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EFFECTS OF CULTURAL PRACTICES ON WINEGRAPE COMPOSITION

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Desirable Aspects

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

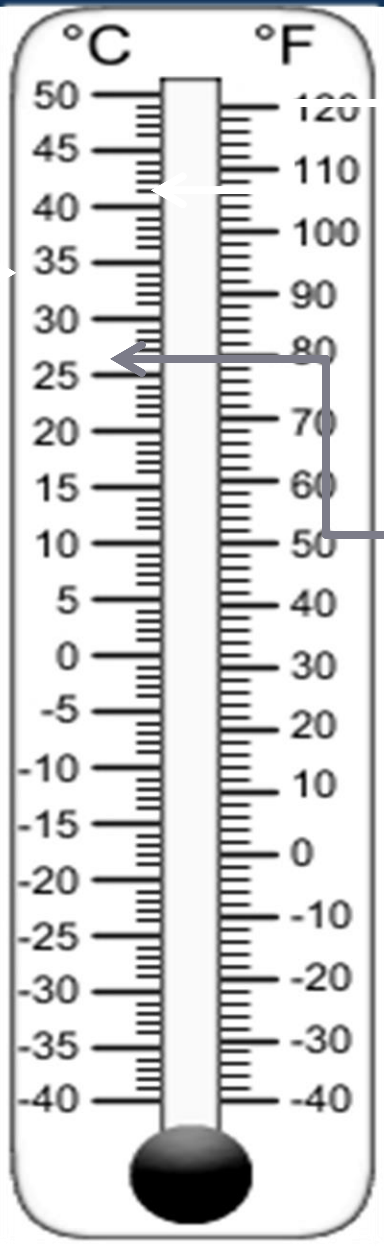
General responses to elevated light and temperature

	Light	Temperature
Berry growth	+	+/-
Berry composition:		
Sugar	+	+
Organic acids	+/-	-
pH		+
Anthocyanins	+	+/-
Phenolics	+	+/-
Methoxypyrazines	-	-
Monoterpenes	+	-

Temperature Thresholds of *Vitis*

86 – 95ºF

- Many metabolic processes slowed or halted
- Anthocyanins
  1. genetic repression
  2. degradation



95 - 105ºF

- Inhibition of carbon assimilation and skin tissue formation

77ºF

Optimal day temperature

Berry anatomy

- Flesh (pulp)
  - Juice
  - Hydroxycinnamates
- Seed
  - Tannins (bitter taste)
  - Flavan-3-ols
- Skin
  - Color pigments
  - Tannins (astringent, tactile sensations)
  - Flavan-3-ols
  - Flavonols

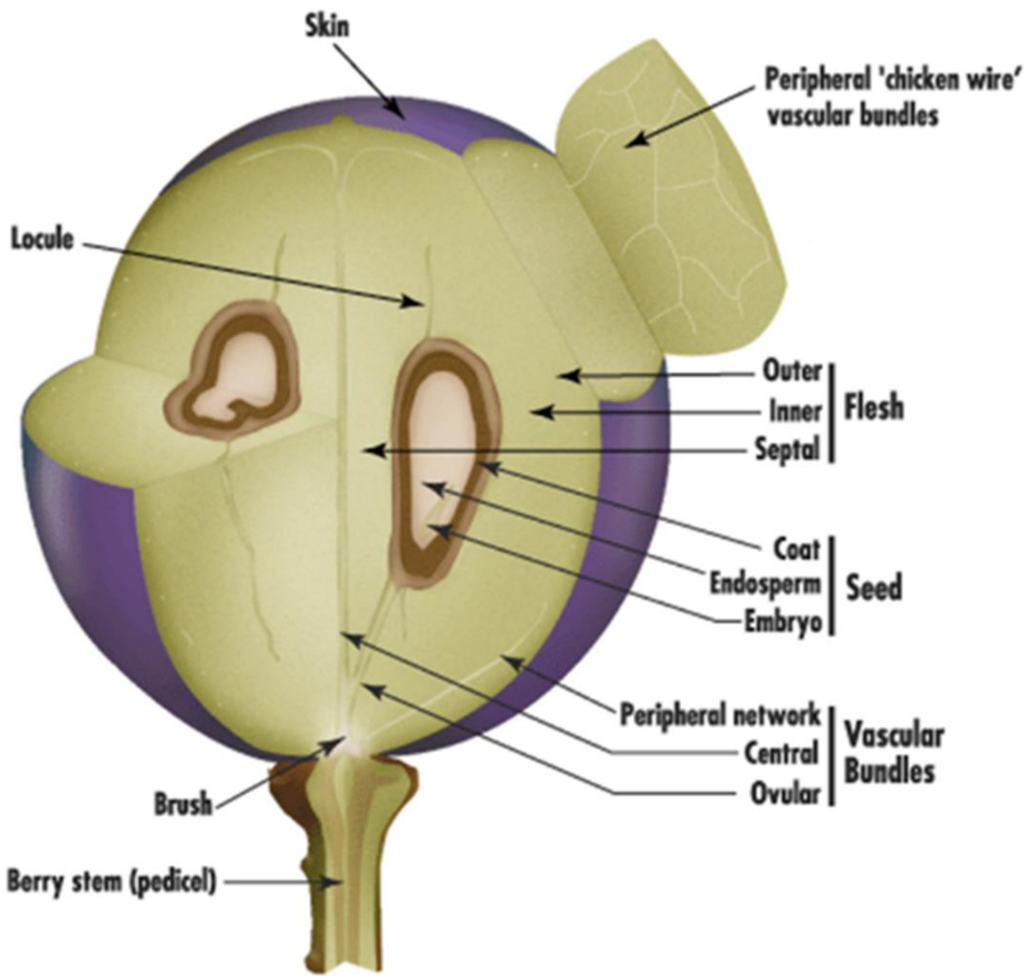


Figure I: Structure of a ripe grape berry partially sectioned on the long and central axis to show internal parts. Illustration by Jordan Koutroumanidis, Winetitles.

Berry development

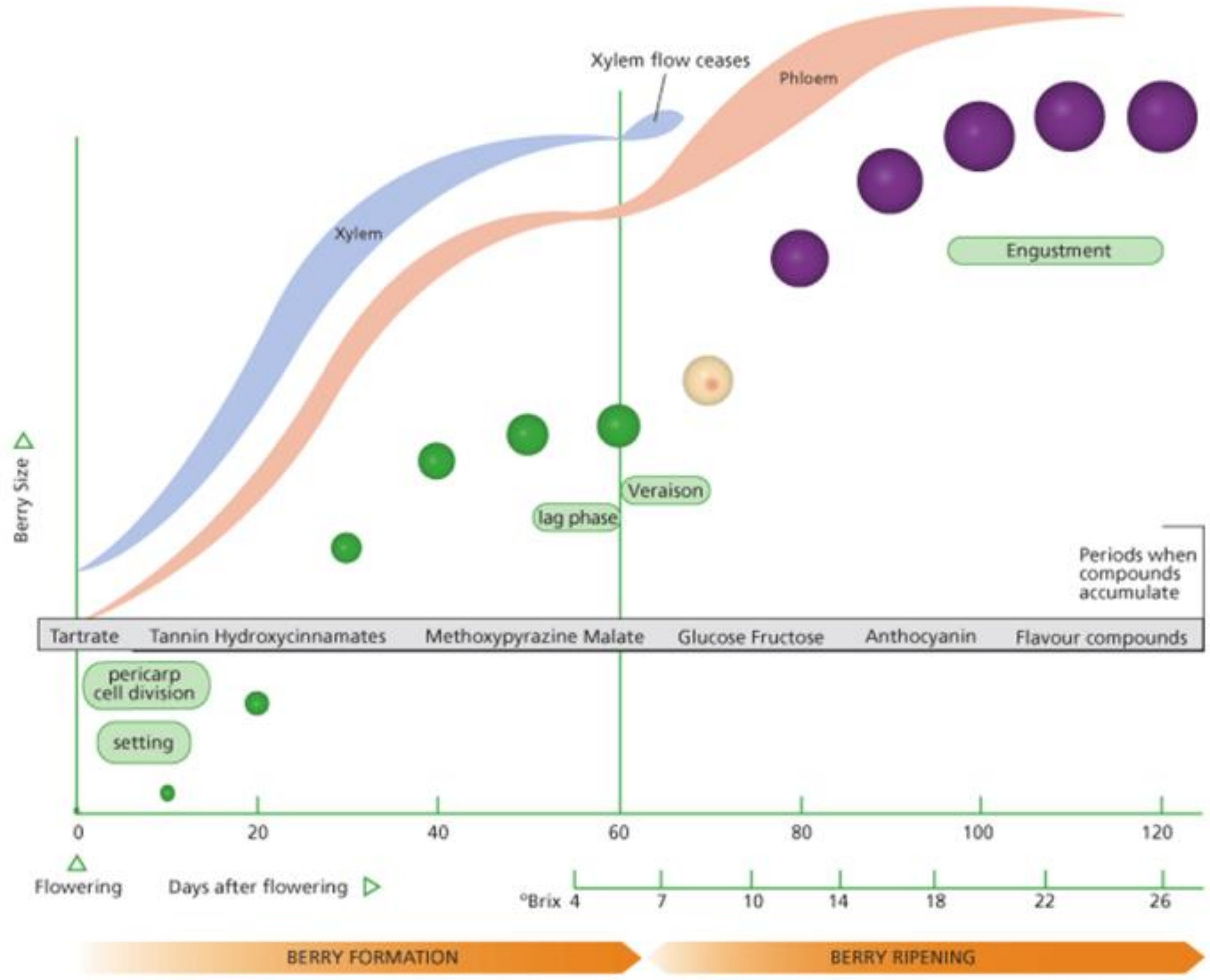


Figure 2: Diagram showing relative size and color of berries at 10-day intervals after flowering, passing through major developmental events (rounded boxes). Also shown are the periods when compounds accumulate, the levels of juice °brix, and an indication of the rate of inflow of xylem and phloem vascular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

Why study tannin composition, rather than content?

