# Measured effects of elevated temperature on vine phenology, yield, berry and wine attributes

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**South Australian R&D Institute, Treasury Wine Estates**

**Funded by**
- **Grape and Wine R&D Corporation**
- **State NRM Program**
- **Department of Agriculture, Fisheries and Forestry**

**Vintage 2030 - Melbourne, 19th June 2013**

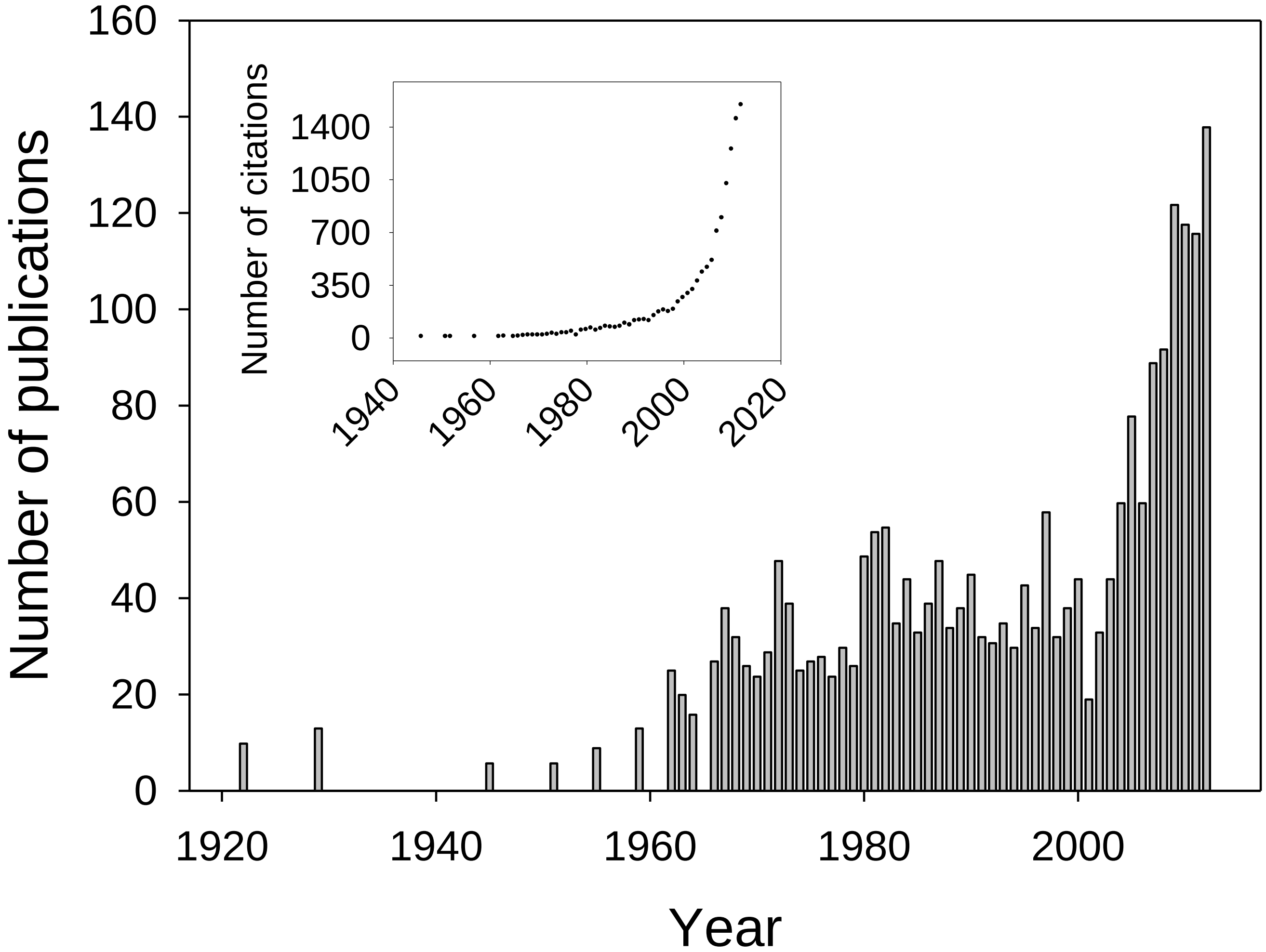
# Aims

**Methods, data sources and reliability**

**Measured effects of elevated temperature on:**

- **time of harvest**
- **yield**
- **berry traits**
- **juice and wine attributes**

# Papers retrieved searching "temperature" + "grapevine" (Web of Science)



# Effect of temperature on vines and wines: indirect vs direct methods

## Indirect methods

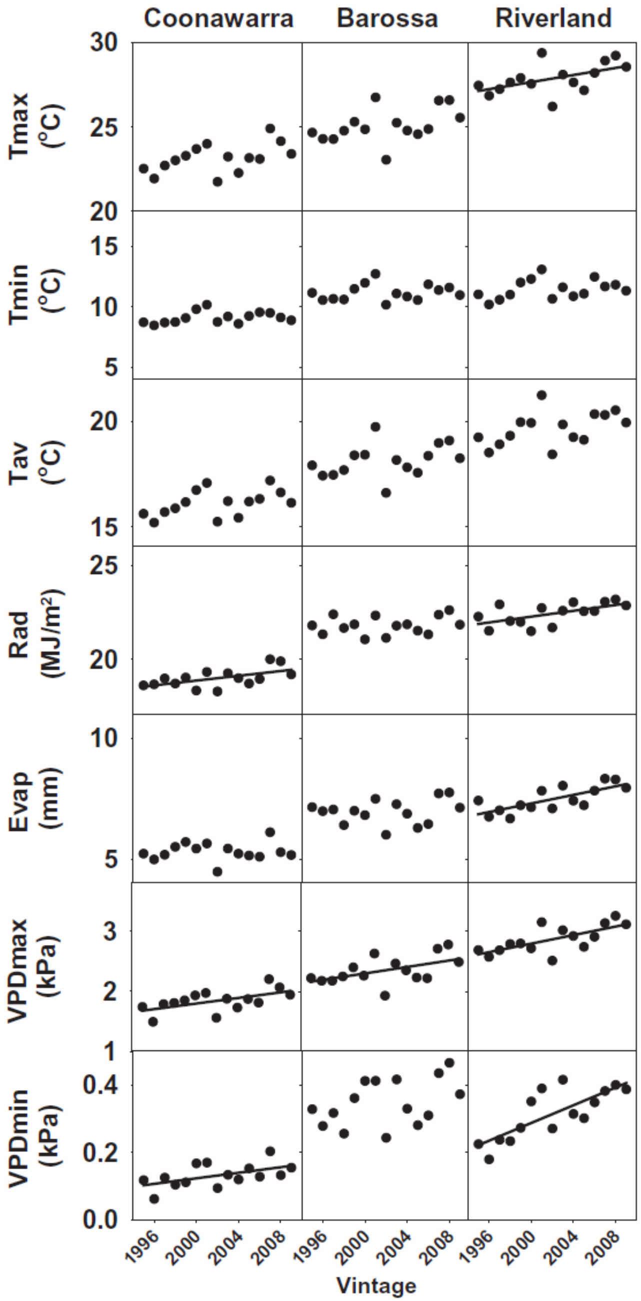
comparison between regions, vintages, row orientation…

large confounded effects

## Direct methods

side-by-side experimental comparison of treatments involving different temperatures

