 

Multi-seasonal effects of warming and elevated CO_2 on the physiology, growth and production of mature, field grown, Shiraz grapevines

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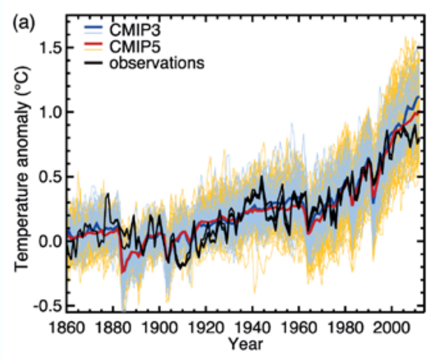
Climate change and Australian viticulture

Potential impacts (ordered by grower perception):



1. *Greater climate extremes (and variability?).*

Increased frequency of heatwaves, can be managed by irrigation (e.g. Soar et al, 2009; Edwards et al, 2011).

Berry composition?

Figures from AR5, IPCC 2014.

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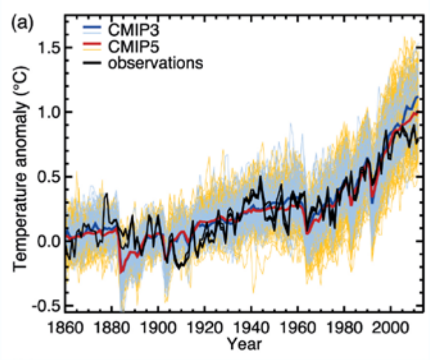

1. *Greater climate extremes (and variability?).*
2. *Increased air temperature.*

Advanced phenology, compressed harvests (logistical problems).

Berry composition?

Figures from AR5, IPCC 2014.

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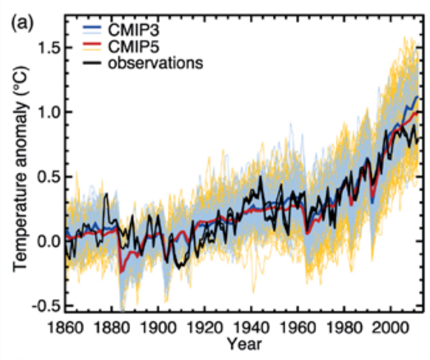
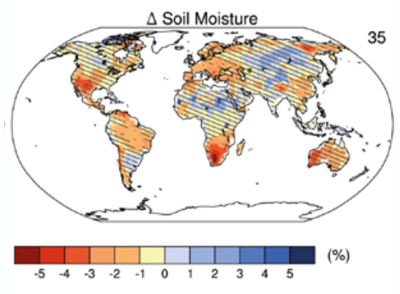




1. *Greater climate extremes (and variability?).*
2. *Increased air temperature.*
3. *Reduced water availability.*

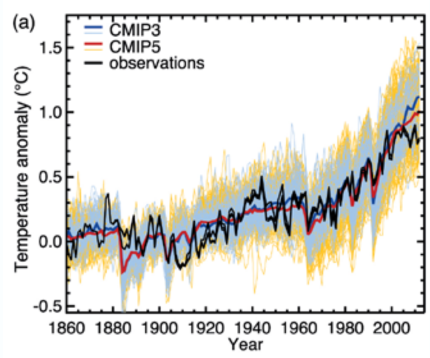
Deficit irrigation.

Access to irrigation?

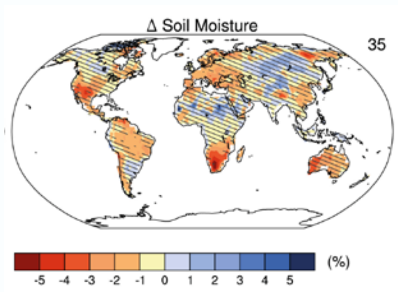
Figures from AR5, IPCC 2014.

Climate change and Australian viticulture

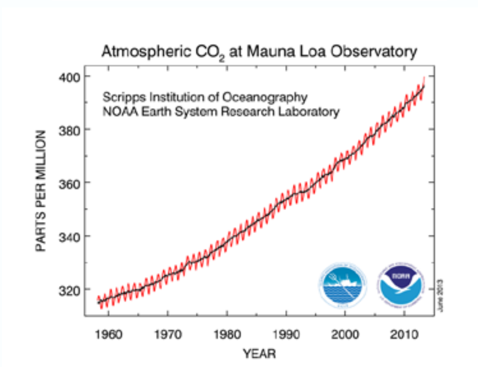
Potential impacts (ordered by grower perception):



1. *Greater climate extremes (and variability?).*
2. *Increased air temperature.*



3. *Reduced water availability.*

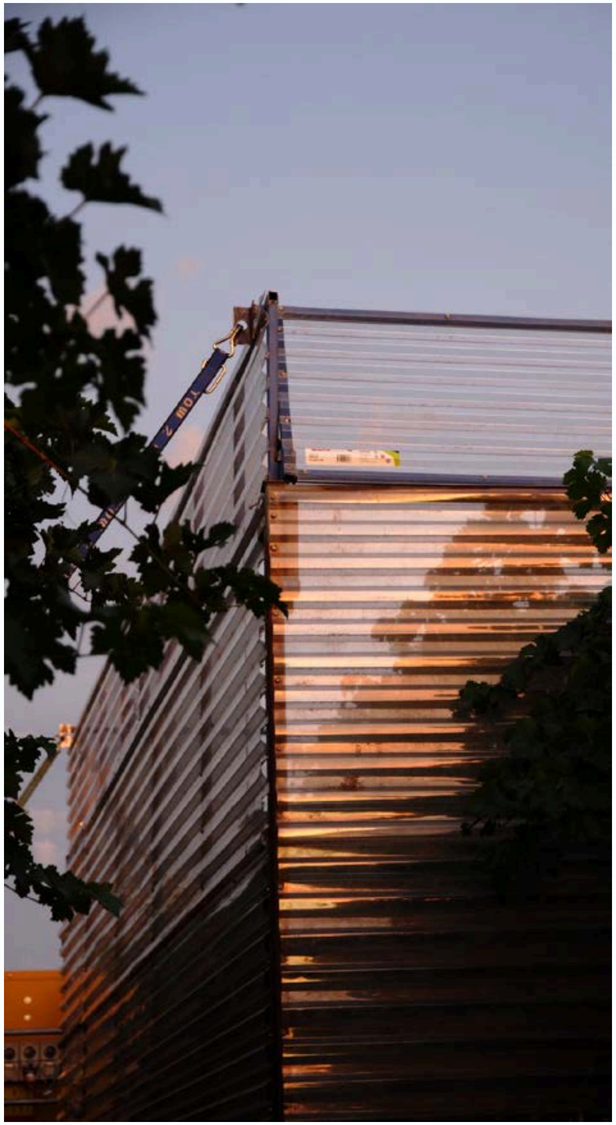


4. *Increased atmospheric CO_2.*

Many studies on C_3 plants; few on grapevines (e.g. Bindi et al. 2001).