• …uthfeel drive…

Tannin Concentration

- Measure of concentration

Wine Matrix

- Acidity
- Ethanol
- Residual Sugars
- Mannoproteins
- Polysaccharides

Tannin Activity

- Composition:
  - Skin/Seed
  - Red Color
  - Oxidation
- Molecular Size

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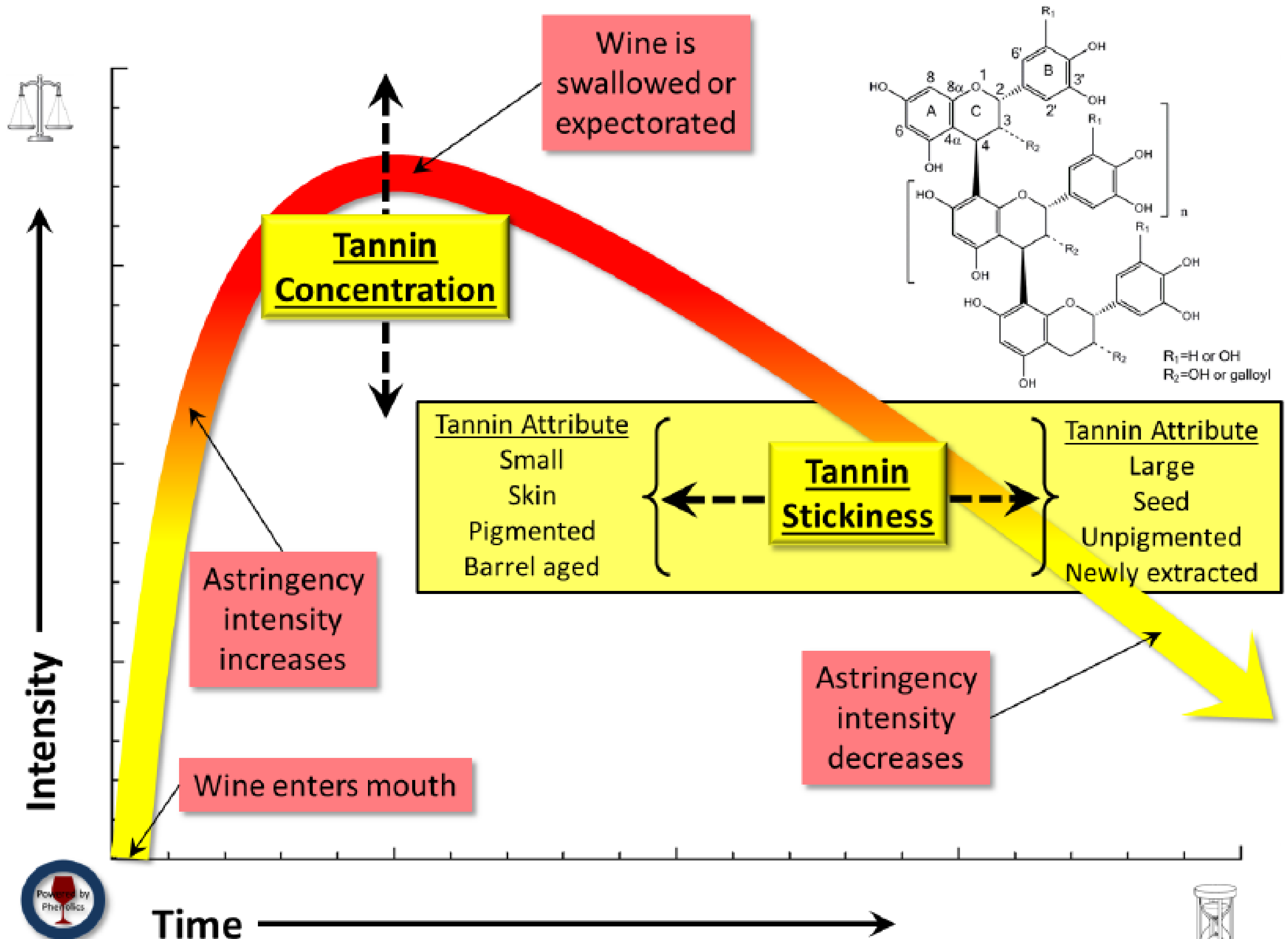
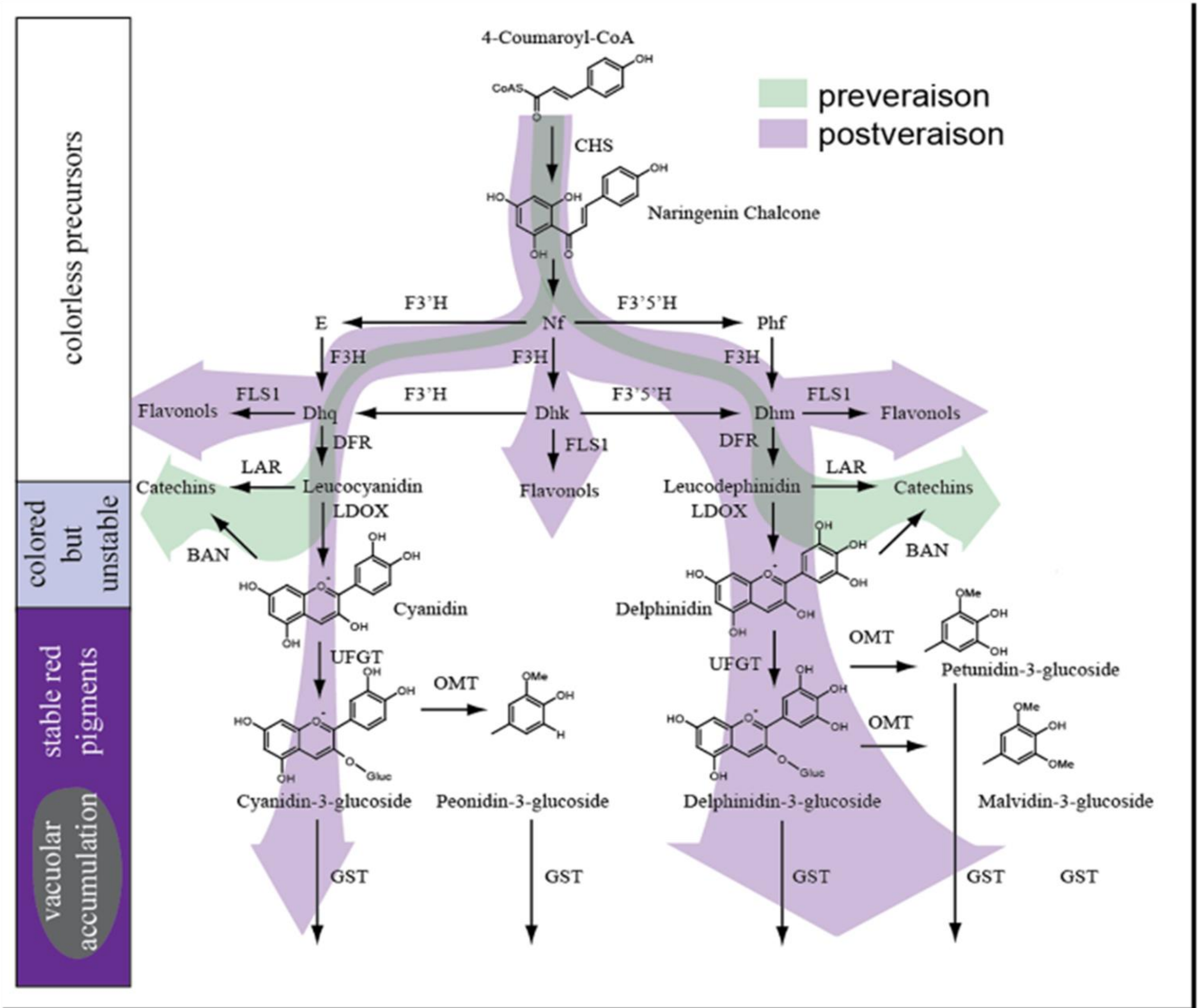


Wine is swallowed or expectorated
Tannin Concentration
Tannin Attribute
Small
Skin
Pigmented
Barrel aged
Tannin Stickiness
Tannin Attribute
Large
Seed
Unpigmented
Newly extracted
Astringency intensity increases
Astringency intensity decreases
Wine enters mouth
Intensity
Time
R1=H or OH
R2=OH or galloyl

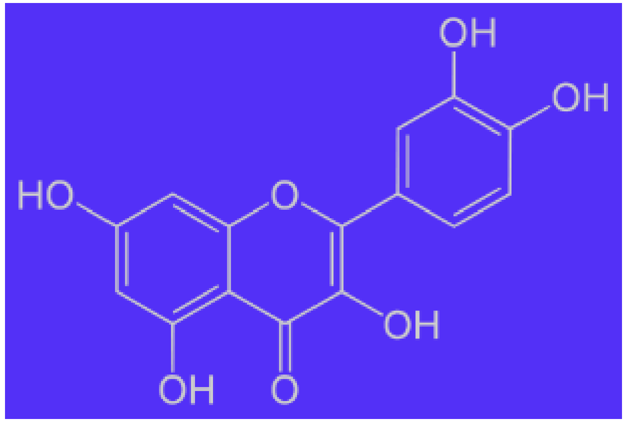
Where do they come from?