large to small confounded effects

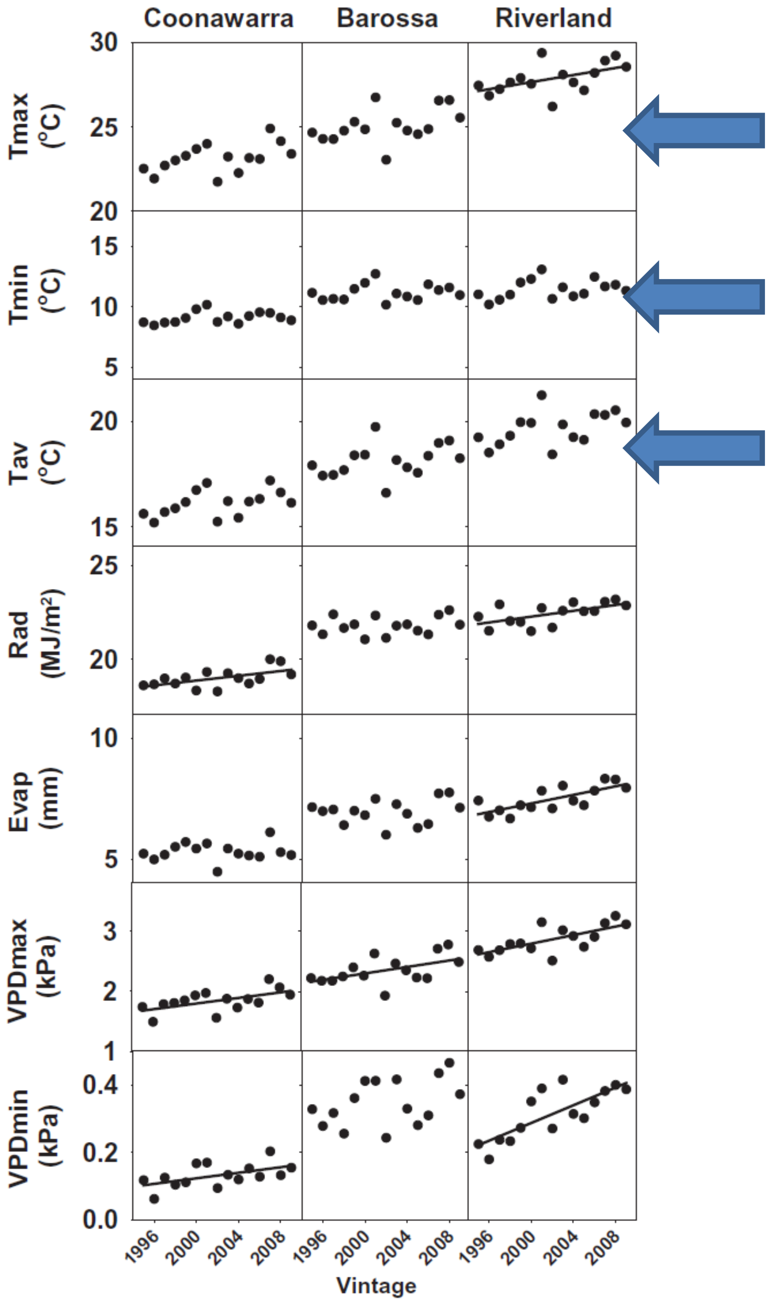



**Regional or seasonal comparisons confound temperature with radiation, humidity, etc (+ soil, + management)**

**Indirect methods cannot prove cause and effect**

**Regional classification as a function of temperature is ok for marketing but is an oversimplification**

**Sadras & Petrie 2011 Austr J Grape Wine Res 17, 199**

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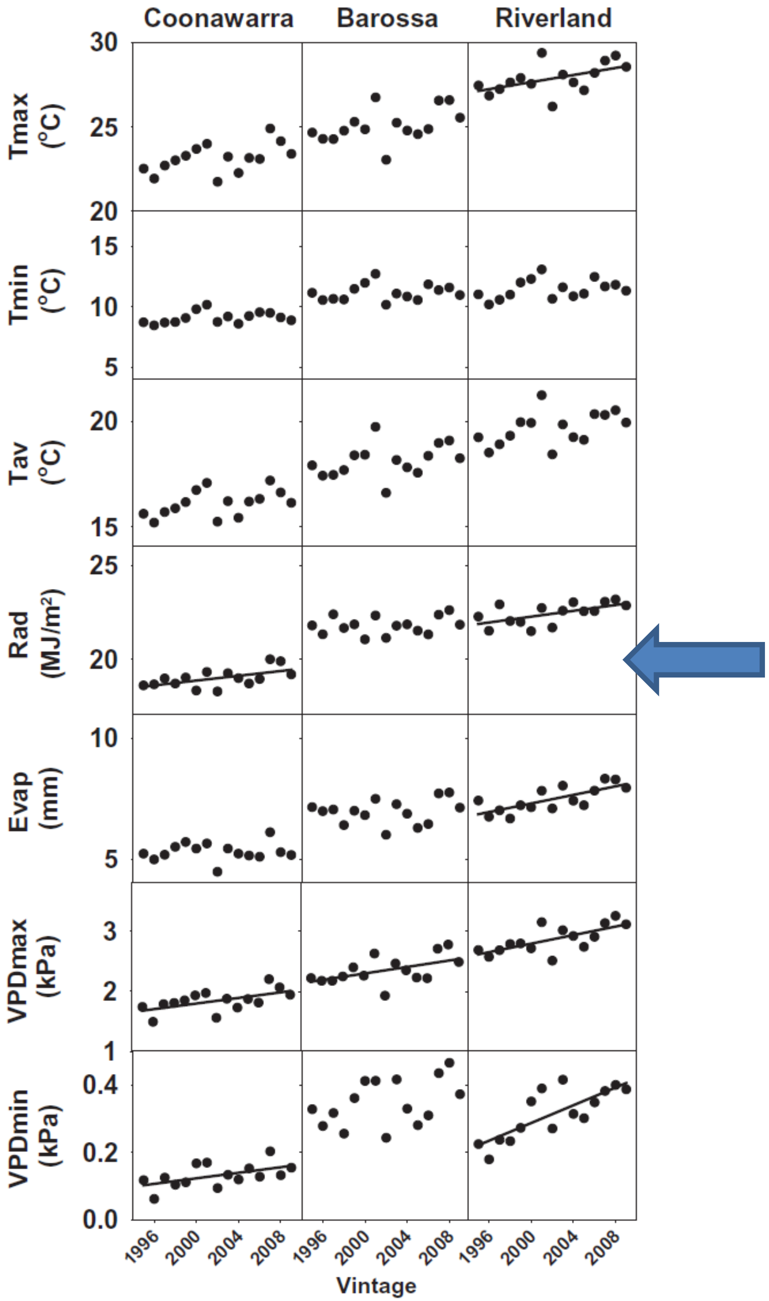


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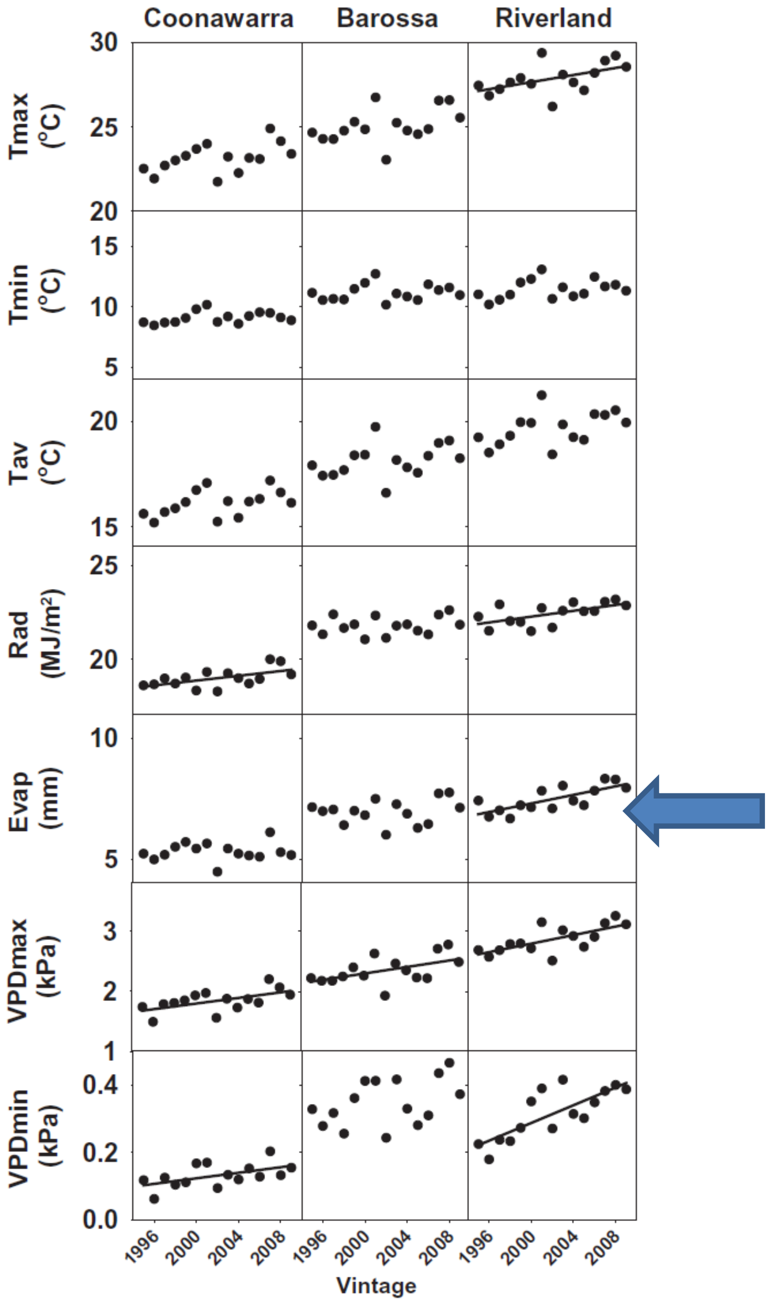


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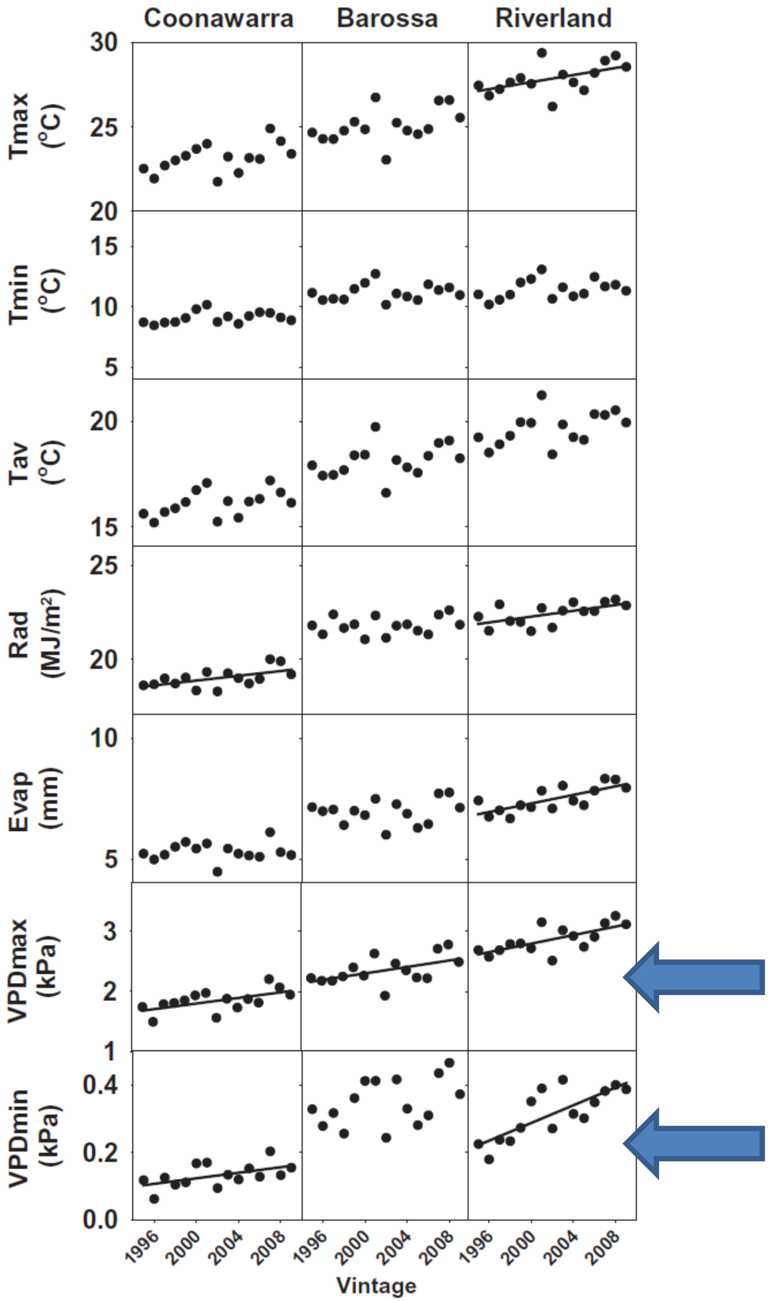