Figures from AR5, IPCC 2014.

VIC DPI Warming Project (2010/11-2012/13)



- *Open top chambers (OTC), with active heating: ≈ +2°C.*
- *Three varieties (Cabernet Sauvignon, Chardonnay, Shiraz), for three seasons.*

- *No direct effect on yield.*
- *No significant effect on leaf physiology (at growth temp).*
- *Phenology and maturity advanced:*
  - *Budburst 3-12 days,*
  - *Anthesis 5-10 days,*
  - *Veraison 5-12 days.*

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Impacts from increased carbon dioxide

Direct effects of temperature are complex: potential to alter the rate of every biological process;

Direct effects of atmospheric CO_2 concentration are relatively simple: alters the concentration of CO_2 in the leaf (C_i).

Consequently, impacts of elevated CO_2 on the vine are primarily driven by changes in vine carbon assimilation rate and changes in stomatal conductance due to high C_i.

Combining elevated CO_2 with active warming

Collaborative project: Agriculture Victoria and CSIRO.

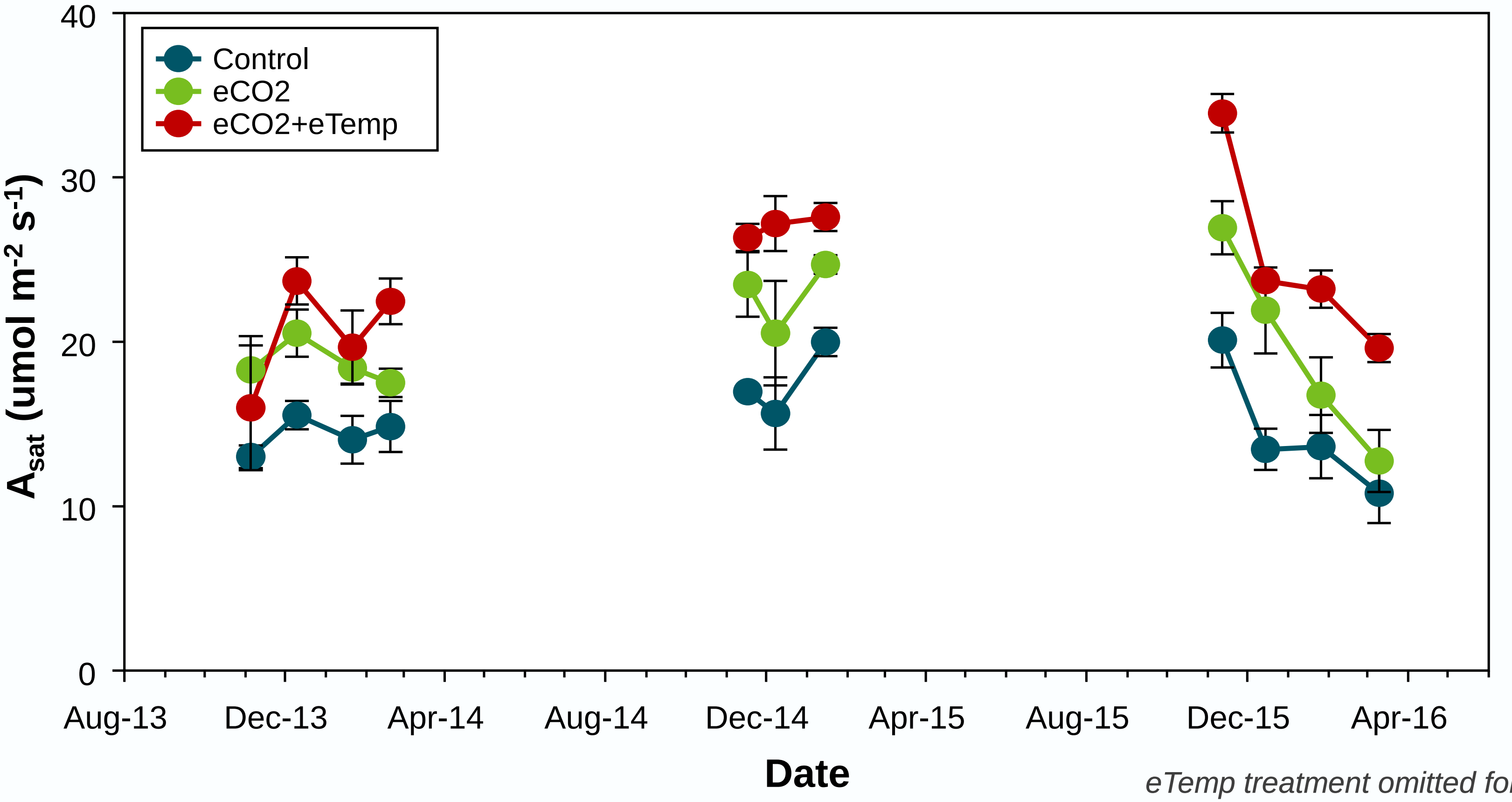
Aim is to determine impact of high CO_2, high temperature, future climate on Australian viticulture.

- *System to elevate CO_2 added to OTCs (650 ppm).*
- *Active heating retained: ≈ +2°C.*
- *Factorial design:*
  - *control OTC,*
  - *eCO_2,*
  - *eTemp,*
  - *eCO_2 + eTemp.*
- *Includes non-chambered control.*

Photosynthesis

Assimilation under saturating light (A_{sat}) of vines grown at 650 ppm CO_2 invariably higher than vines in ambient conditions.

Vines grown under combination of 650 ppm CO_2 and 2°C warming resulted in further increase in A_{sat}.



eTemp treatment omitted for clarity.