Anthocyanins

- Berry: attractant to animals (i.e. seed dispersal) and photo-protection
- Wine: visual perception, stability and age-ability of wine matrix, and antioxidative properties

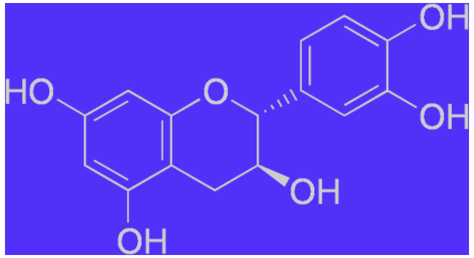
Flavonols



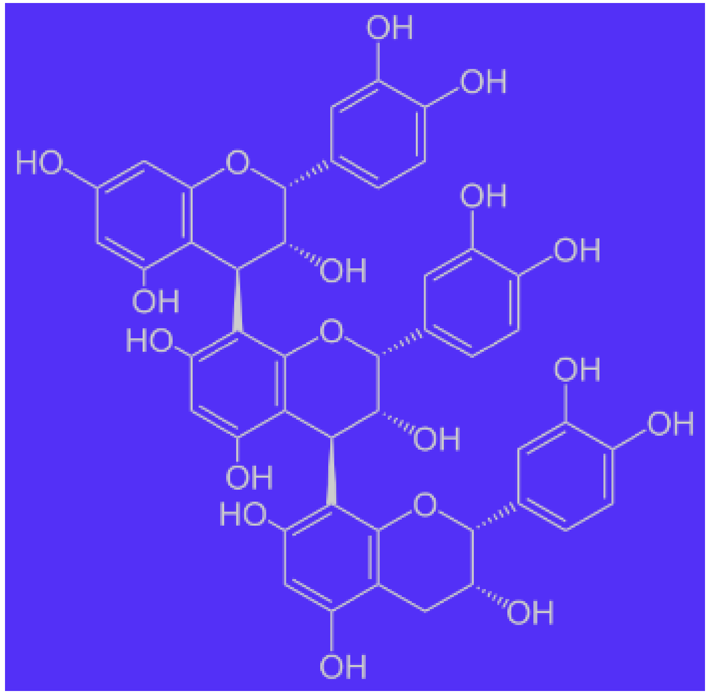
- Photo-protection
  - highly responsive to visible light and U-V
    - particularly UVB
  - less clear regarding temperature
  - studies show concentration not reliably paralleled with berry skin mass
- Cofactor of co-pigmentation in wine matrix

Flavanols

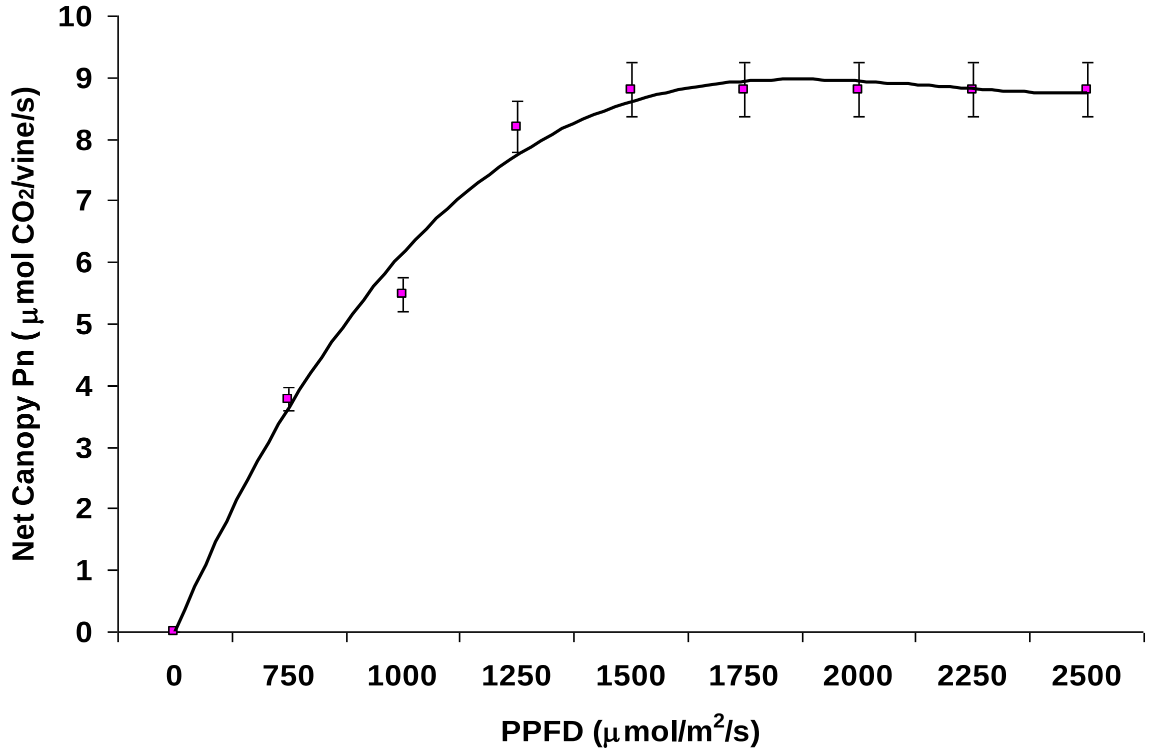
- **Monomeric**
- **Polymeric (condensed tannins)**

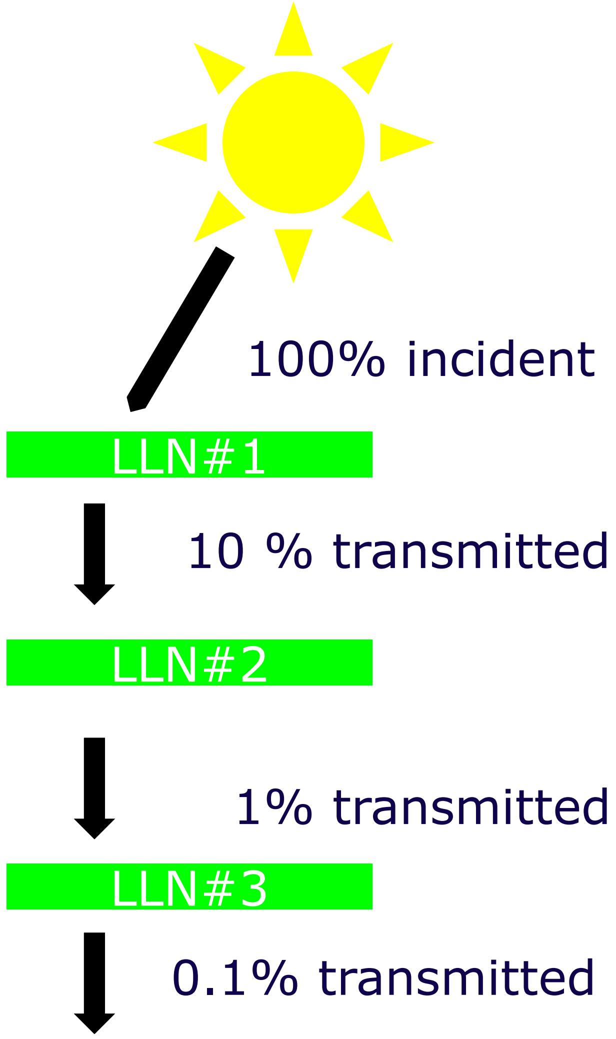


- **Berry**
  - deterrent towards animals
- **Wine**
  - bitterness and astringency (seed vs. skin)
  - critical for wine matrix stability and age-ability



Radiation Effects on Whole Canopy





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

Irrigation regimes

- Sustained Deficit Irrigation (SDI)
  - 80% ET_c from bloom to harvest
- Regulated Deficit Irrigation (RDI)
  - 80% ET_c from bloom to fruit set, 50% ET_c from fruit set to veraison, 80% ET_c from veraison to harvest
  - Moving forward…
    - Calculating ET_c

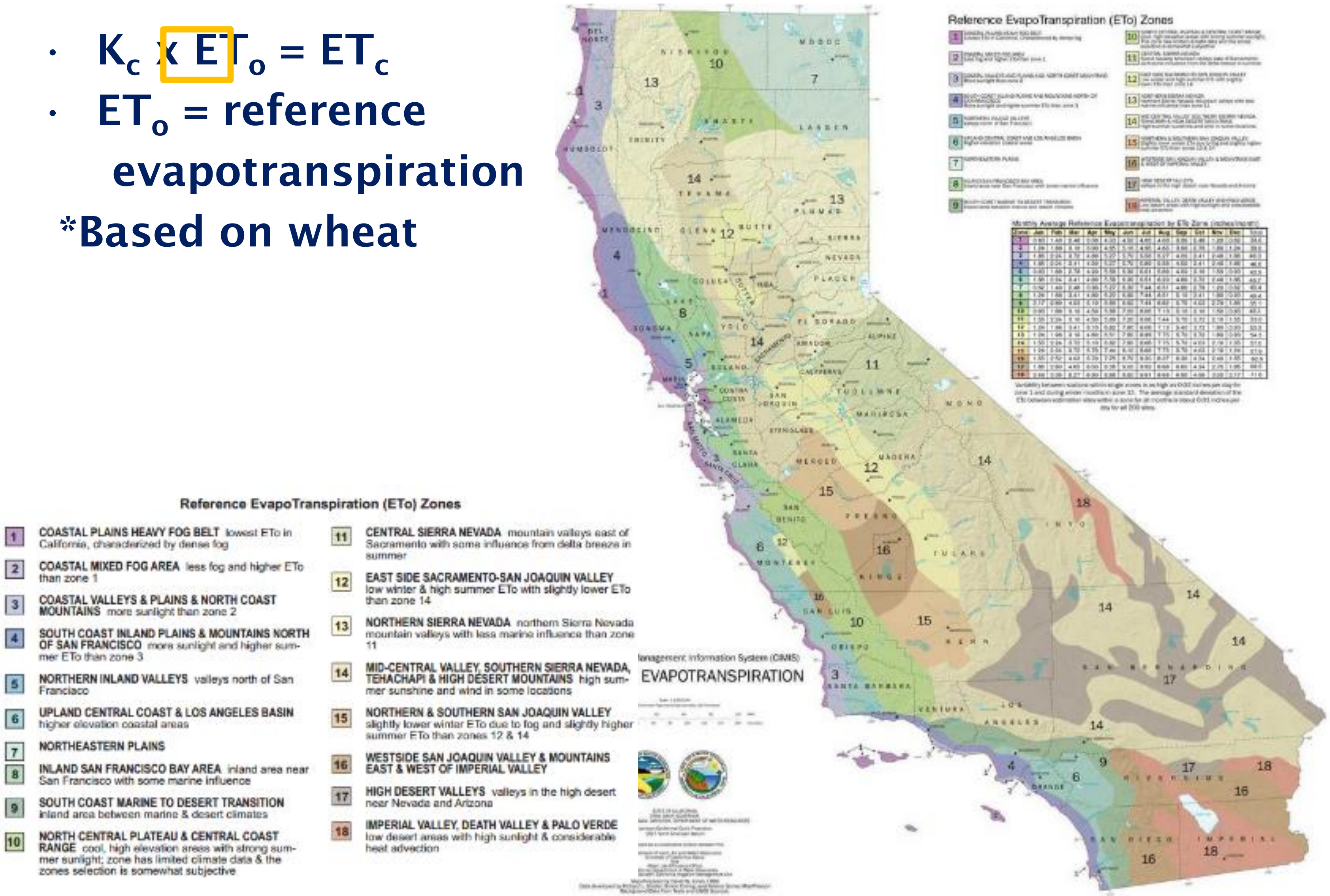
Irrigation scheduling

- $Et_c = K_c \times ET_o$
- K_c = crop coefficient
  - Calculated by weekly shade estimates
  - Remotely sensed and extrapolated from energy balance models
- ET_o = reference crop evapotranspiration
- ET_c = cultivar specific evapotranspiration
- Strongly affected by drought