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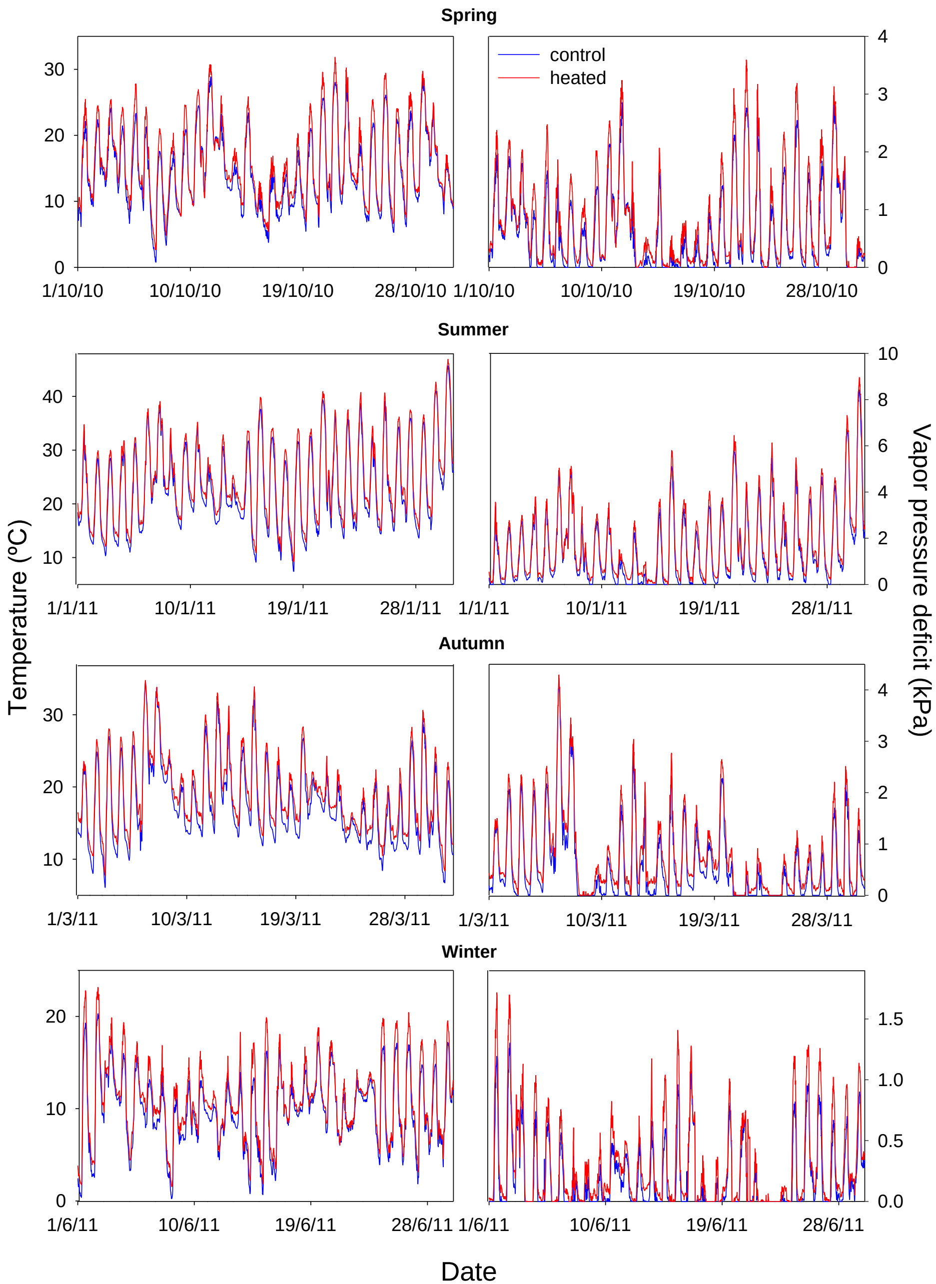
# Large scale open-top heating systems
## (9 vines per rep x 3 reps + buffers)