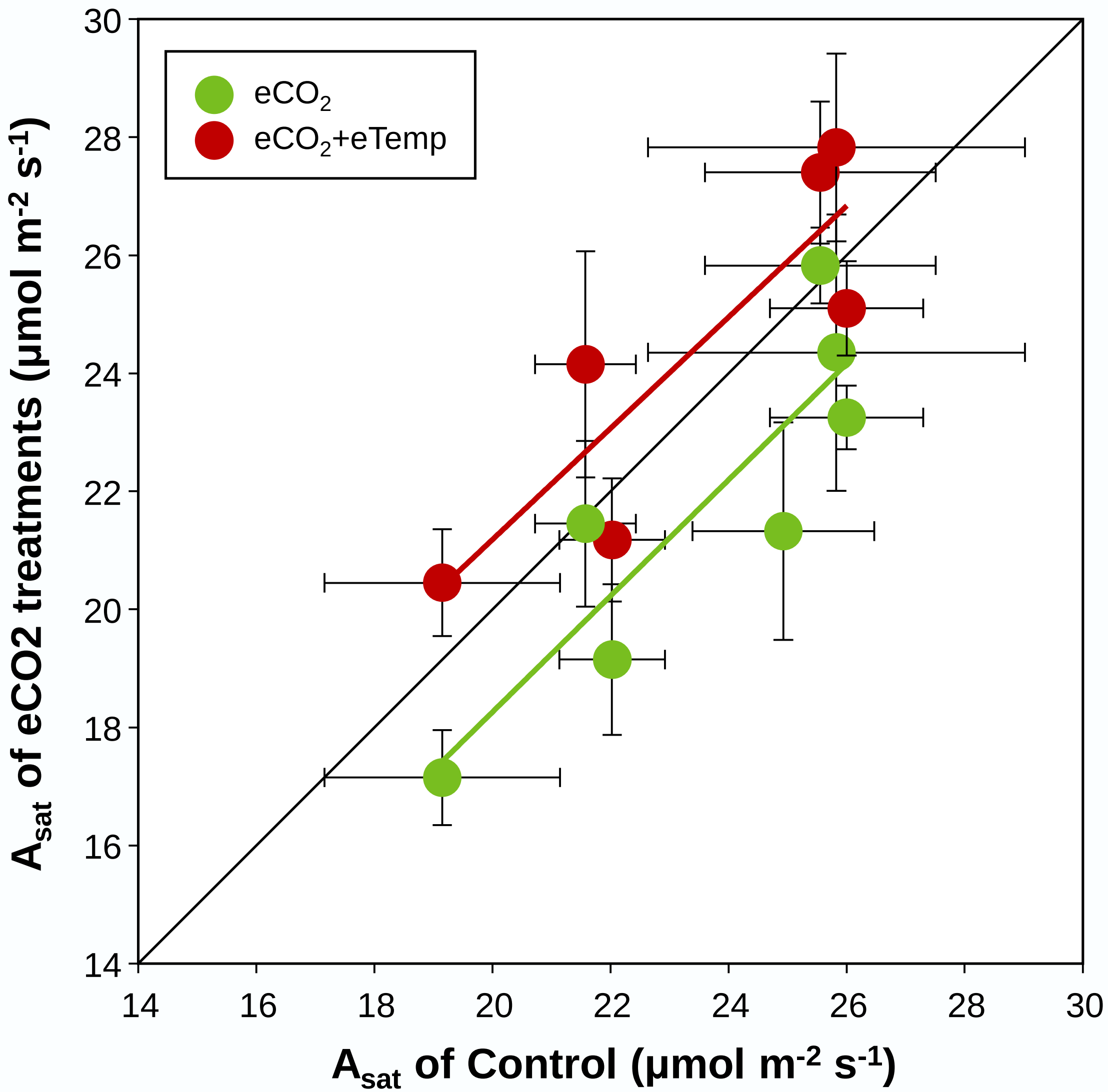
Photosynthetic acclimation?

Assimilation at a common CO_2 is a simple measure of acclimation.

When A_{sat} measured at 650 ppm:

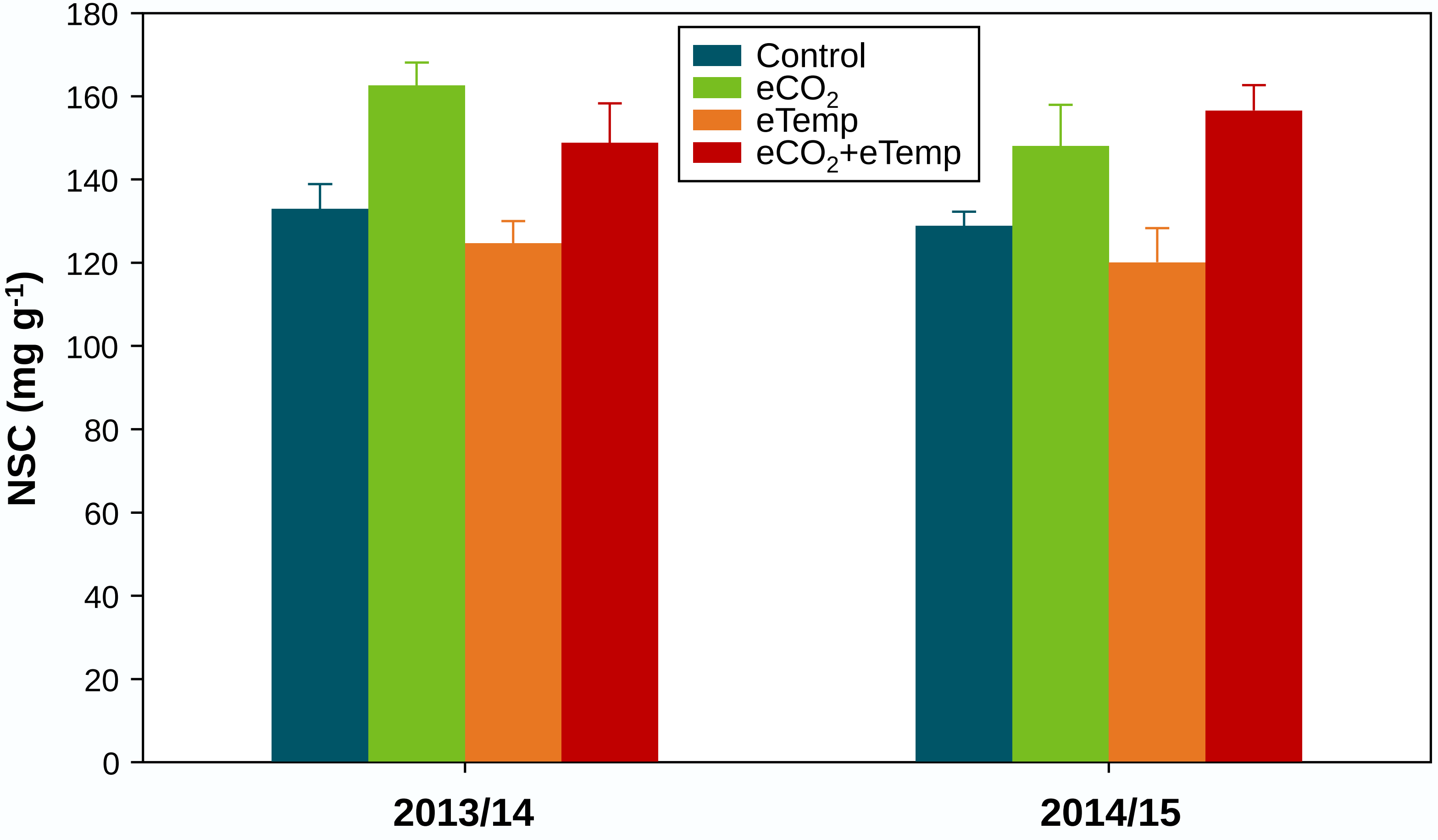
- *Low degree of acclimation in eCO_2 treatment,*
- *No acclimation when eCO_2 combined with 2°C warming.*

Almost no effect on leaf %N.