Reference (ET)

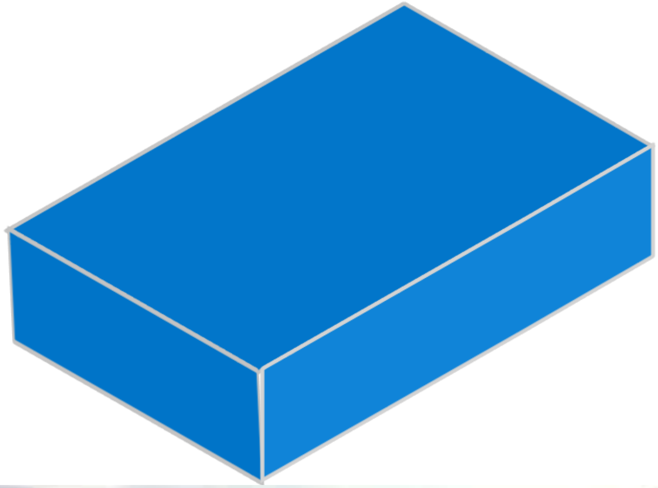
- $K_c \times ET_o = ET_c$
- ET_o = reference evapotranspiration

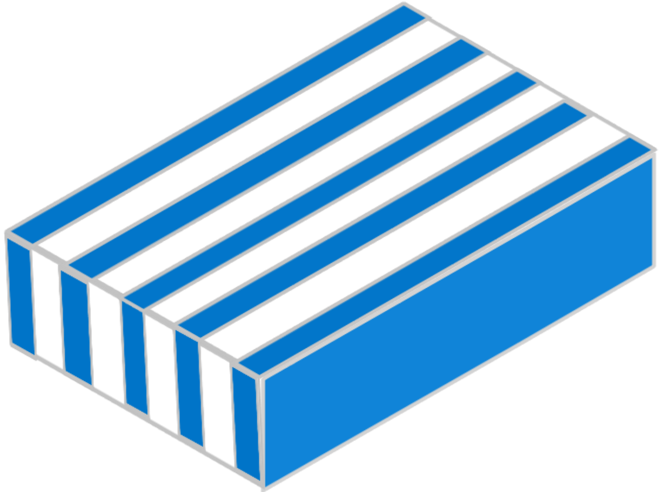
*Based on wheat



Why use a crop coefficient (K_c)?

* K_c based on canopy development; changes as season progresses, only irrigating effective rooting zone





*If no grape K_c used, over-irrigating to full field capacity the entire season

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How can we relate this information to tactile and taste sensation?

- **Increase Tannin Molecular Size→ increase astringency/ chalky**
  Sun et al, *J. Agric. Food Chem*. 2013, 61: 939-946
  Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

- **Increase %ECG→ increase drying and chalkiness**
  Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

- **Increase %EGC→ lower coarseness**
  Vidal et al, *J Sci Food Agric.* 2003, 83: 564–573

- **Increase Color Incorporation→ less astringent**
  Vidal et al, *Analytica Chimica Acta.* 2004, 513: 57-65

Light exposure and applied water amounts

Leaf removal

- Pre-bloom leaf removal
  - reduced fruit set (yield control)
  - increase in skin mass
  - improved phenolic composition

- Post-fruit set leaf removal
  - no reduction in fruit set
  - improved phenolic composition
  - berry sunburn an issue in warm climate
  - overexposure to sunlight reduces phenolic composition
  - increase in total soluble solids

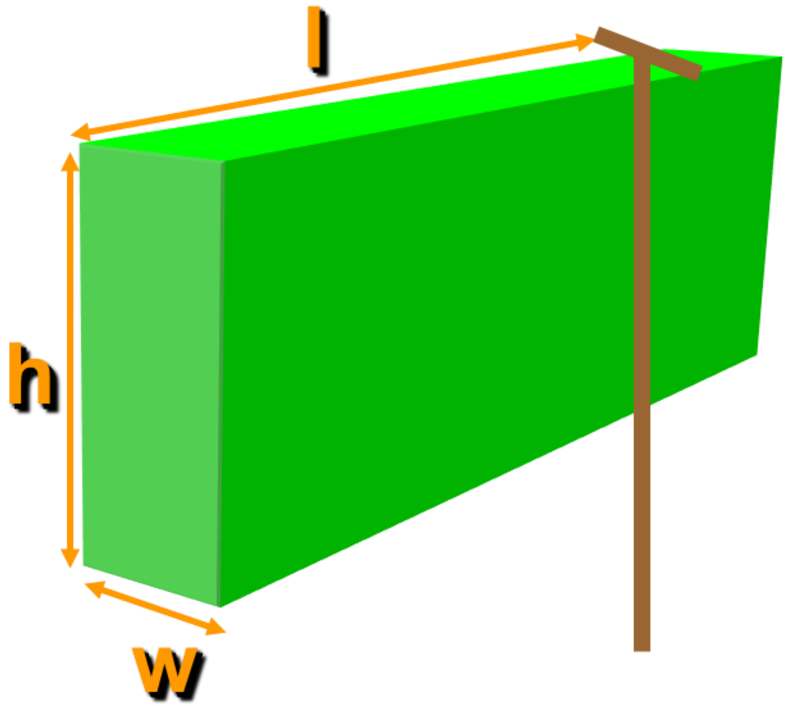
Applied water

- Deficit irrigation
  - reduced berry size
  - reduction in vegetative growth
  - increase in anthocyanin concentration
  - accelerated ripening

Plant Material and Research Site

- Merlot (01)/Freedom
- Planted in 1998
- Located in Merced County
- 80 acre research site
- 7’ x 11’ spacing (N-S)
- Whitney and Rocklin Sandy-Loam soil
- Drip irrigated
- Head trained and cane pruned to six-canes

Canopy Architecture
North Valley Cane-Pruned



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Irrigation Treatments

Irrigation hours

- calculated based on weekly CIMIS Et_o

Sustained Deficit Irrigation (SDI)

- control treatment
- received 80% of Et_c from bloom to harvest
- dynamic grape coefficient factor (K_c) included
- leaf Ψ maintained at -1.2 Mpa

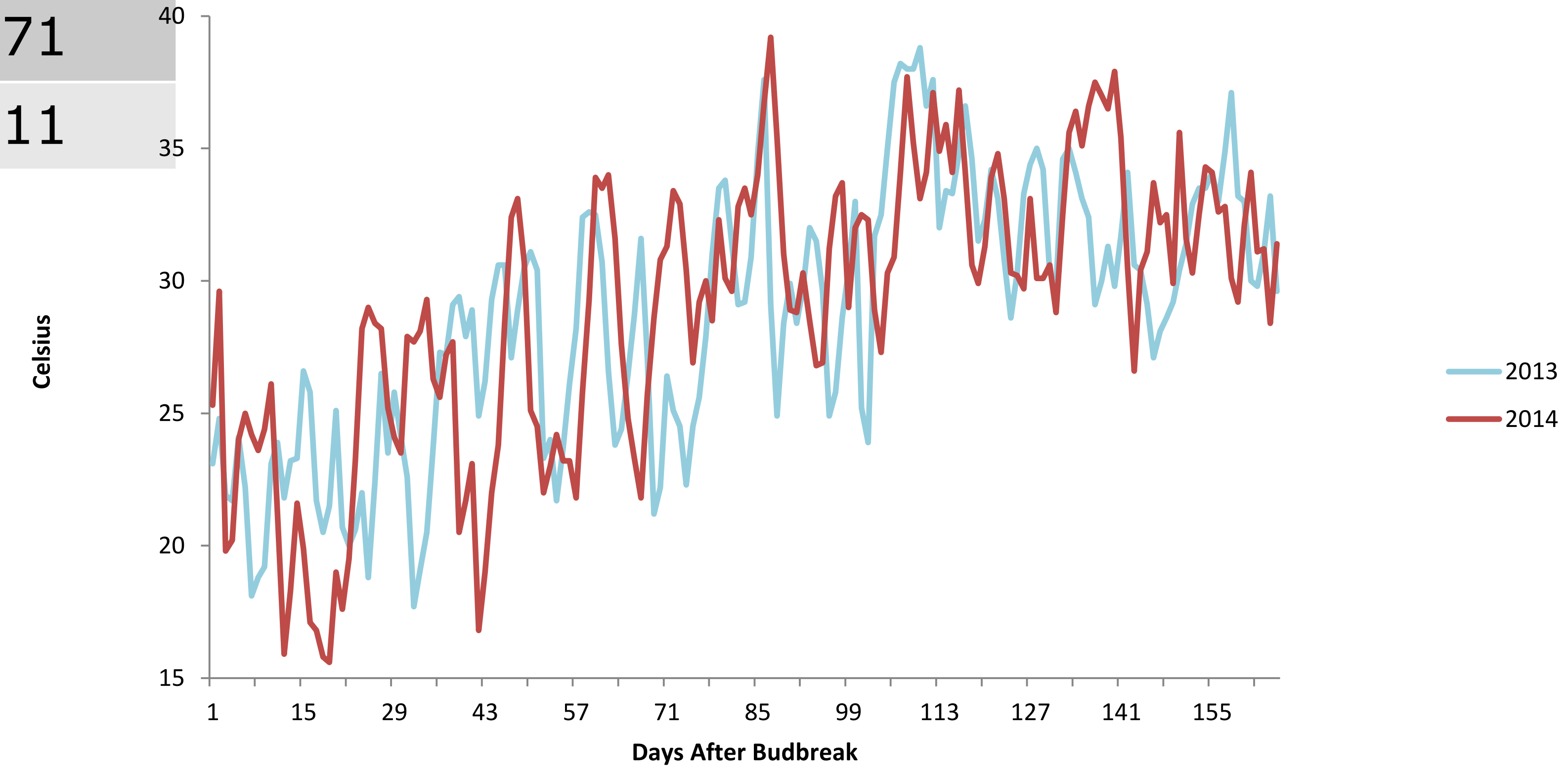
Regulated Deficit Irrigation (RDI)

