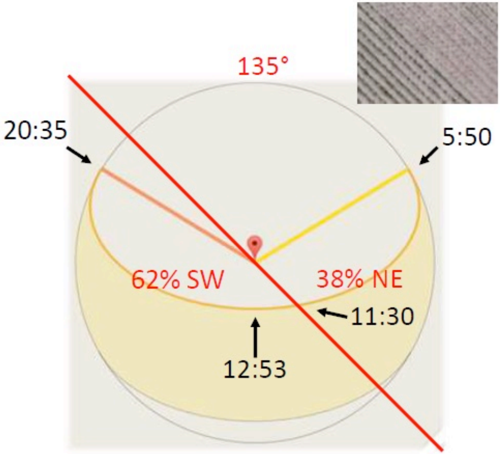
IS THERE ANY DISADVANTAGE OF RIPENING TOO FAST?

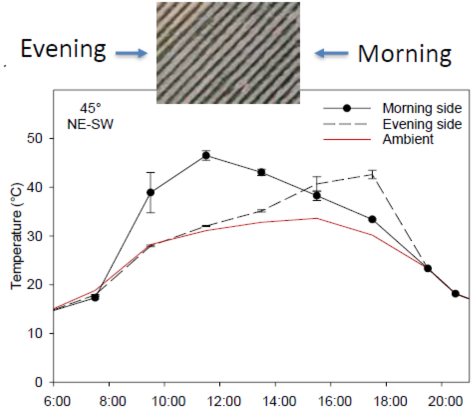
Shift towards positioned and sprawling systems

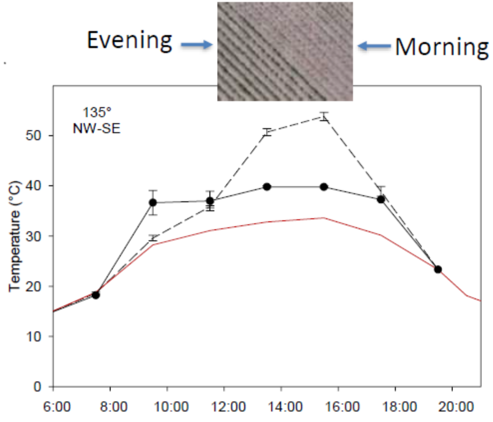
The UCDavis30 Trellis











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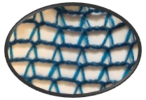
Experiment 1: Colored Shade Net Trial

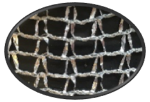
- Control: Uncovered
- 20% shading factor – White

- 40% Shading factor - Black

- 40% Shading factor – Blue



- 40% Shading factor - Aluminet

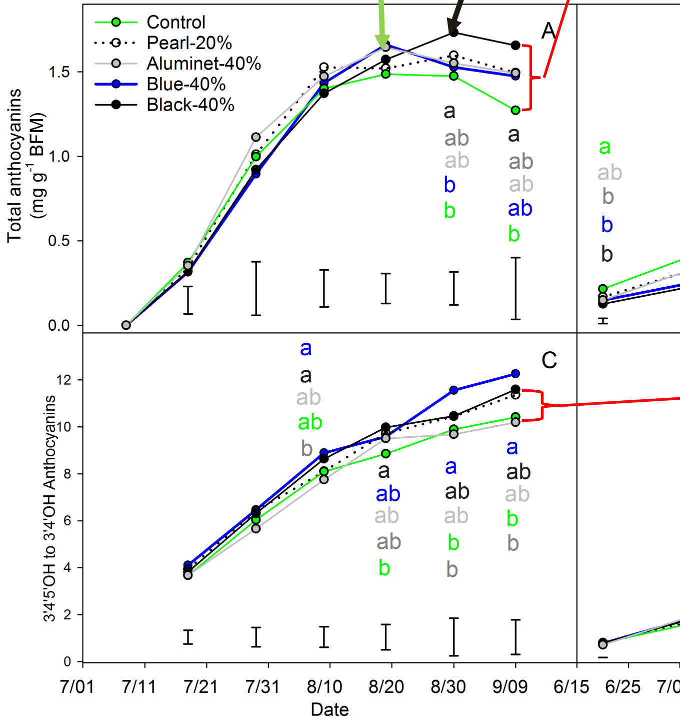


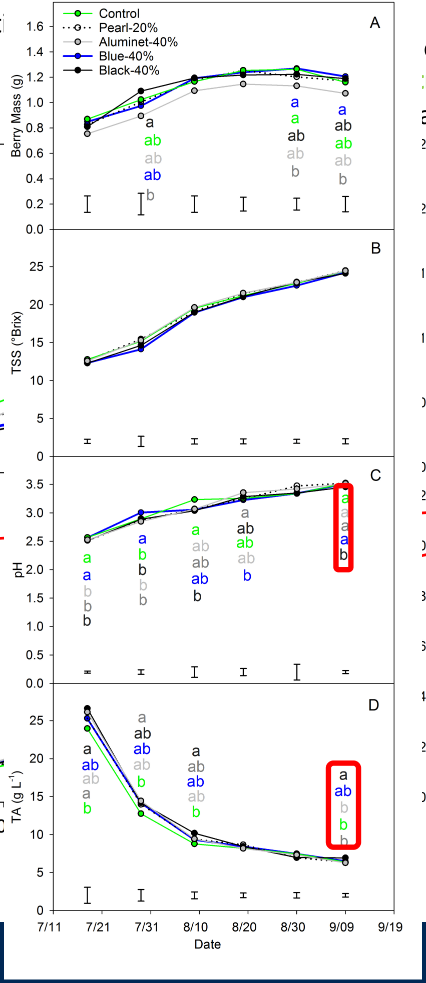
n=4 (3 vines per rep)
Cabernet Sauvignon on VSP
Oakville (Napa)
NE to SW row orientation