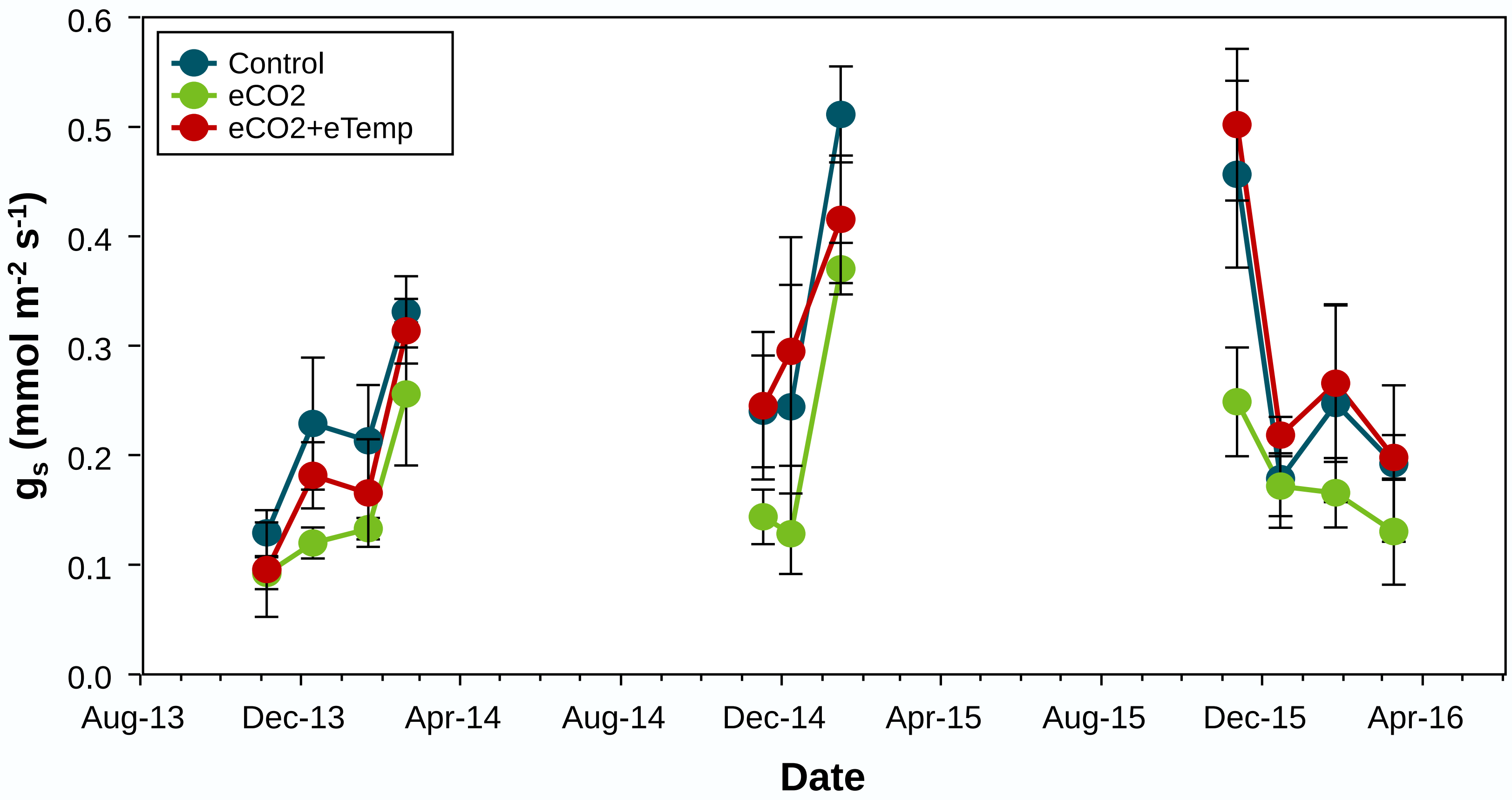
Carbohydrates

Average leaf non-structural carbohydrate (NSC) concentration over full season reflected short-term photosynthesis results.



Impacts on water use?

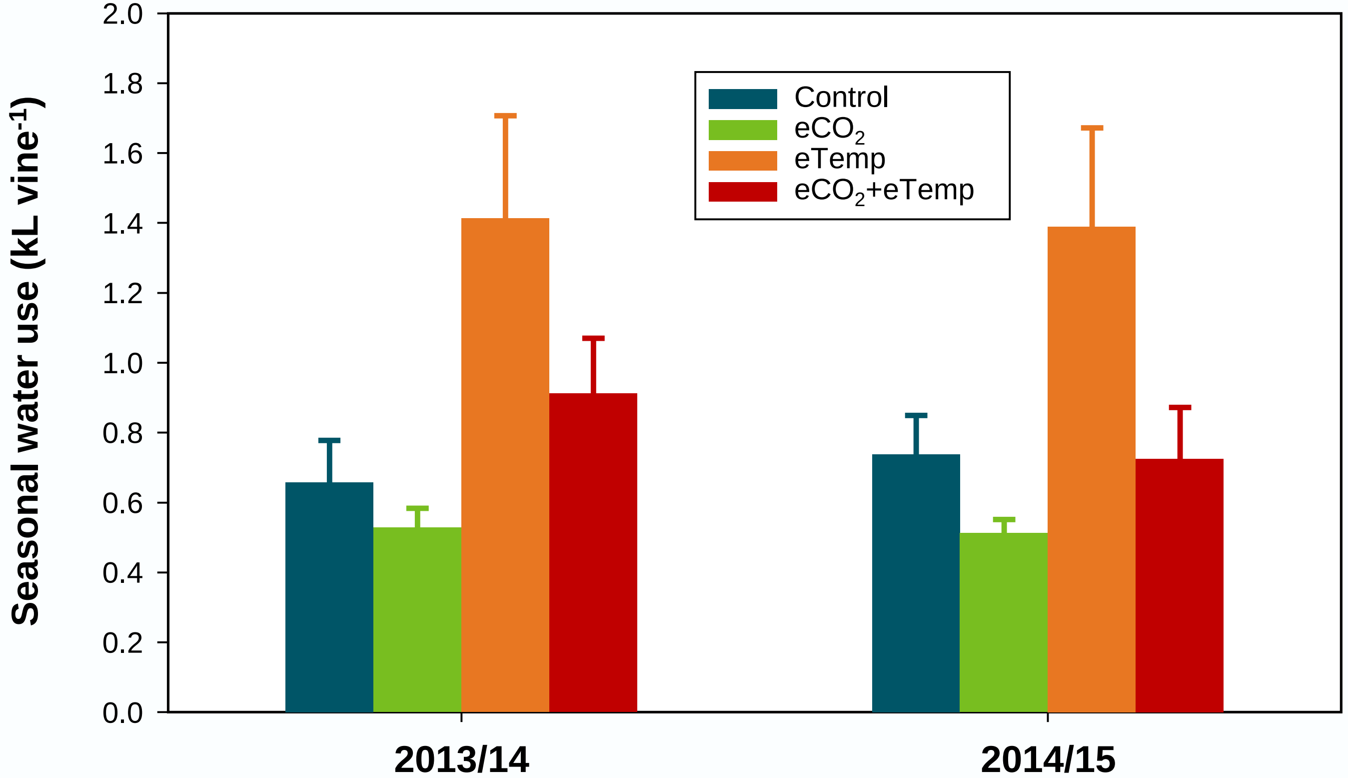
Stomatal conductance (g_s) was reduced under eCO_2, but not when in combination with warming.