- received 80% of Et_c from bloom to set and from veraison to harvest
- received 50% of Et_c from set to veraison
- dynamic grape coefficient factor (K_c) included
- leaf Ψ maintained at -1.4 Mpa

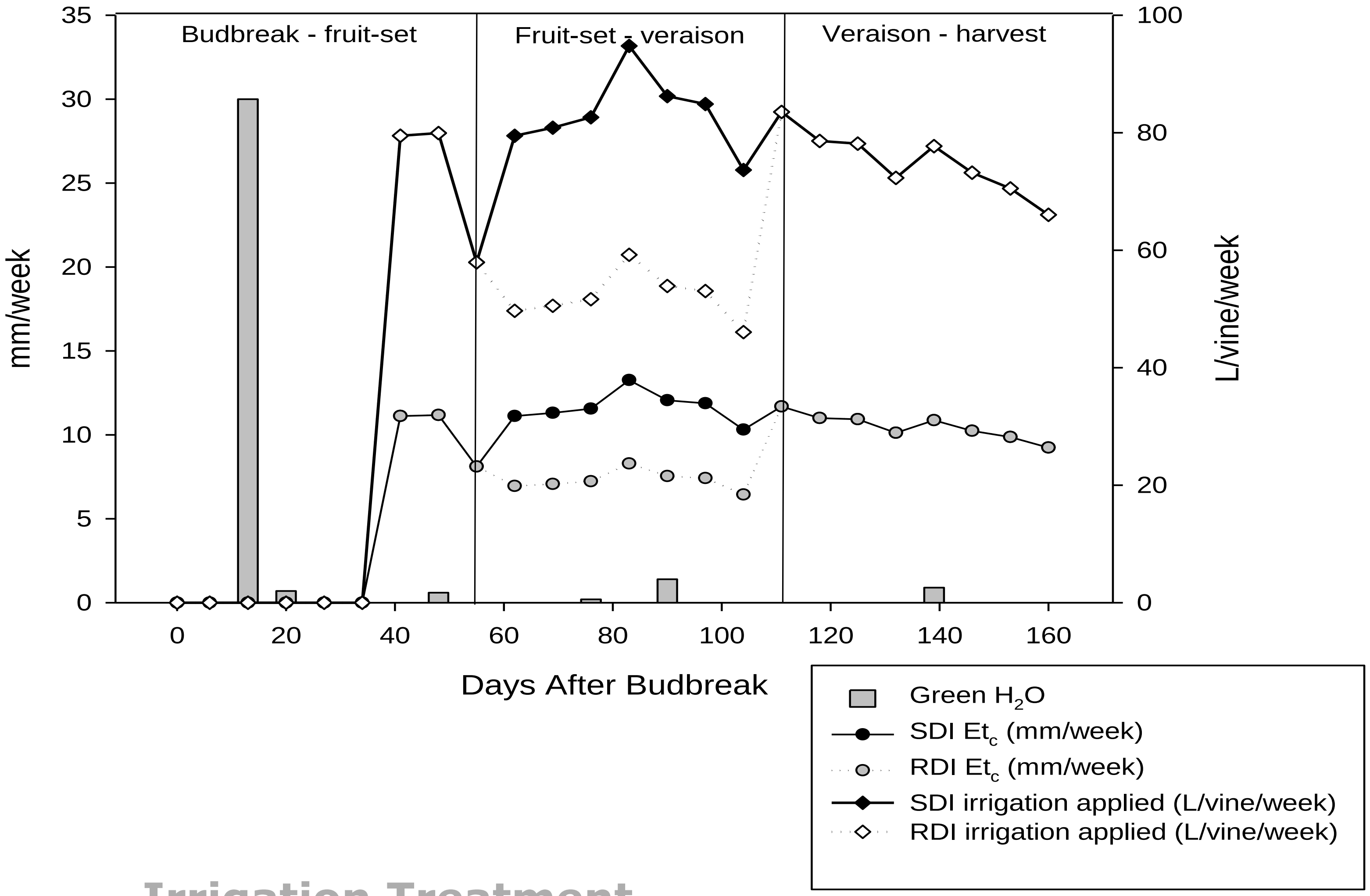
Results

Daily Ambient Temperature Maxima

Number of Days	2013	2014
> 32°C	61	71
> 37°C	10	11

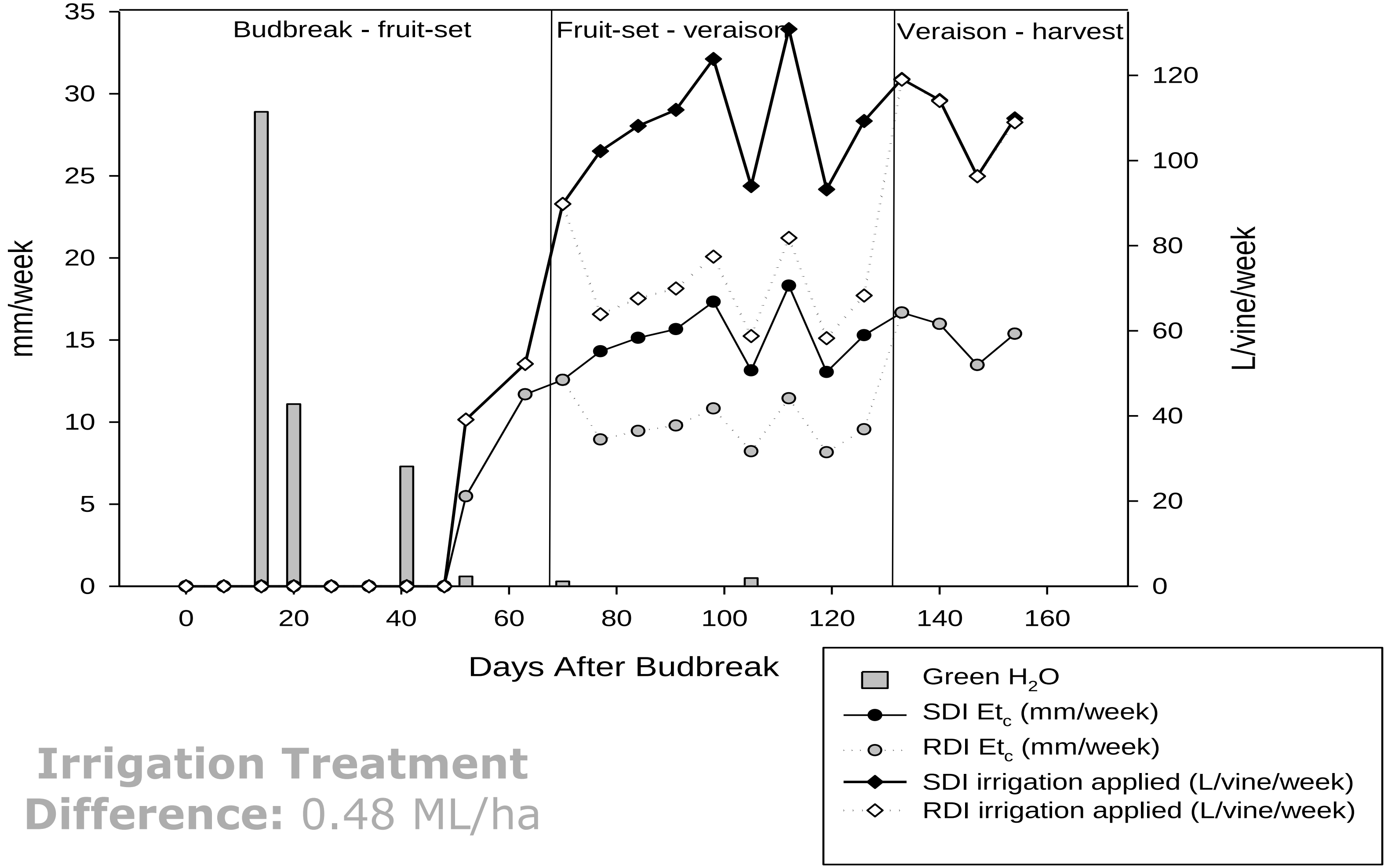


Seasonal Water Relations
2013



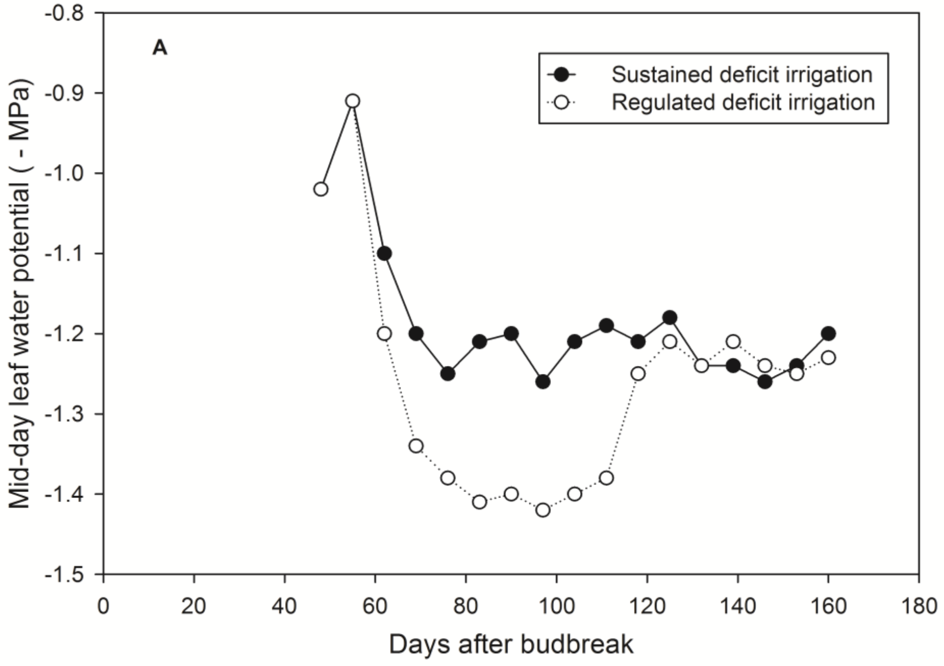
Irrigation Treatment Difference:
0.34 ML/ha