**Passive, daytime +2 to 4 $^{o}C$**

**Experiments 1 and 2**

**Active/Passive, day & night +2 $^{o}C$**

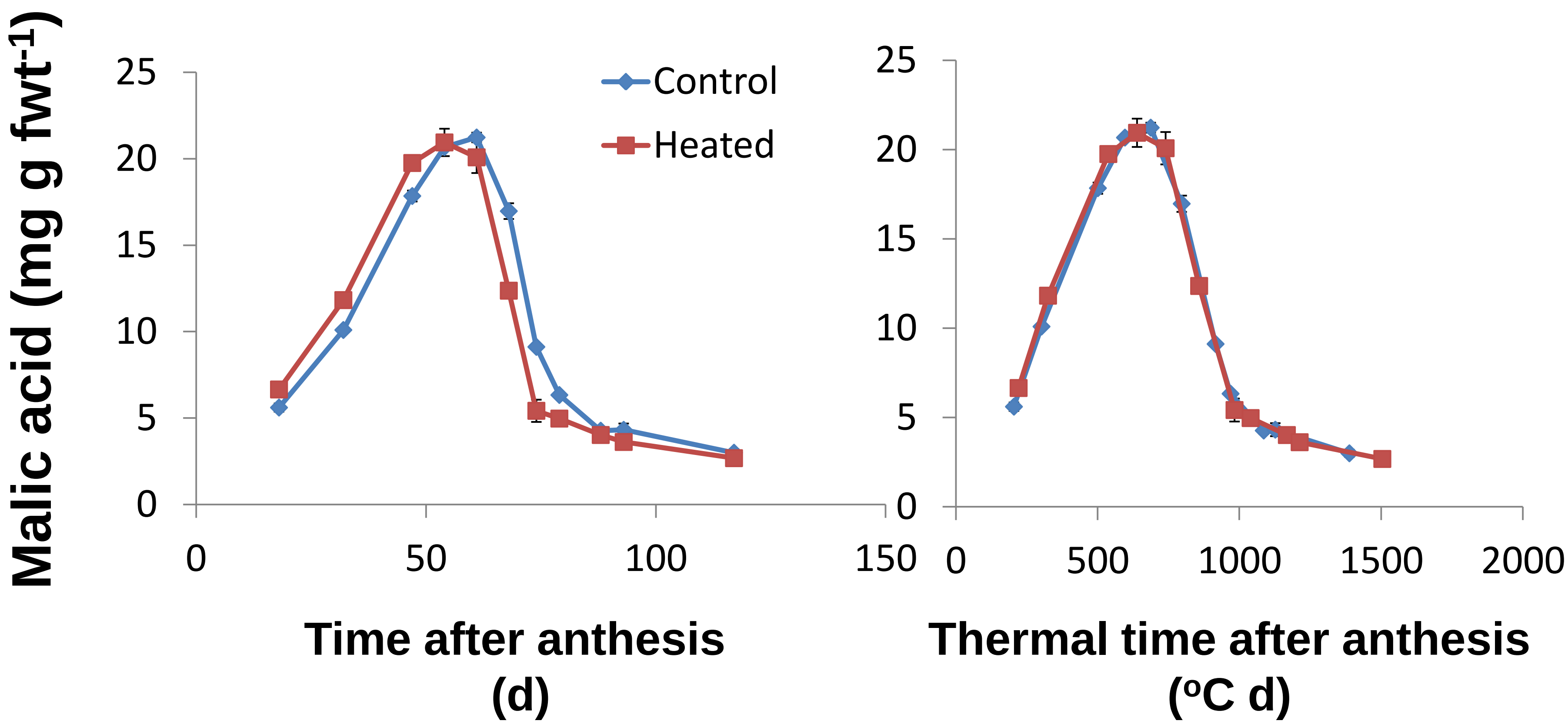

**Experiment 3**



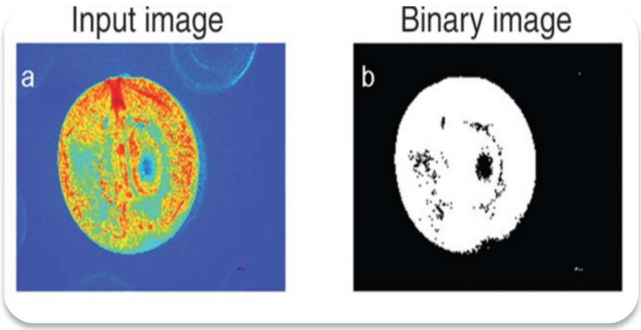

# Design Criteria

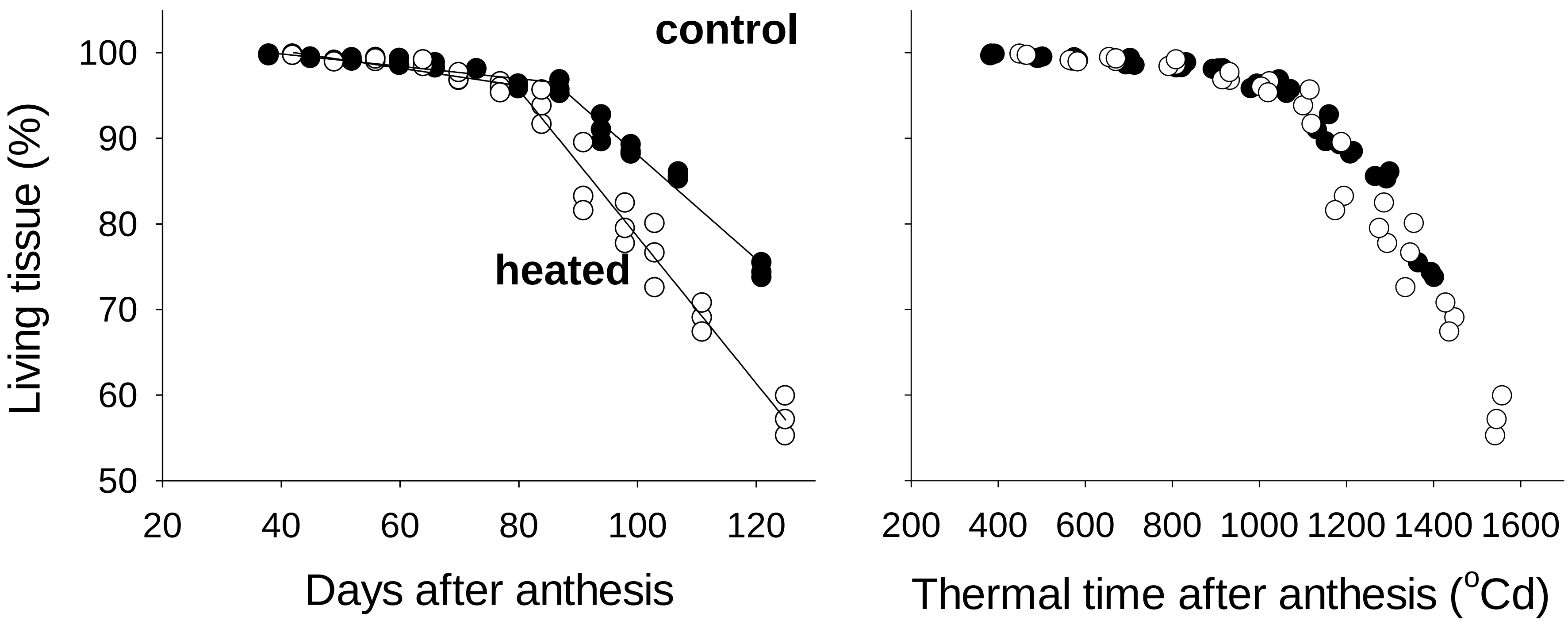
1. Reproduces the daily and seasonal cycles of temperature and vapour pressure deficit.
2. Does not increase relative humidity, hence allowing for increased vapour pressure deficit.
3. Minimises biologically important secondary effects.
4. Has structural strength to withstand the weather (particularly wind) to ensure a reasonable longevity.
5. Allows for number and size of replicates required for statistical resolution and viticultural needs, including sufficient fruit for meaningful wine production.