Impacts on water use: seasonal sapflow

Sapflow sensors installed and operational for two seasons, 2013/14 and 2014/2015.

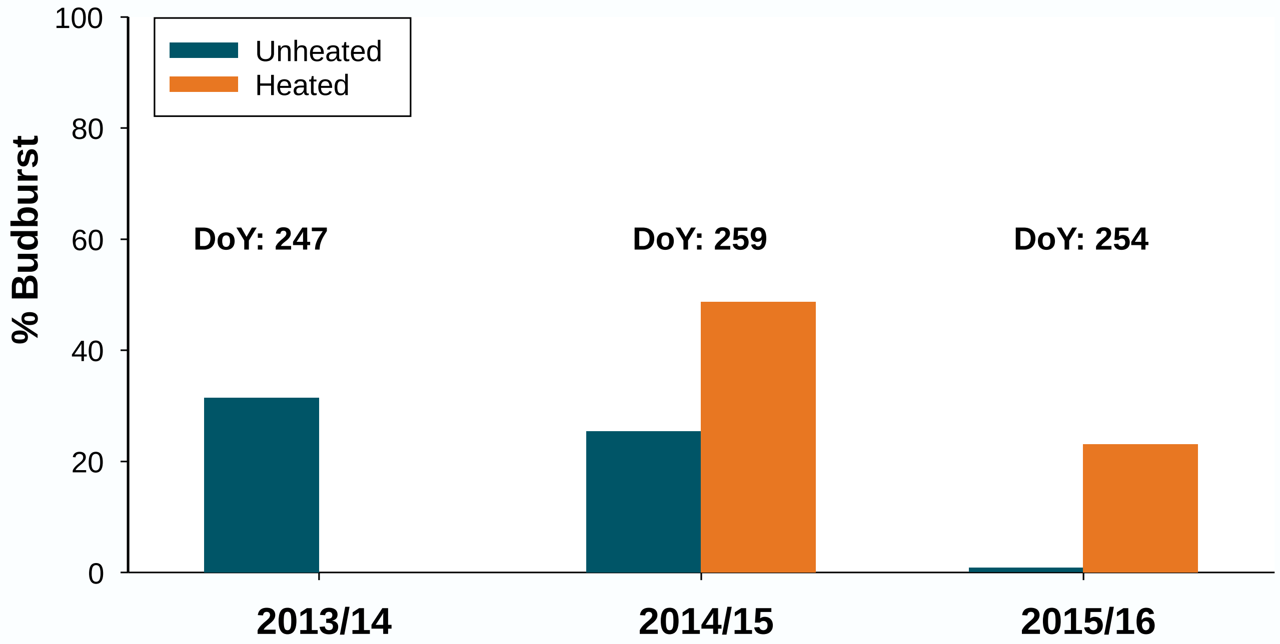
Whole season vine water use reflected short-term measurements.



Phenology

Effects of warming on phenology were observed from flowering in the first season.

Effects of eCO_2 on phenology did not appear until the third season.



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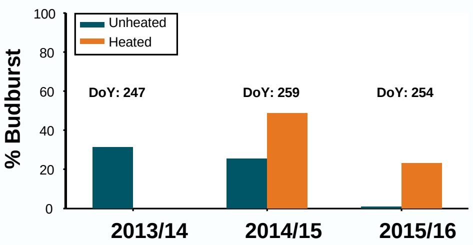