Results

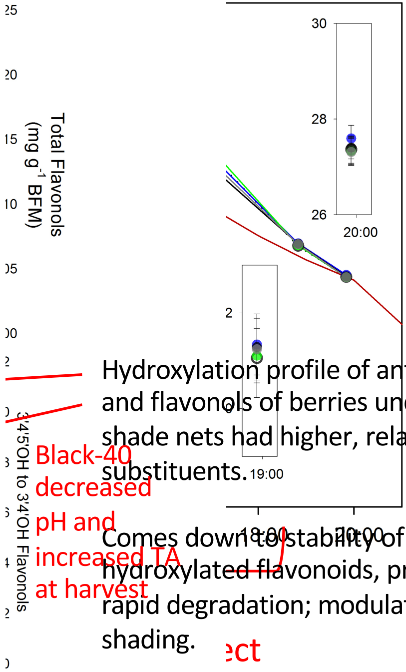
Peak content **control** & **Black-40**

Degradati **control** > **Black-40**





of flavonols in
rol, but less
as well.



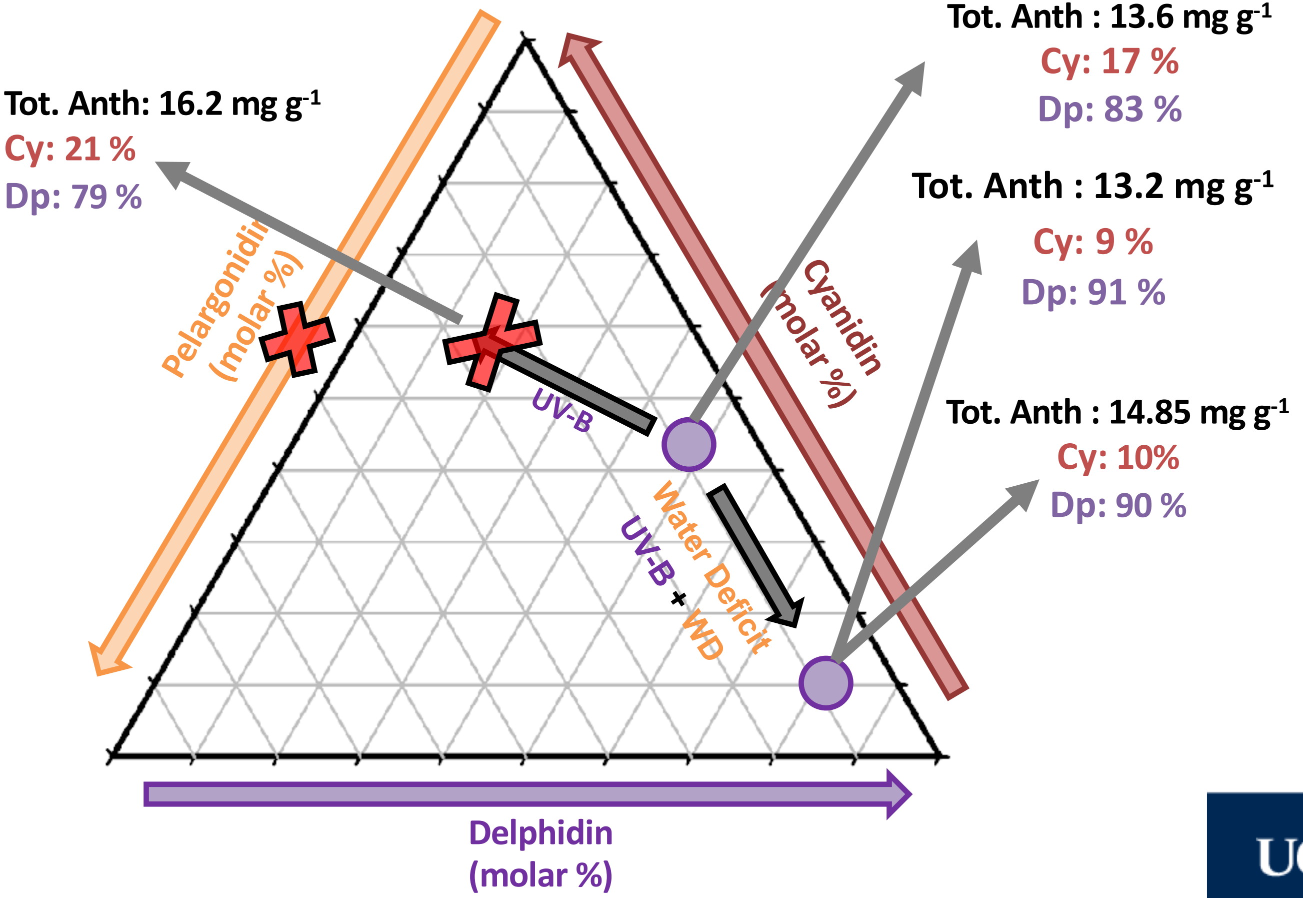
Black-40 decreased pH and increased TA at harvest

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

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

ect
n

Anthocyanin profile hydroxylation under higher light and water deficit



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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	↓	↑

TAKE HOME MESSAGES

- After ~23°brix, berries experience dramatic changes: better extraction of phenolic compounds but also degradation

- Ripening stage of berries follow a bell shape distribution. These can be spread, do not care only about the average!

- The impact of ripening asynchrony on wine quality deserves more attention

- Knowing your vineyard (research) may be the greatest asset

THANK YOU FOR LISTENING!