# Probing for experimental artefacts




**Sweetman et al (unpublished)**




Bondada et al 2013 Austr J Grape Wine Res 19: 97

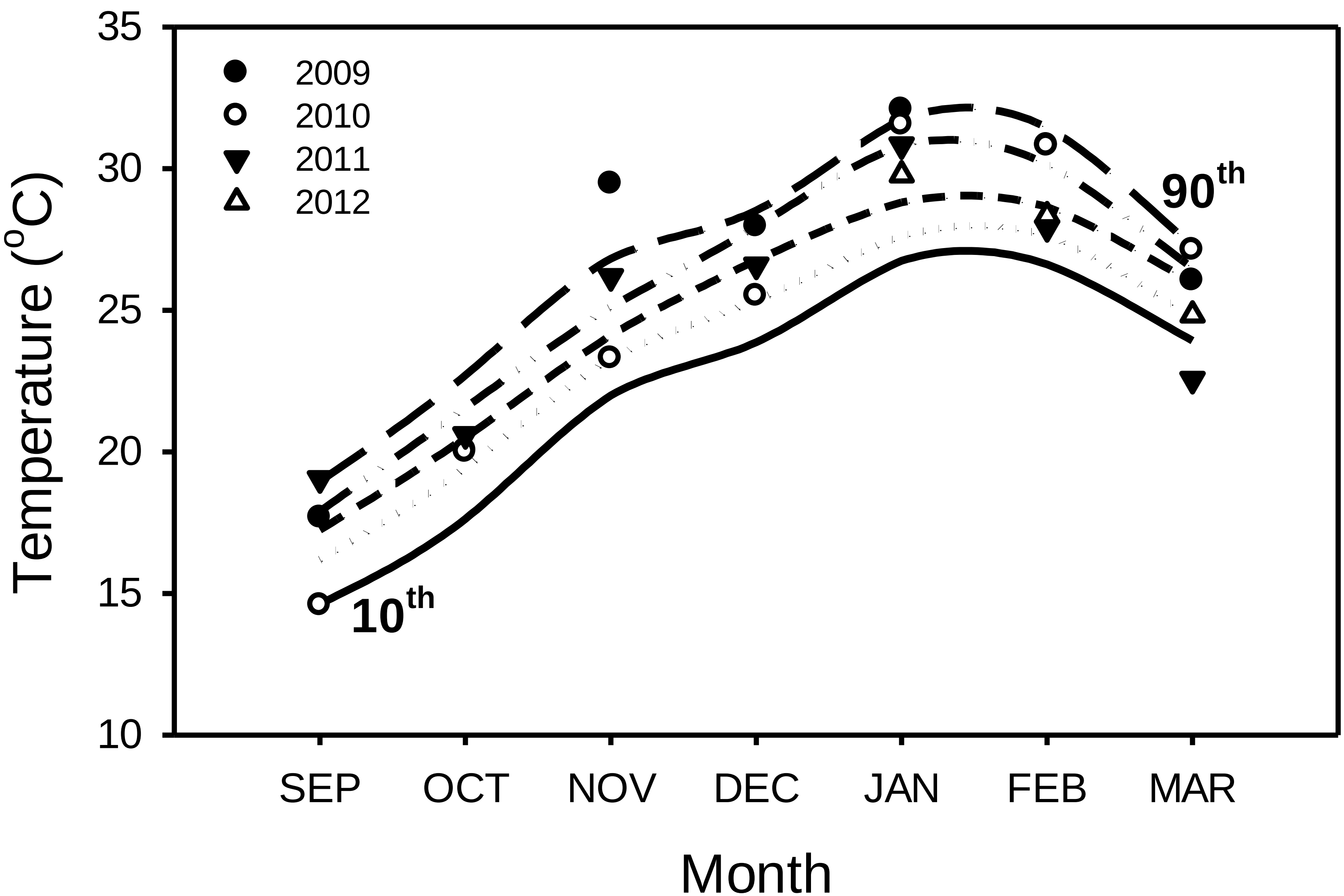
# Experiments

## Exp 1
**2 temperatures (high, control) x 4 varieties  x 3 seasons**

## Exp 2 (Shiraz)
**2 temperatures x 2 fruit loads (thinned, control) x 2 seasons**

## Exp 3 (Shiraz)
**2 temperatures x 2 water regimes (irrigated, deficit) x 2 seasons**

# experiments explored a good range of Barossa seasonal variation



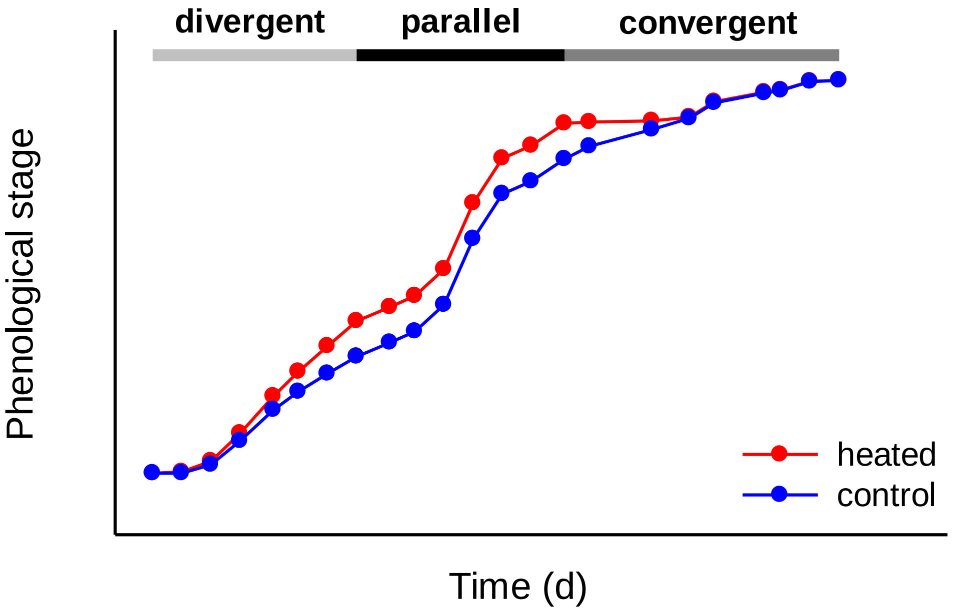
# Traits

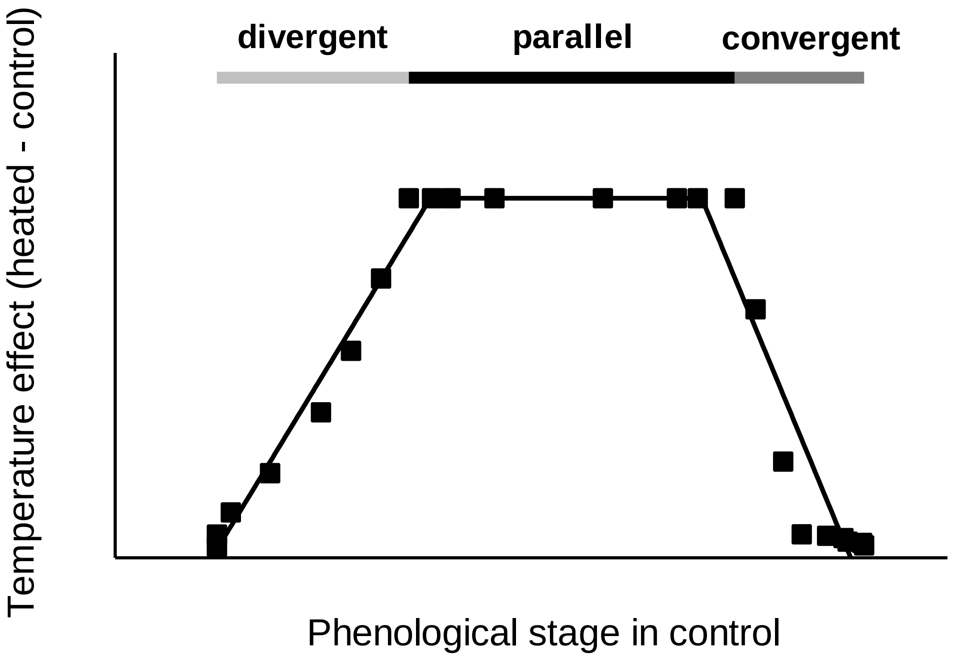
Phenology
Yield and components
Pruning weight and components
Starch reserves in trunk and roots

Stomatal conductance, density and size
Photosynthesis
Leaf chlorophyll
Pre-dawn and mid-day leaf water potential
Canopy and bunch temperature
Sap flow

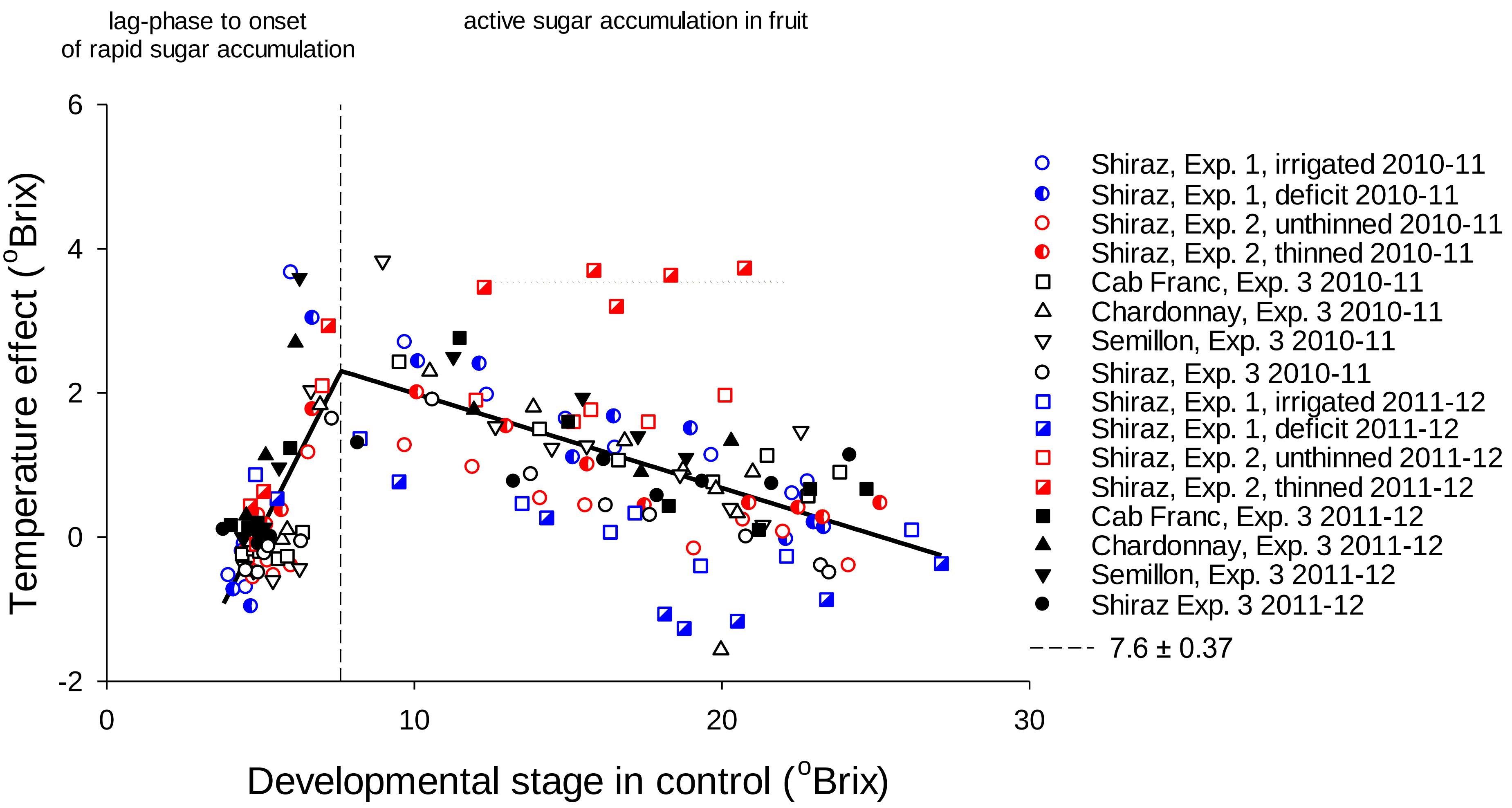
Berry: dynamics of TA, pH, TSS and anthocyanins