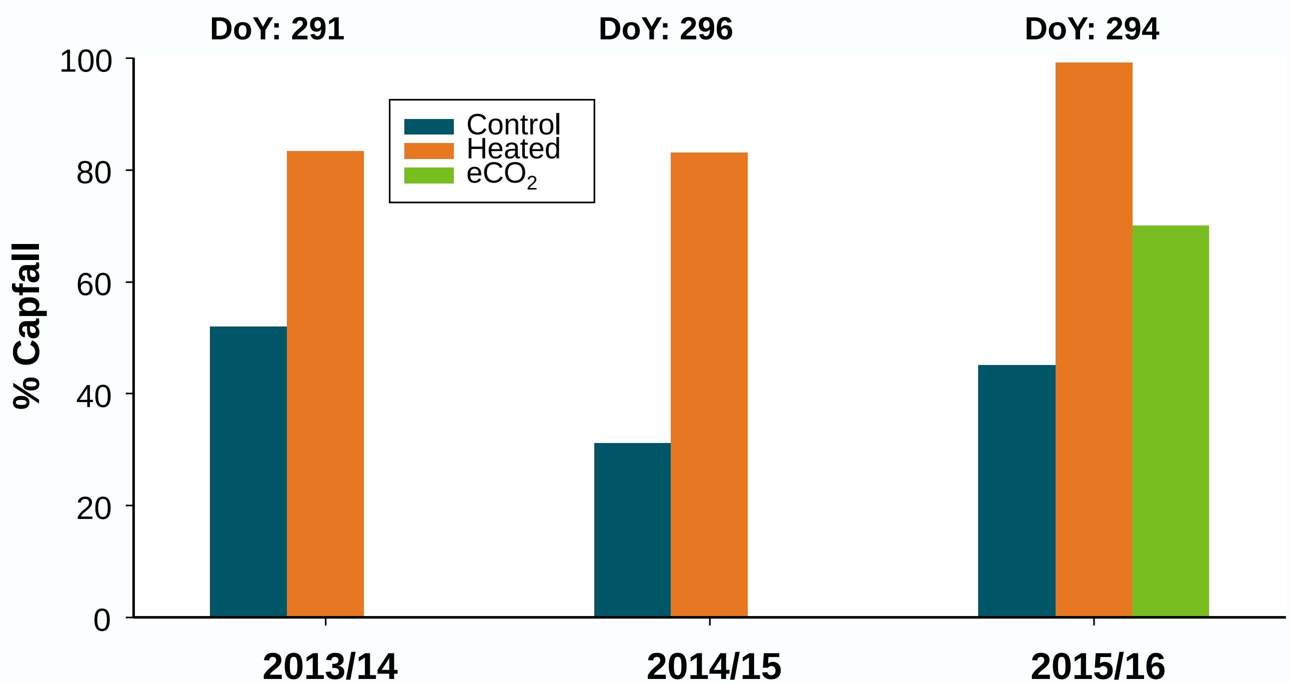

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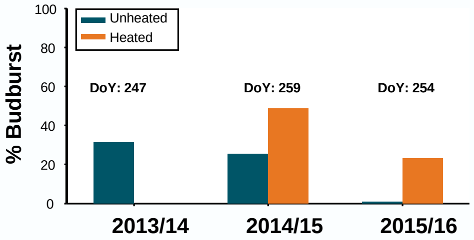
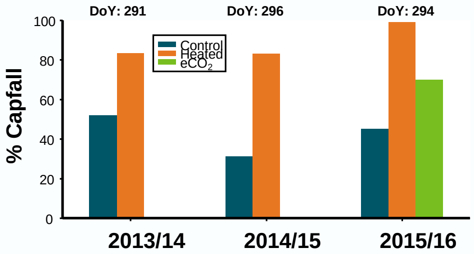
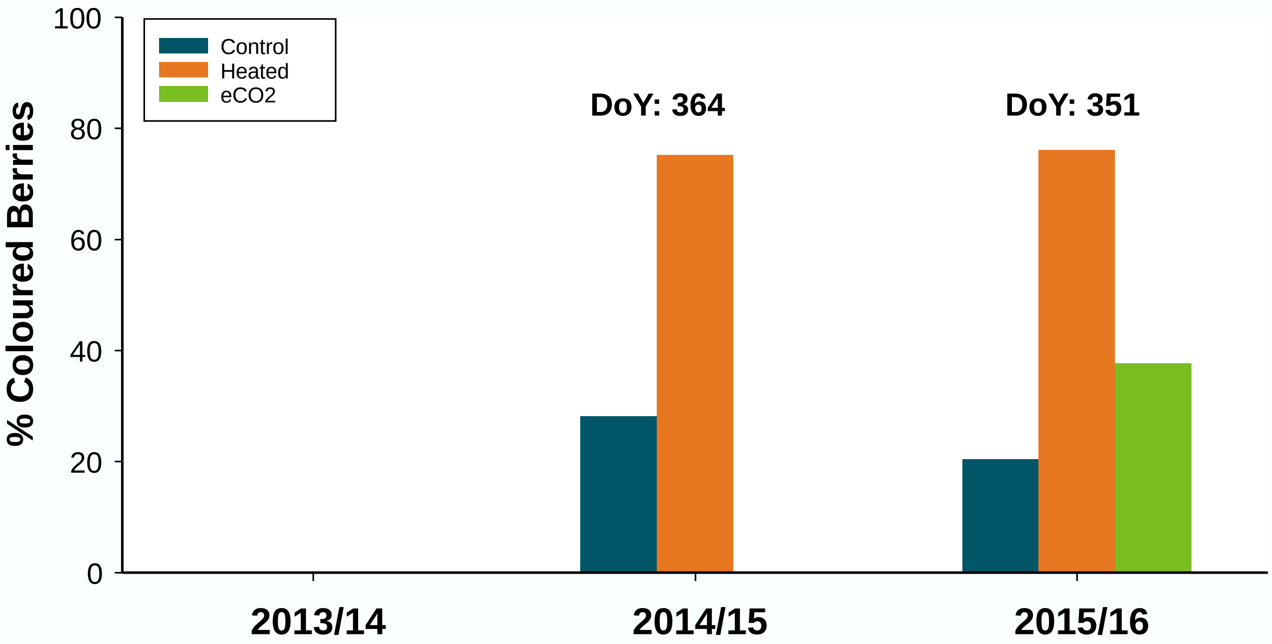
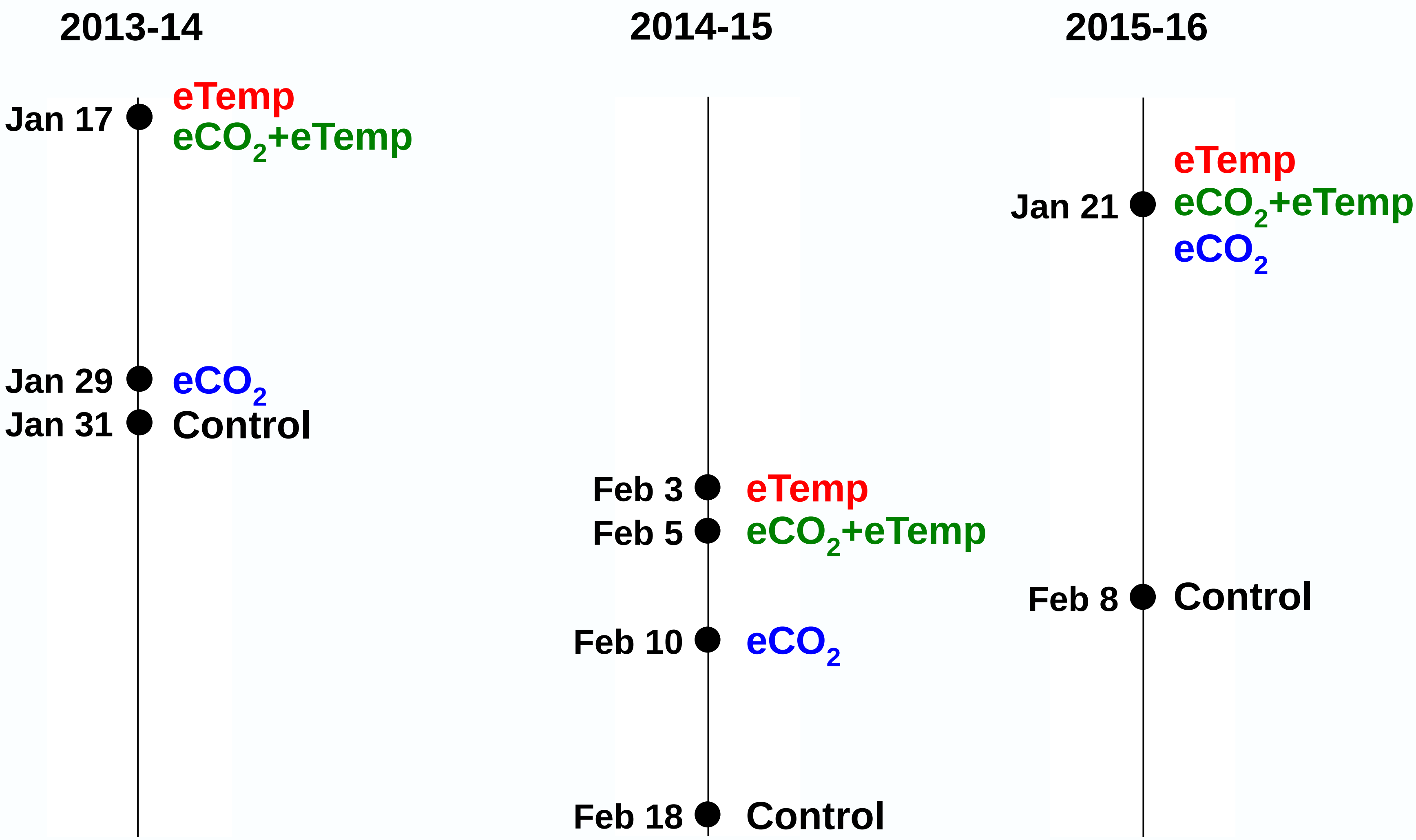