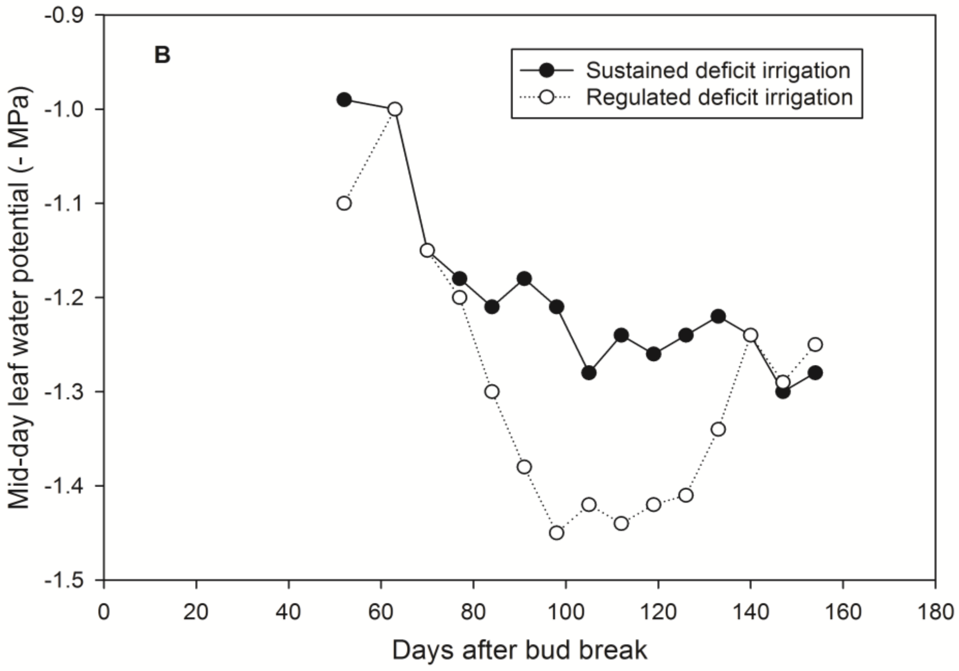
Seasonal Water Relations
2014



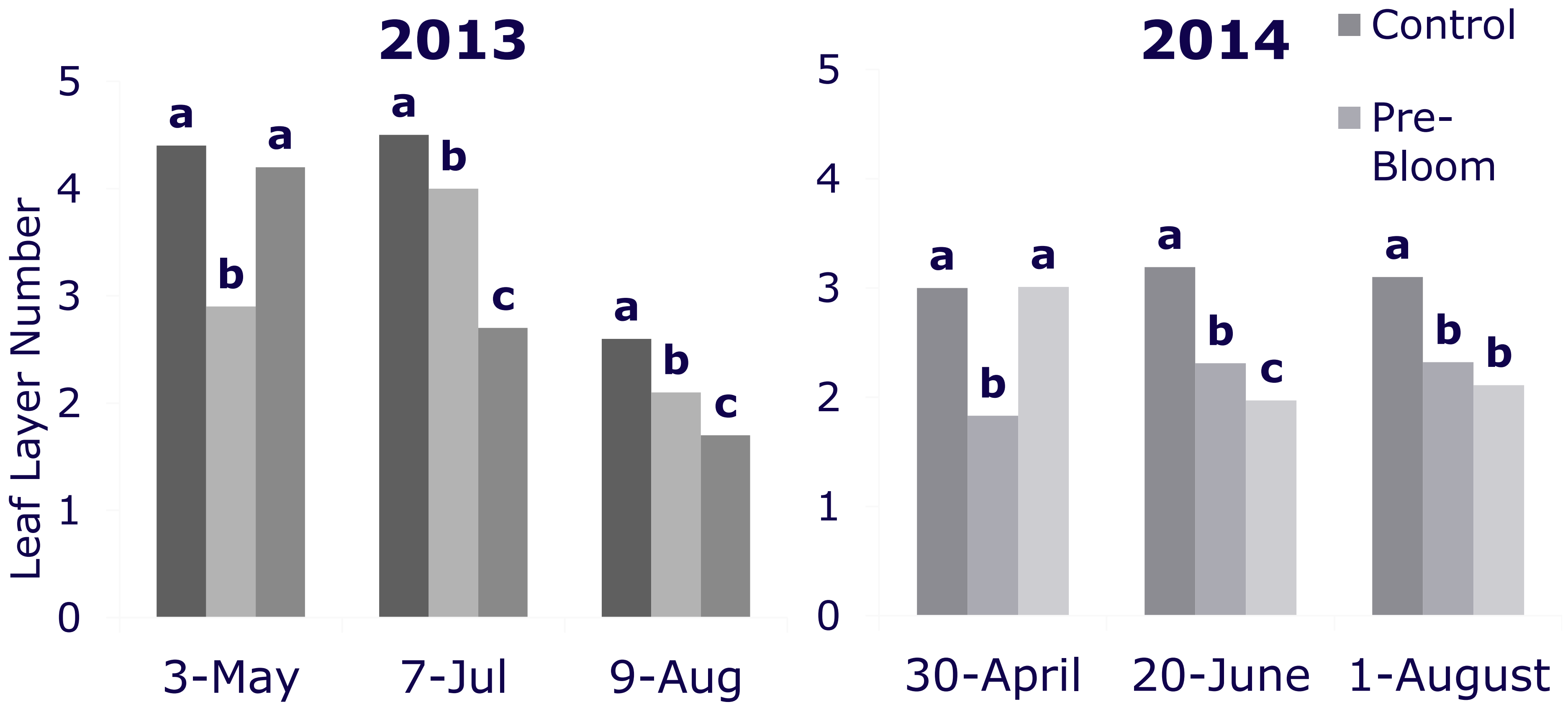
Irrigation Treatment Difference: 0.48 ML/ha