Berry progression of cell death

Sensory traits in berries and wines


divergent
parallel
convergent
Phenological stage
heated
control
Time (d)


divergent
parallel
convergent
Temperature effect (heated - control)
Phenological stage in control

# nonlinear thermal effect on grapevine phenology




**Sadras & Moran 2013 Agric Forest Meteorol 173:107**

**smaller than expected effect of temperature on maturity (**21.6 $^o$Brix)

# Experiments

Approx 3 d $^oC^{-1}$

# Indirect methods

6.6 ± 0.92 d $^oC^{-1}$ (Petrie and Sadras 2008)

8 d $^oC^{-1}$ (Tomasi et al 2011)

9.8 ± 0.94 d $^oC^{-1}$ (Sadras and Petrie 2011)

**Sadras & Moran 2013 Agric Forest Meteorol 173:107**

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**Yield and components**
**Pruning weight and components**
**Starch reserves in trunk and roots**

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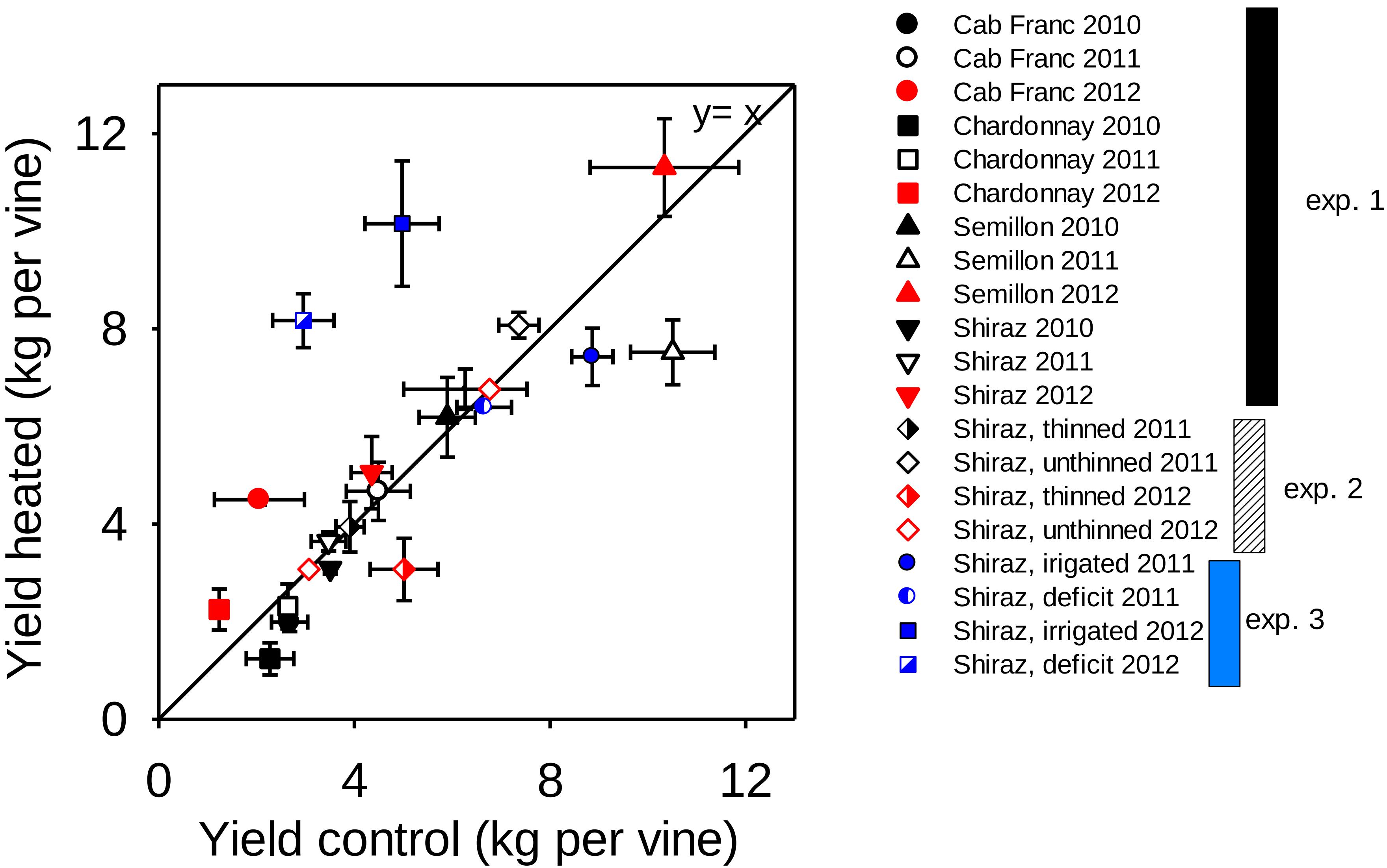
Berry progression of cell death