Phenology: harvest date

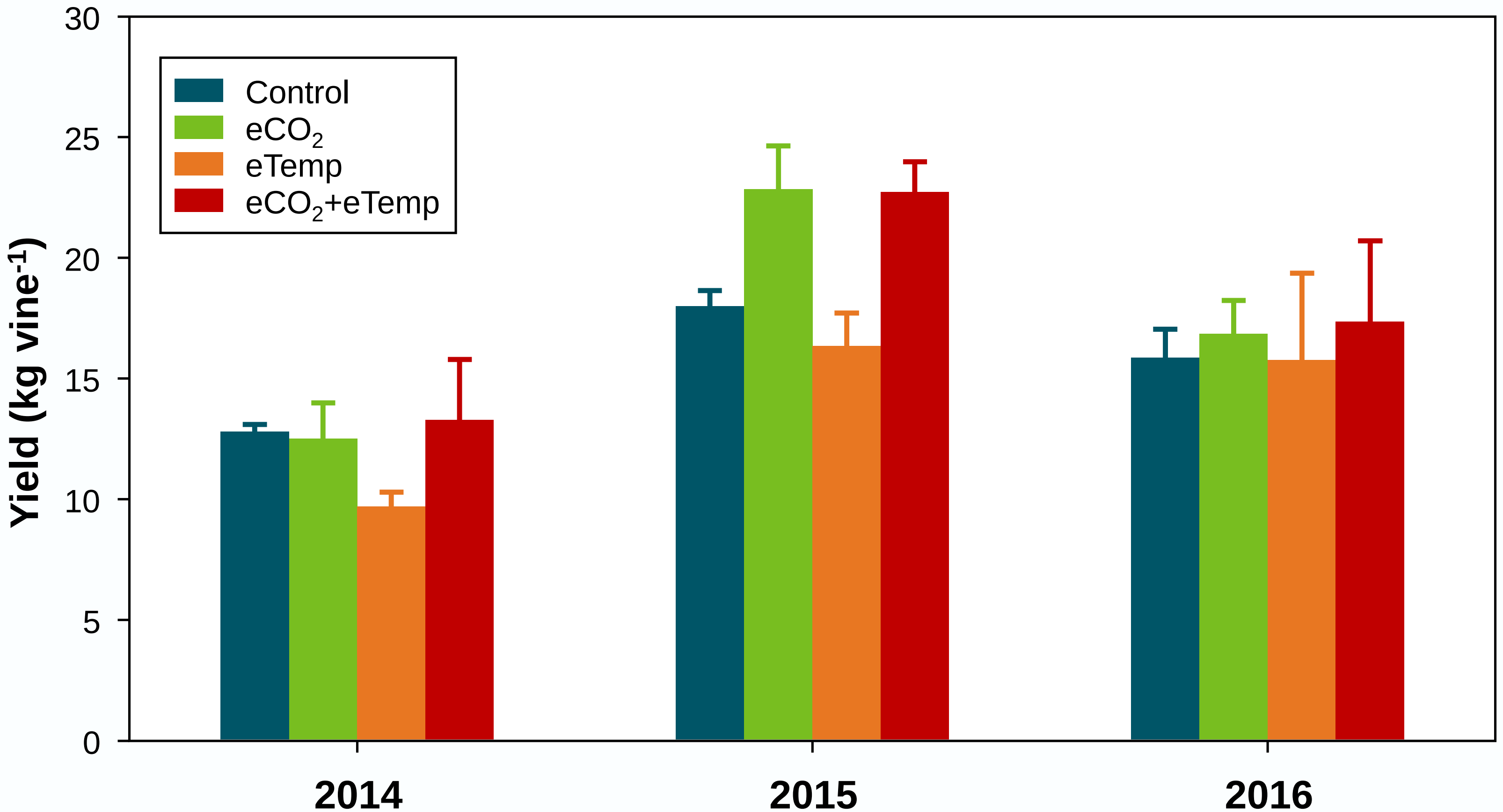


Each treatment harvested when average soluble solids reached 24°Brix (13.3 Baumé).

Yield

Large inter-seasonal effect on yield. In 2014, a heat-wave resulted in significant fruit loss in the eTemp treatment (but not eCO_2+eTemp).

The eCO_2 effect was only significant in 2015 (↑ berry FWt).