Mid-day leaf water potential

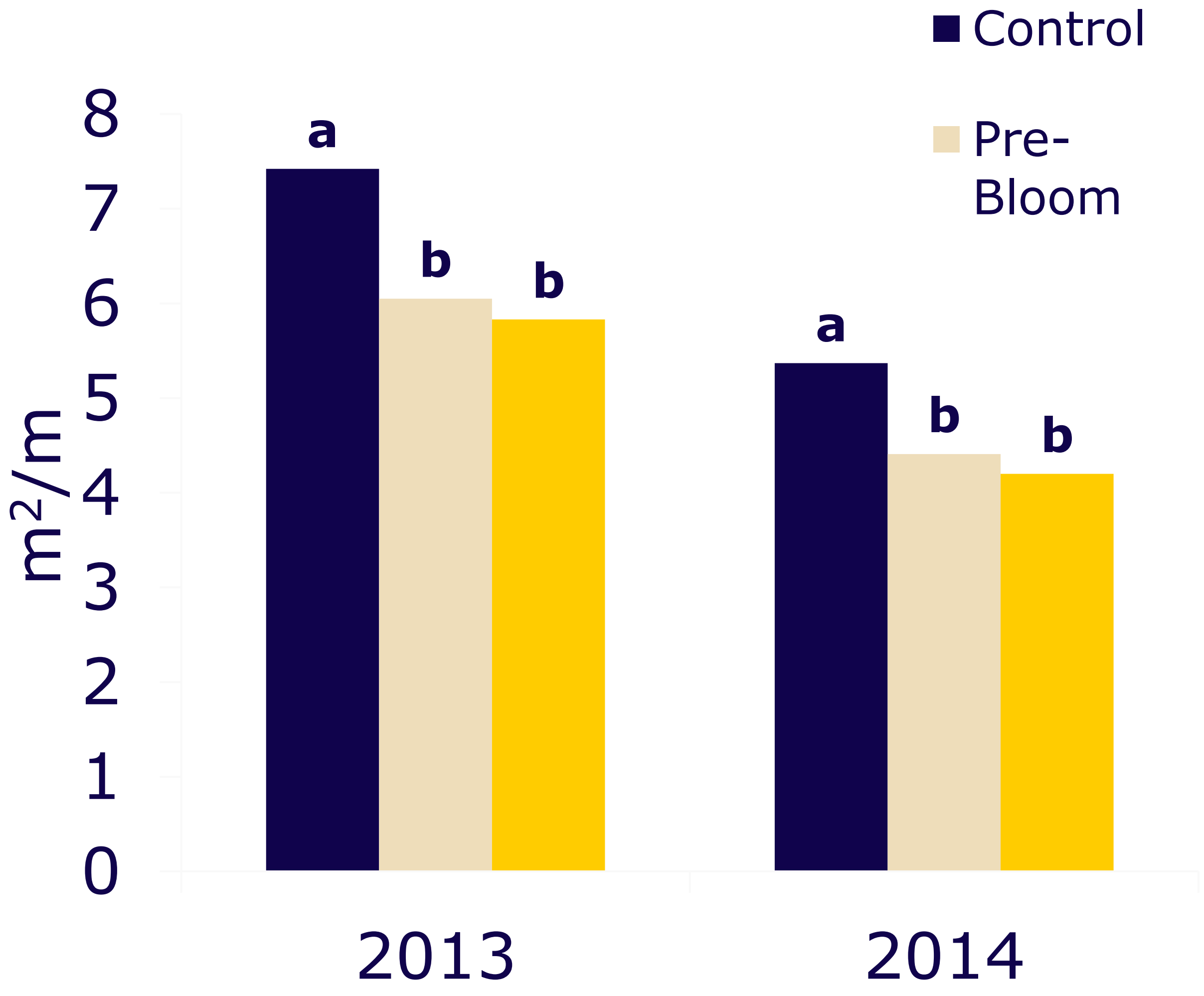




Leaf Layer Number



Functional Leaf Area/m



Mechanical Severity – approx. 20% reduction in leaf area

Light Transmittance

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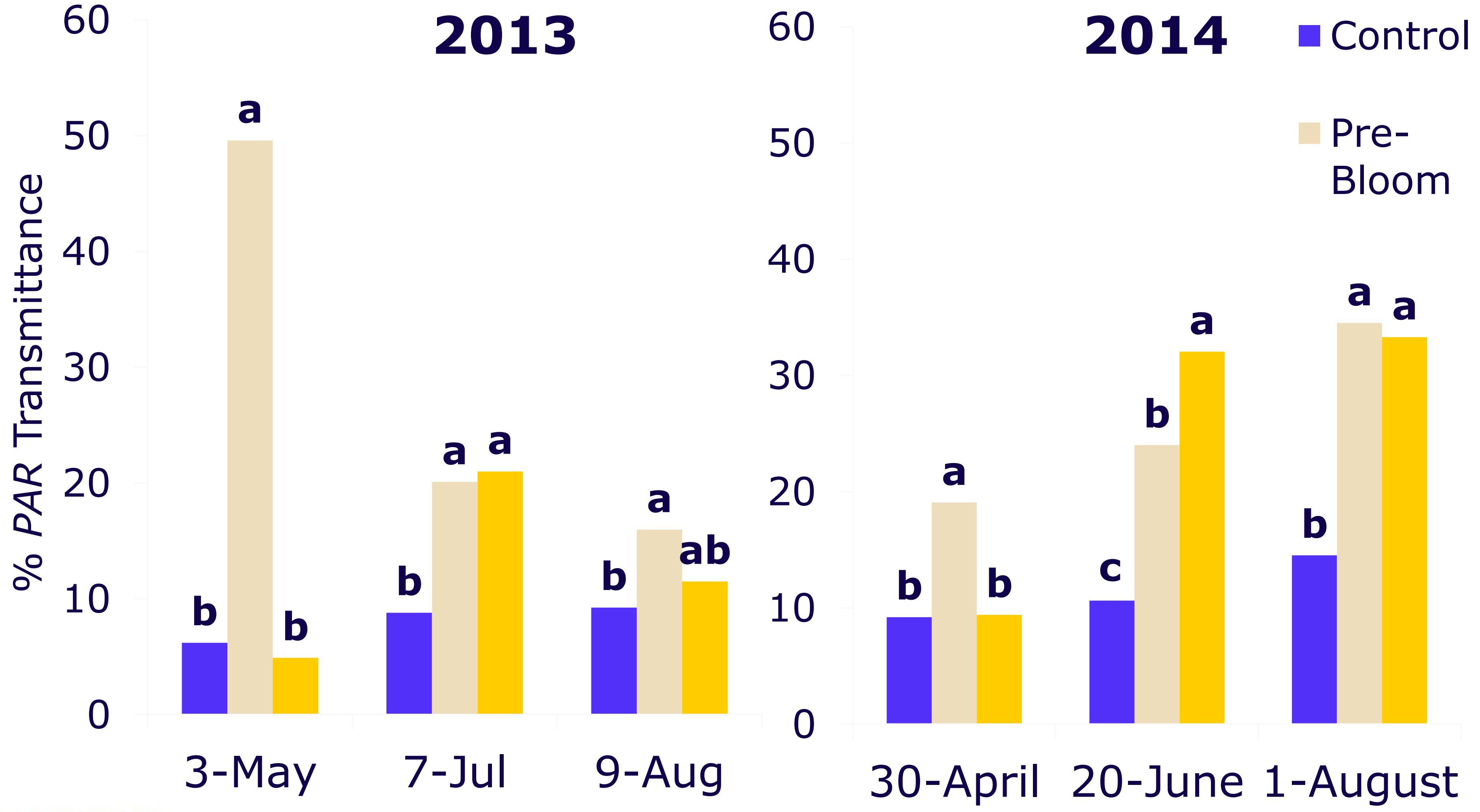

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Vegetative Compensation Response

- critical factor in determining lasting effects of improved microclimate and yield status
- response dependent on severity, timing, and frequency of LR

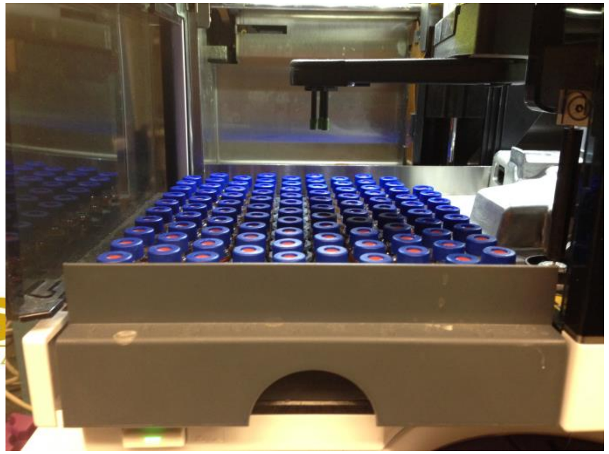
- Pre-Bloom
  - recovery response observed but incomplete
    - mechanical blower effect on incipient and lateral shoot tips
    - positive effects of defoliation long lived

- Post-fruit set
  - in 2013 vines re-filled soon after defoliation
  - in 2014 recovery occurred but remained more open
    - due to cane pulling as observed in previous studies

Yield components

	Berry mass (g)	Berry skin mass (mg)	Yield (kg/m)
		2013	
Leaf removal			
Control	1.36[a] a	55.0 a	6.64
Pre-bloom	1.27 b	51.7 a	6.34
Post-fruit set	1.28 b	45.0 b	6.78
Pr>F	0.0216	0.002	0.4996
ET_c fraction			
SDI	1.34 a	51.3	6.86
RDI	1.26 b	47.8	6.31
Pr>F	0.0068	0.5103	0.0748
LR × ET_c fraction	0.9004	0.9074	0.8684
		2014	
Leaf removal			
Control	1.09	45.3 a	6.17 a
Pre-bloom	1.07	42.9 ab	6.10 a
Post-fruit set	1.11	39.5 b	4.46 b
Pr>F	0.5314	0.031	0.0016
ET_c fraction			
SDI	1.14 a	42.7	6.08 a
RDI	1.04 b	42.3	5.27 b
Pr>F	0.0021	0.6963	0.0003
LR × ET_c fraction	0.4878	0.5892	0.0053

Chemical Composition



Fruit Composition

	TSS (%)	Juice pH	TA (g/L)
Leaf removal		2013	
Control	24.6 a	3.57	5.26
Pre-bloom	24.7 a	3.59	4.78
Post-fruit set	24.0 b	3.58	5.06
Pr>F	0.0171	ns	ns
Deficit irrigation			
SDI	24.2 b	3.59	5.04
RDI	24.7 a	3.57	5.02
Pr>F	0.0206	ns	ns
Leaf removal		2014	
Control	24.3	3.60	4.83
Pre-bloom	24.1	3.62	4.66
Post-fruit set	24.2	3.64	4.69
Pr>F	ns	ns	ns
Deficit irrigation			
SDI	23.9 b	3.63	4.83
RDI	24.5 a	3.61	4.62
Pr>F	0.0199	ns	ns

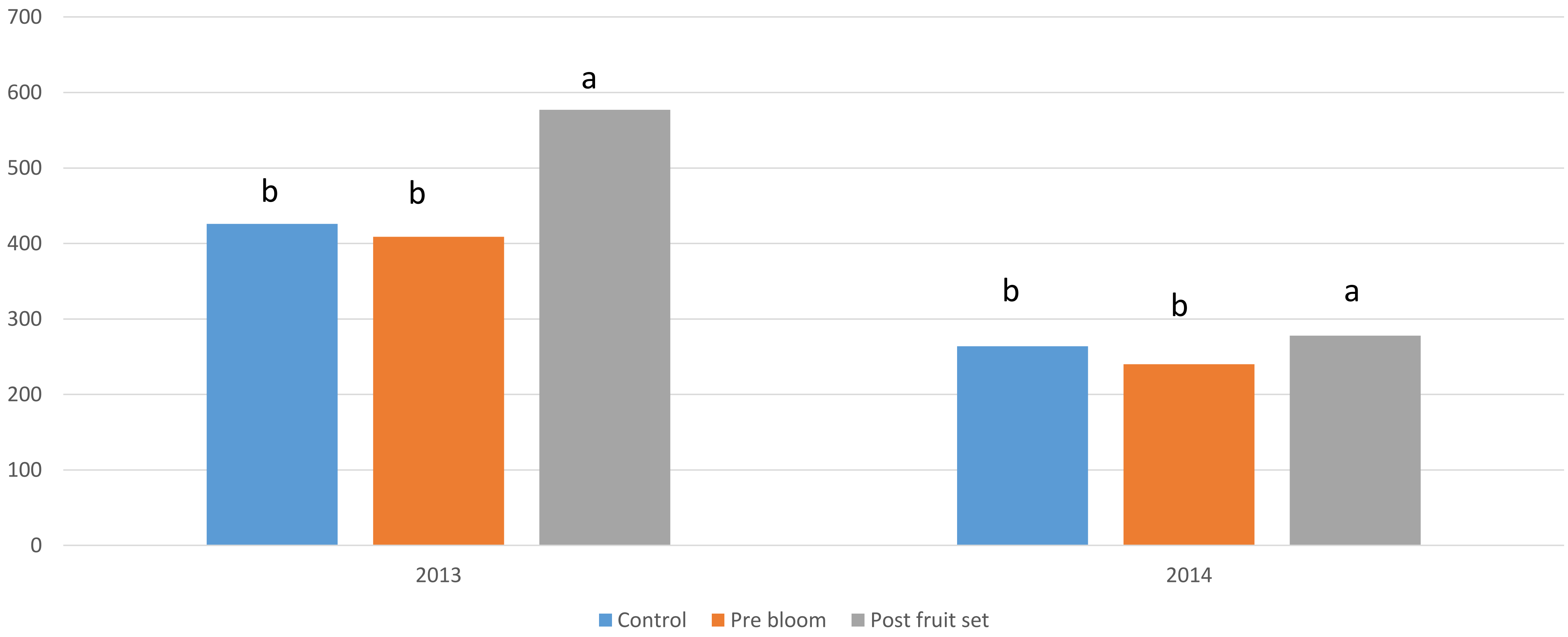
Mechanical leaf removal effects on flavonoid composition (Merlot/Freedom) in mg/kg