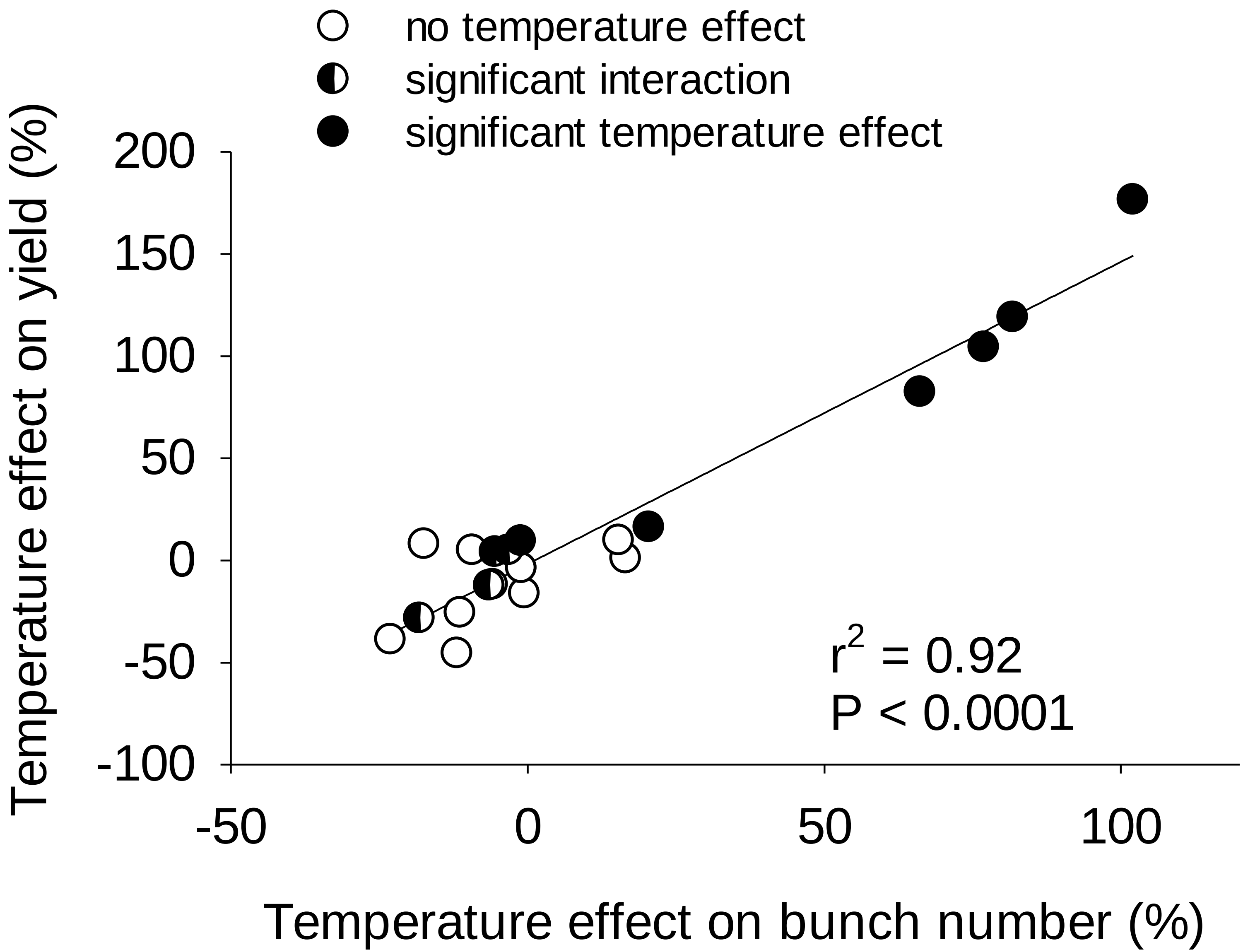
Sensory traits in berries and wines

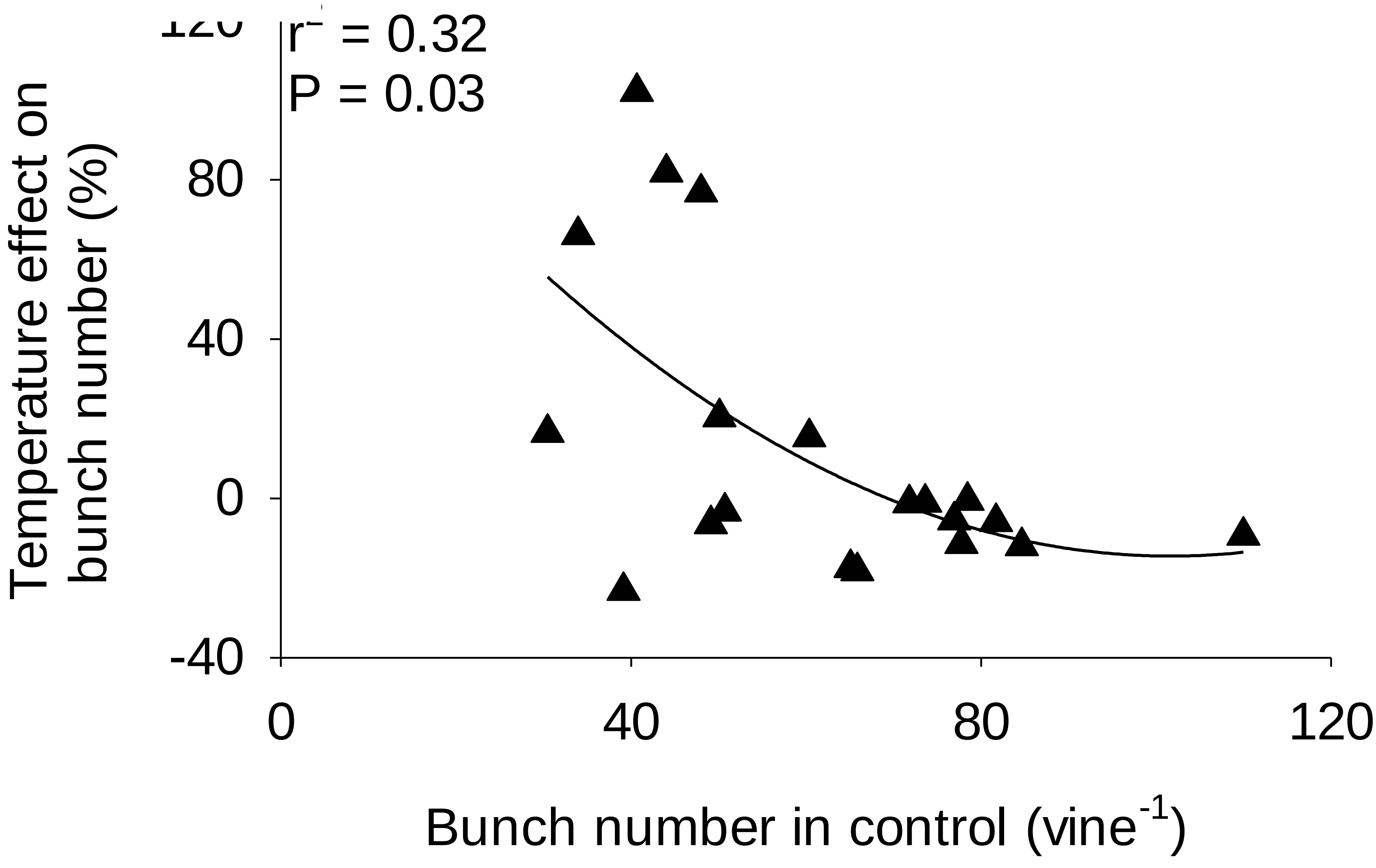
# asymmetric effect of warming on yield

## 46% reduction to 177% increase



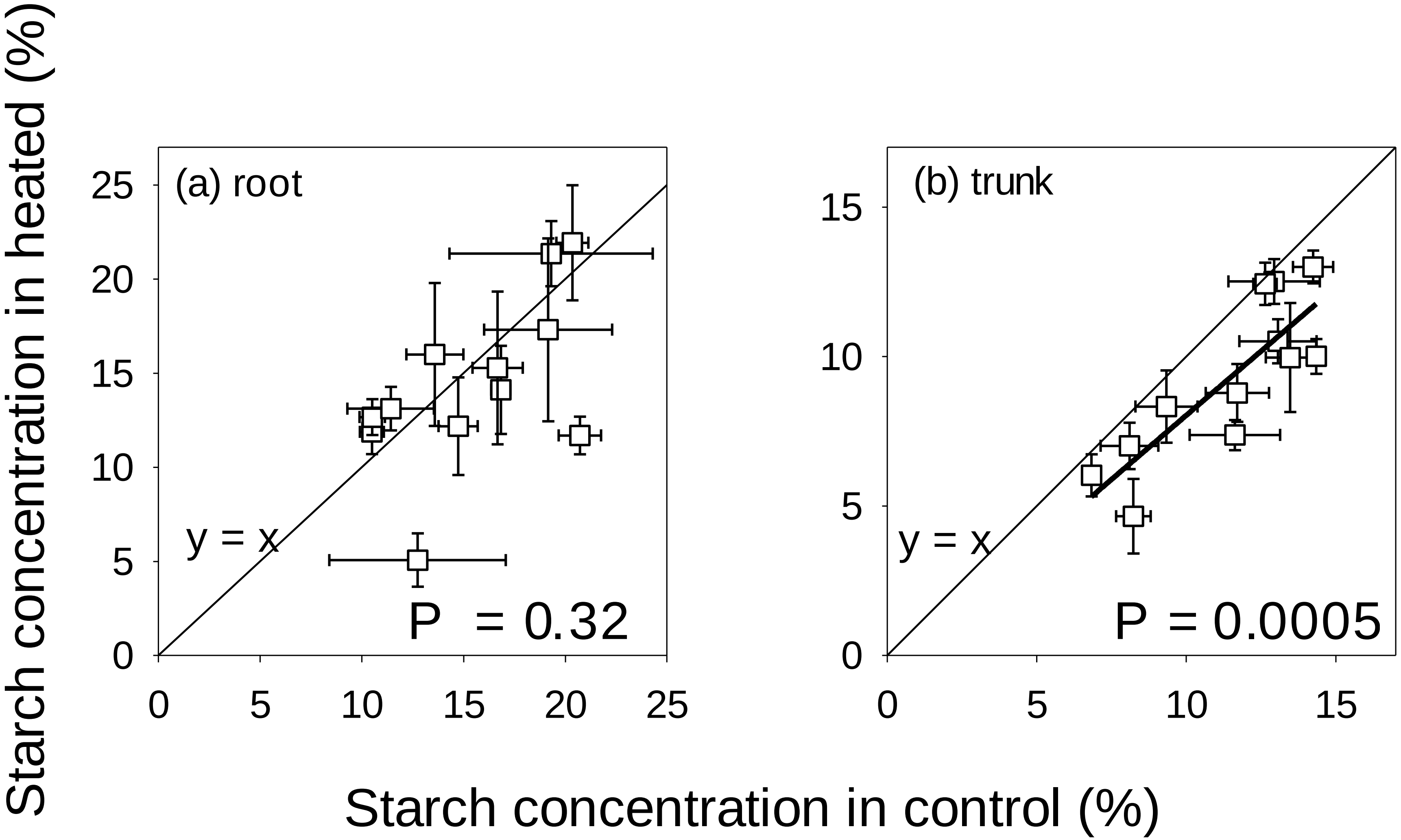

**Sadras & Moran 2013 Agric Forest Meteorol 173:116**


no temperature effect
significant interaction
significant temperature effect
Temperature effect on yield (%)
200
150
100
50
0
-50
-100
-50
0
50
100
Temperature effect on bunch number (%)
r2 = 0.92
P < 0.0001



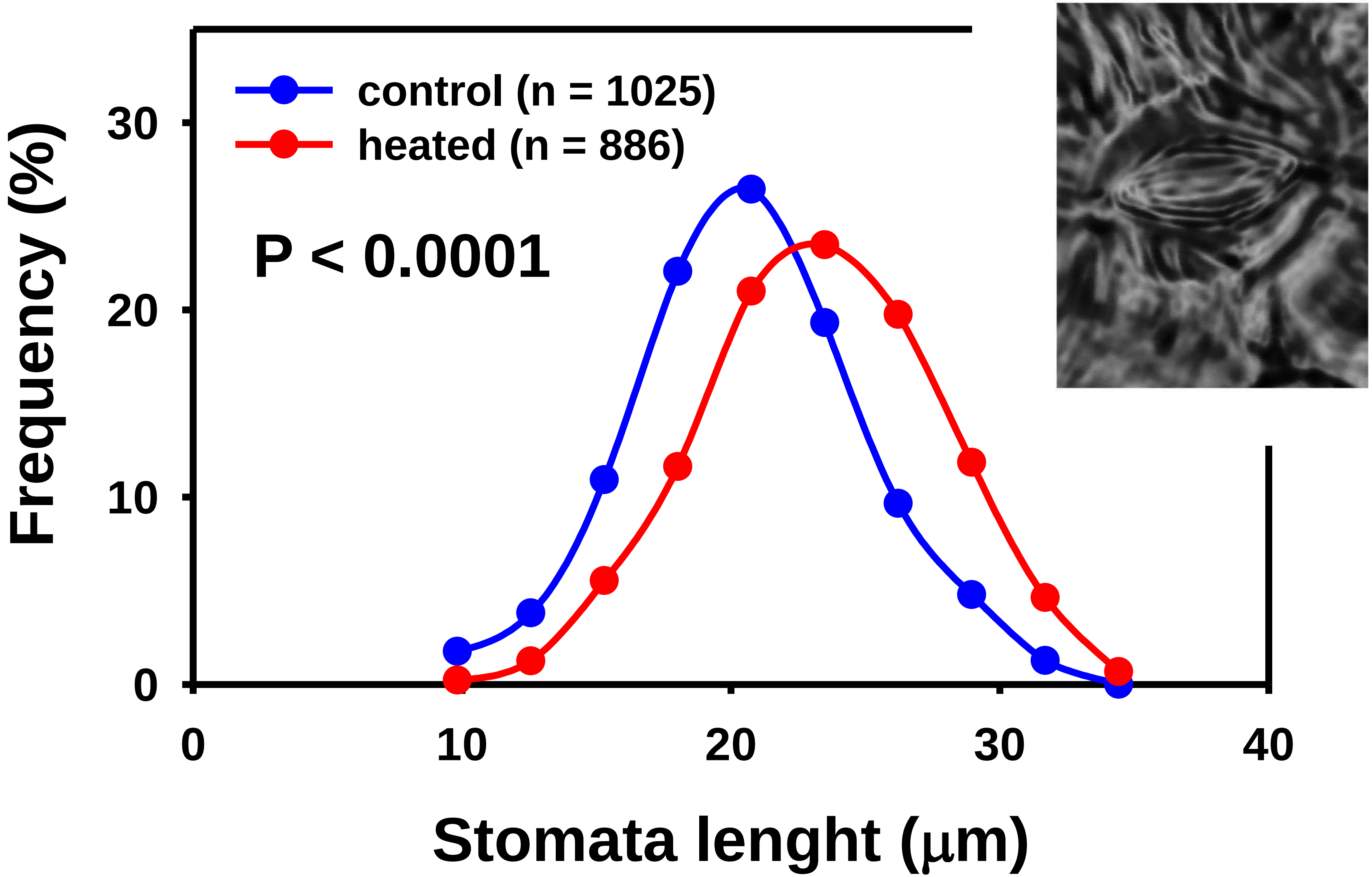
r² = 0.32
P = 0.03
120
80
40
0
-40
0
40
80
120
Temperature effect on bunch number (%)
Bunch number in control (vine-1)