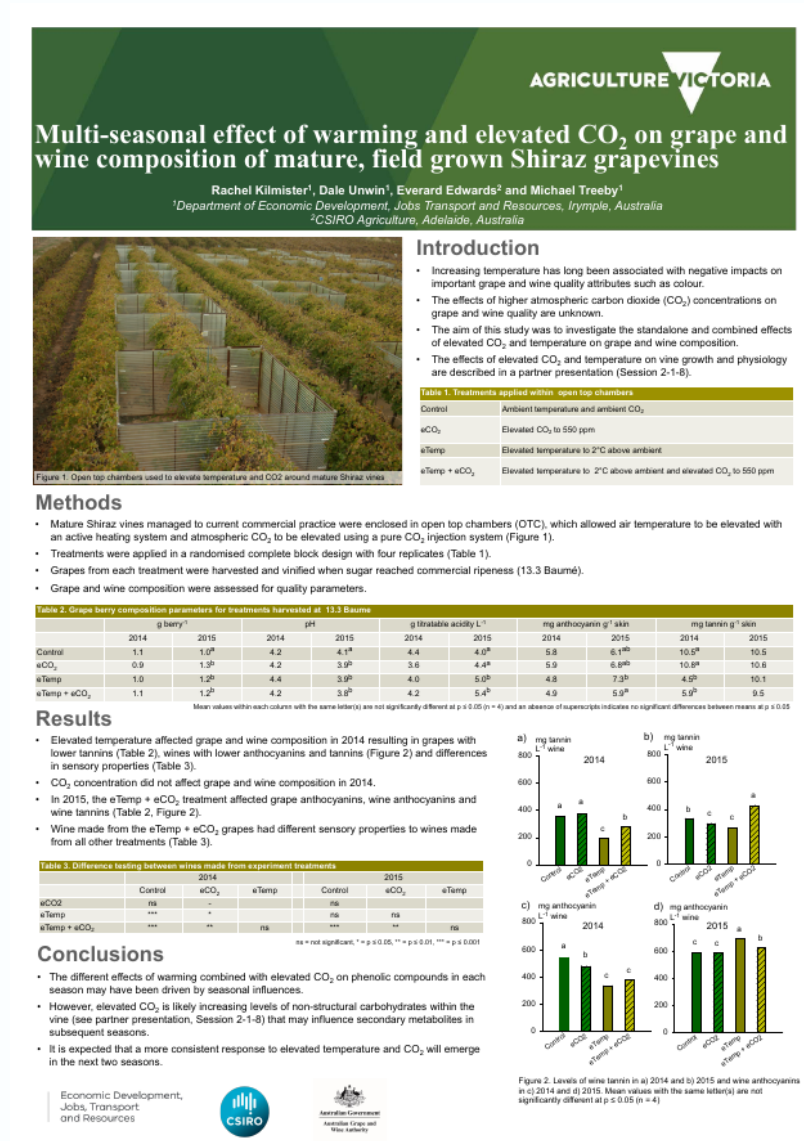


Berry and wine composition

Treatment effects on berry and wine quality parameters not consistent across seasons.

Driven by heat in 2014.

See companion poster for further details: Kilmister et al.



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Multi-seasonal effect of warming and elevated CO_2 on grape and wine composition of mature, field grown Shiraz grapevines

Rachel Kilmister[1], Dale Unwin[1], Everard Edwards[2] and Michael Treeby[1]

[1]Department of Economic Development, Jobs Transport and Resources, Irymple, Australia

[2]CSIRO Agriculture, Adelaide, Australia

Figure 1. Open top chambers used to elevate temperature and CO2 around mature Shiraz vines

Introduction

- Increasing temperature has long been associated with negative impacts on important grape and wine quality attributes such as colour.
- The effects of higher atmospheric carbon dioxide (CO_2) concentrations on grape and wine quality are unknown.
- The aim of this study was to investigate the standalone and combined effects of elevated CO_2 and temperature on grape and wine composition.
- The effects of elevated CO_2 and temperature on vine growth and physiology are described in a partner presentation (Session 2-1-8).

Table 1. Treatments applied within open top chambers

Control	Ambient temperature and ambient CO_2
eCO_2	Elevated CO_2 to 550 ppm
eTemp	Elevated temperature to 2°C above ambient
eTemp + eCO_2	Elevated temperature to 2°C above ambient and elevated CO_2 to 550 ppm

Methods

- Mature Shiraz vines managed to current commercial practice were enclosed in open top chambers (OTC), which allowed air temperature to be elevated with an active heating system and atmospheric CO_2 to be elevated using a pure CO_2 injection system (Figure 1).
- Treatments were applied in a randomised complete block design with four replicates (Table 1).
- Grapes from each treatment were harvested and vinified when sugar reached commercial ripeness (13.3 Baumé).
- Grape and wine composition were assessed for quality parameters.

Table 2. Grape berry composition parameters for treatments harvested at 13.3 Baume

	g berry^{-1}		pH		g titratable acidity L^{-1}		mg anthocyanin g^{-1} skin		mg tannin g^{-1} skin	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Control	1.1	1.0^{a}	4.2	4.1^{a}	4.4	4.0^{a}	5.8	6.1^{ab}	10.5^{a}	10.5
eCO_2	0.9	1.3^{b}	4.2	3.9^{b}	3.6	4.4^{a}	5.9	6.8^{ab}	10.8^{a}	10.6
eTemp	1.0	1.2^{b}	4.4	3.9^{b}	4.0	5.0^{b}	4.8	7.3^{b}	4.5^{b}	10.1
eTemp + eCO_2	1.1	1.2^{b}	4.2	3.8^{b}	4.2	5.4^{b}	4.9	5.9^{a}	5.9^{b}	9.5

Mean values within each column with the same letter(s) are not significantly different at $p \le 0.05$ (n = 4) and an absence of superscripts indicates no significant differences between means at $p \le 0.05$

Results

- Elevated temperature affected grape and wine composition in 2014 resulting in grapes with lower tannins (Table 2), wines with lower anthocyanins and tannins (Figure 2) and differences in sensory properties (Table 3).
- CO_2 concentration did not affect grape and wine composition in 2014.
- In 2015, the eTemp + eCO_2 treatment affected grape anthocyanins, wine anthocyanins and wine tannins (Table 2, Figure 2).
- Wine made from the eTemp + eCO_2 grapes had different sensory properties to wines made from all other treatments (Table 3).

Table 3. Difference testing between wines made from experiment treatments

	2014			2015		
	Control	eCO_2	eTemp	Control	eCO_2	eTemp
eCO2	ns	-		ns		
eTemp	***	*		ns	ns	
eTemp + eCO_2	***	**	ns	***	**	ns

ns = not significant, * = $p \le 0.05$, ** = $p \le 0.01$, *** = $p \le 0.001$

Figure 2. Levels of wine tannin in a) 2014 and b) 2015 and wine anthocyanins in c) 2014 and d) 2015. Mean values with the same letter(s) are not significantly different at $p \le 0.05$ (n = 4)

Conclusions

- The different effects of warming combined with elevated CO_2 on phenolic compounds in each season may have been driven by seasonal influences.
- However, elevated CO_2 is likely increasing levels of non-structural carbohydrates within the vine (see partner presentation, Session 2-1-8) that may influence secondary metabolites in subsequent seasons.
- It is expected that a more consistent response to elevated temperature and CO_2 will emerge in the next two seasons.

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Summary

- *Results of warming alone similar to previous work.*
  - *Advanced phenology, earlier harvest, greater risk of loss to heat.*
- *Effects of elevated CO_2 on phenology appear to be increasing season by season.*
- *Little evidence of significant acclimation to elevated CO_2 at leaf level, but evidence of a interaction with warming.*
- *Likely that vine CHO reserves are building in eCO_2 treatments, which will result in further impacts.*

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Wine Australia for Australian Wine

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