	quercetin	myricetin	Total skin anthocyanin	Astringency
	2013			
No leaf removal	180 b	16.4 b	2066.4 b	14.1ab
Pre-bloom	335 a	23.7 a	2763.9 a	13.9 b
Post-fruit set	262 a	22.9 a	2381.5ab	15.9a
Pr>F	0.0003	0.0133	0.0055	0.0172
	2014			
No leaf removal	325 b	17.9 b	1554.1 b	20.2 a
Pre-bloom	390 ab	22.0 a	2135.3 a	17.9 b
Post-fruit set	432.1 a	22.3 a	2044.9 a	18.6 a
Pr>F	0.0132	0.0395	0.0014	0.0454

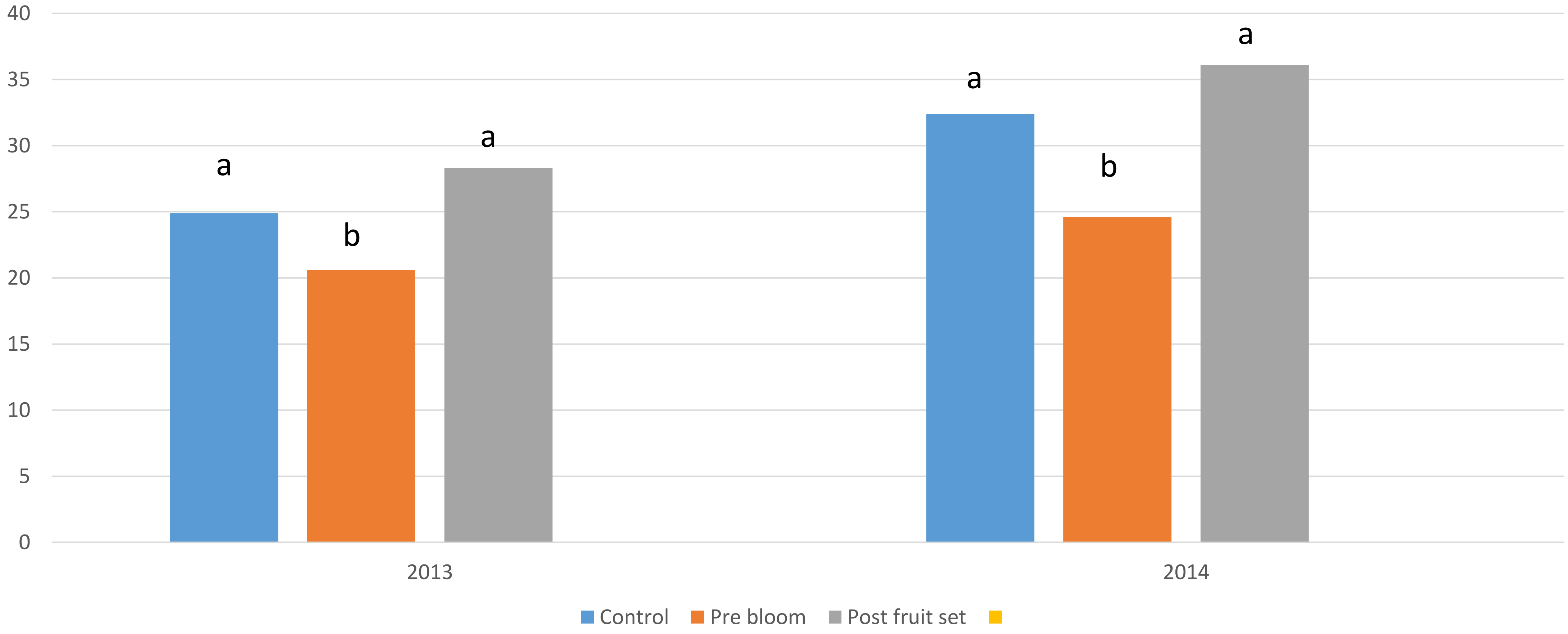
Effect of applied water amounts on anthocyanin composition in presence of leaf removal

Applied water amount	Less stable (%)	More stable (%)
	Year 1	
Sustained deficit irrigation	22.9 a	77.1 b
Regulated deficit irrigation	20.5 b	79.5 a
Pr>F	0.0011	0.0483
	Year 2	
Sustained deficit irrigation	15.9 a	84.1 b
Regulated deficit irrigation	12.1 b	87.9 a
Pr>F	0.0012	0.0011

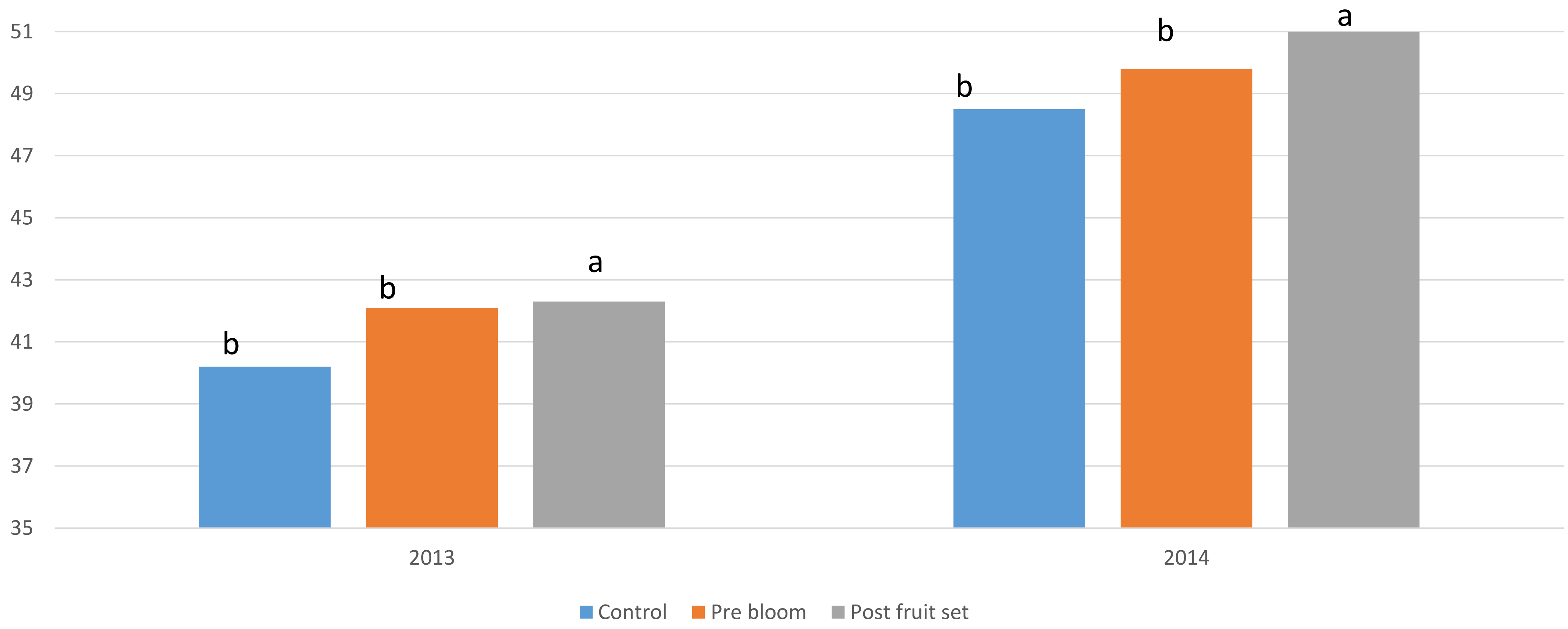
Effect of light exposure on skin and seed tannin concentration



Effects of light exposure and applied water on skin tannin conversion yield



Effects of light exposure and applied water on skin tannin on coarseness



Summary

- Pre-Bloom Leaf Removal
  - allowed increased light filtration earlier in season
  - canopy open throughout season to 20% ambient PAR
  - promoted skin tissue formation (acclimation is key)
  - maximum phenolic concentration without loss of yield
  - Less skin tannin, but more stable and less coarse
- Post-Set Leaf Removal
  - often performed poorly, seemingly better in 2014 but loss of yield
  - sudden increase in light and temperature detrimental to phenolic biosynthesis
  - More tannin concentration
  - Subject to oxidation
  - Coarser skin tannin

Summary

- Applied water
  - no effect on majority of parameters, direct and positive compositional shift towards tri-OH anthocyanins with RDI, yield may be reduced
  - allows growers to reduce costs

- Applied water
  - No effect on tannin content or composition
  - Ability to apply less to reduce costs

Acknowledgements

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