# elevated temperature reduced starch concentration in trunk




**Sadras & Moran 2013 Agric Forest Meteorol 173:116**

# leaves formed under high temperature had larger stomata




Sadras et al. 2012 Agric Forest Meteorol 165:35

# Traits

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Sap flow

**Berry: dynamics of TA, pH, TSS and anthocyanins**
**Berry progression of cell death**

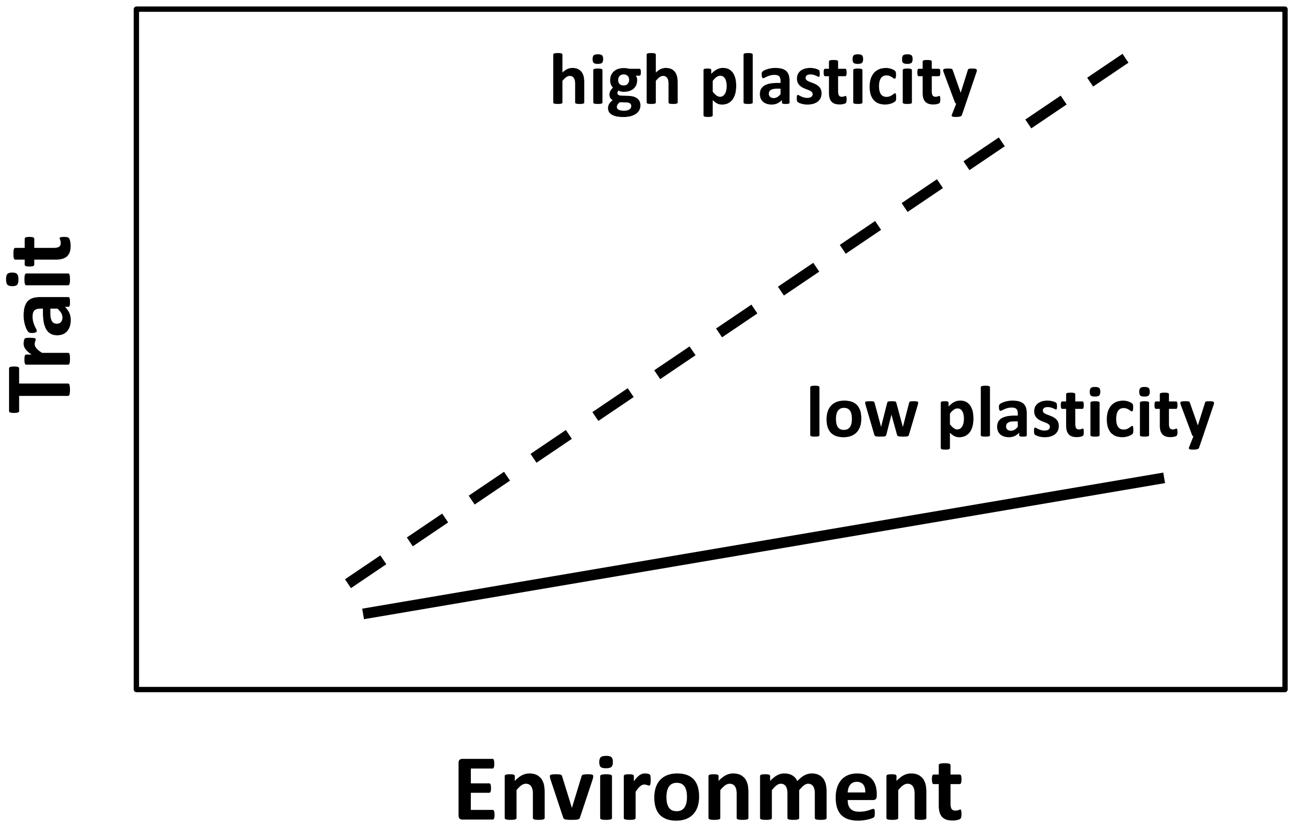
**Sensory traits in berries and wines**

# temperature effect on TA and pH is strongly dependent on variety

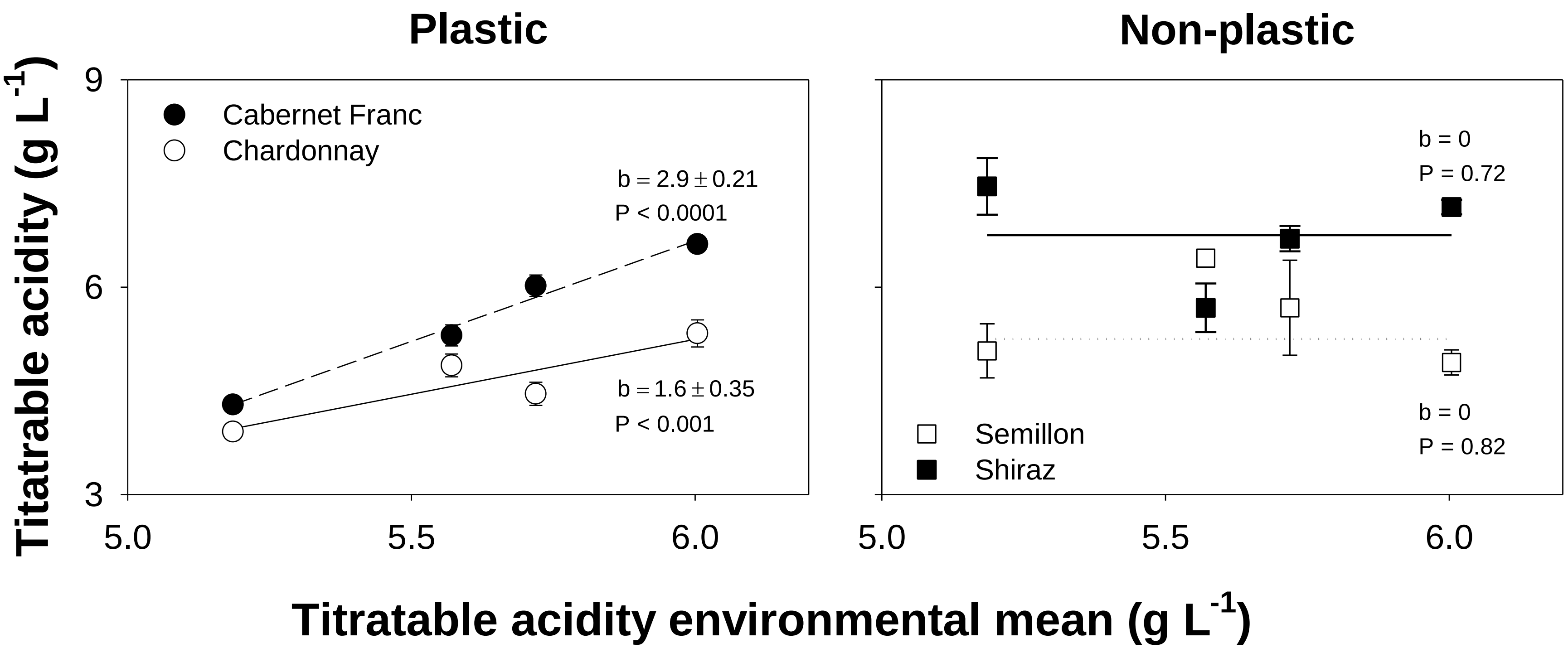
| Vintage | Variety | TA (g $L^{-1}$) | | pH | |
|---|---|---|---|---|---|
| | | control | heated | control | heated |
| 2010 | Semillon | 6.4 ±0.12 | 5.1 ±0.39 | 3.11 ±0.0167 | 3.30 ±0.0780 |
| | Chardonnay | 4.9 ±0.16 | 3.9 ±0.12 | 3.52 ±0.0567 | 3.80 ±0.0285 |
| | Shiraz | 5.7 ±0.35 | 7.5 ±0.41 | 3.44 ±0.0458 | 3.40 ±0.0318 |
| | Cab Franc | 5.3 ±0.15 | 4.3 ±0.10 | 3.66 ±0.0088 | 3.85 ±0.0384 |
| 2011 | Semillon | 4.9 ±0.18 | 5.7 ±0.69 | 3.37 ±0.0318 | 3.54 ±0.0361 |
| | Chardonnay | 5.3 ±0.20 | 4.5 ±0.17 | 3.57 ±0.0265 | 3.82 ±0.0713 |
| | Shiraz | 7.2 ±0.10 | 6.7 ±0.18 | 3.37 ±0.0231 | 3.43 ±0.0463 |
| | Cab Franc | 6.6 ±0.06 | 6.0 ±0.16 | 3.50 ±0.0120 | 3.65 ±0.0208 |
| *Source of variation* | | | | | |
| variety (V) | | 0.0001 | | 0.0001 | |
| temperature (T) | | 0.0185 | | 0.0001 | |
| season (S) | | 0.0011 | | 0.3320 | |
| V x T | | 0.0010 | | 0.0008 | |
| V x S | | 0.0002 | | 0.0001 | |
| T x S | | 0.7135 | | 0.9675 | |
| V x T x S | | 0.0001 | | 0.5544 | |

**Sadras et al. 2012 Austr J Grape & Wine Res 19, 107**

# Phenotypic plasticity allows for complex variety x environment interaction



# text-book expected increase in pH and reduction in TA with high temperature is an oversimplification




Sadras et al. 2012 Austr J Grape & Wine Res 19, 107

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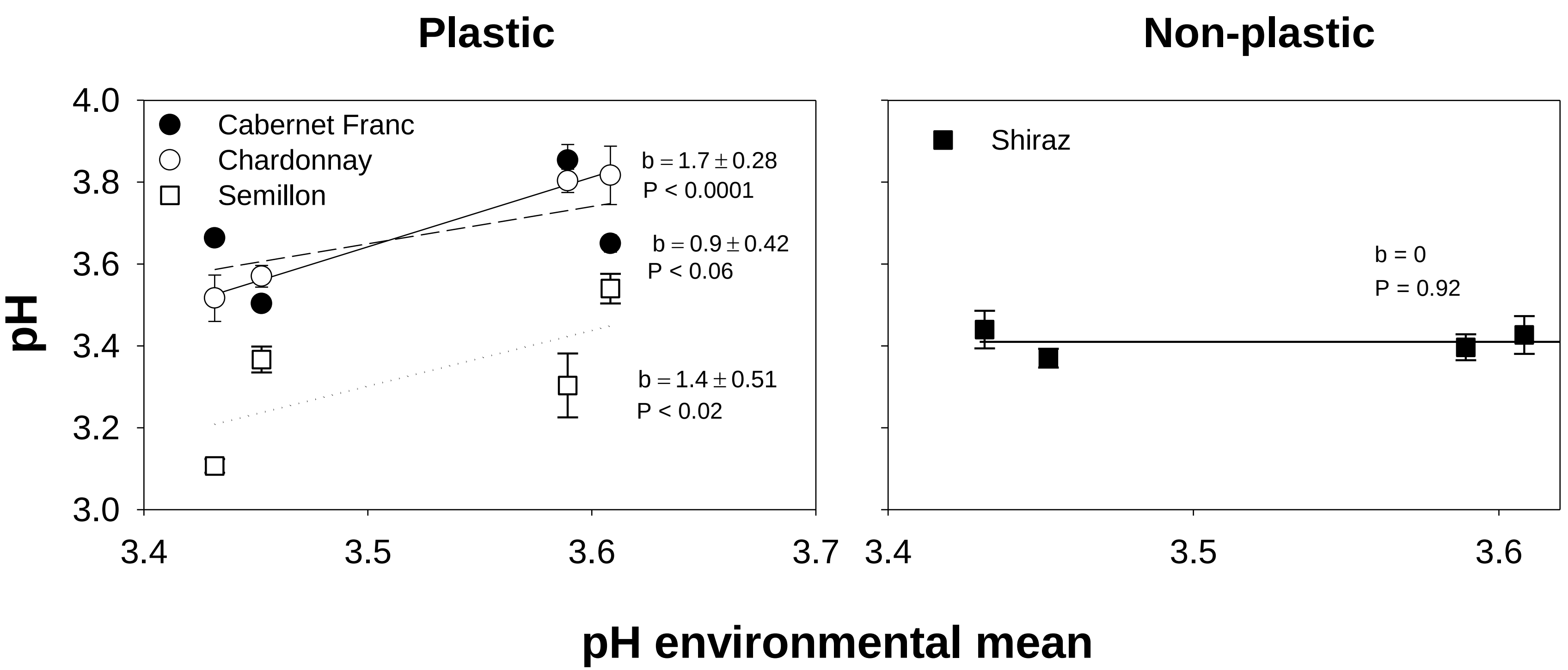



**Sadras et al. 2012 Austr J Grape & Wine Res 19, 107**

# trait decoupling

## Thermal decoupling is the consequence of differential responses of related traits.

**Balanced fruit**

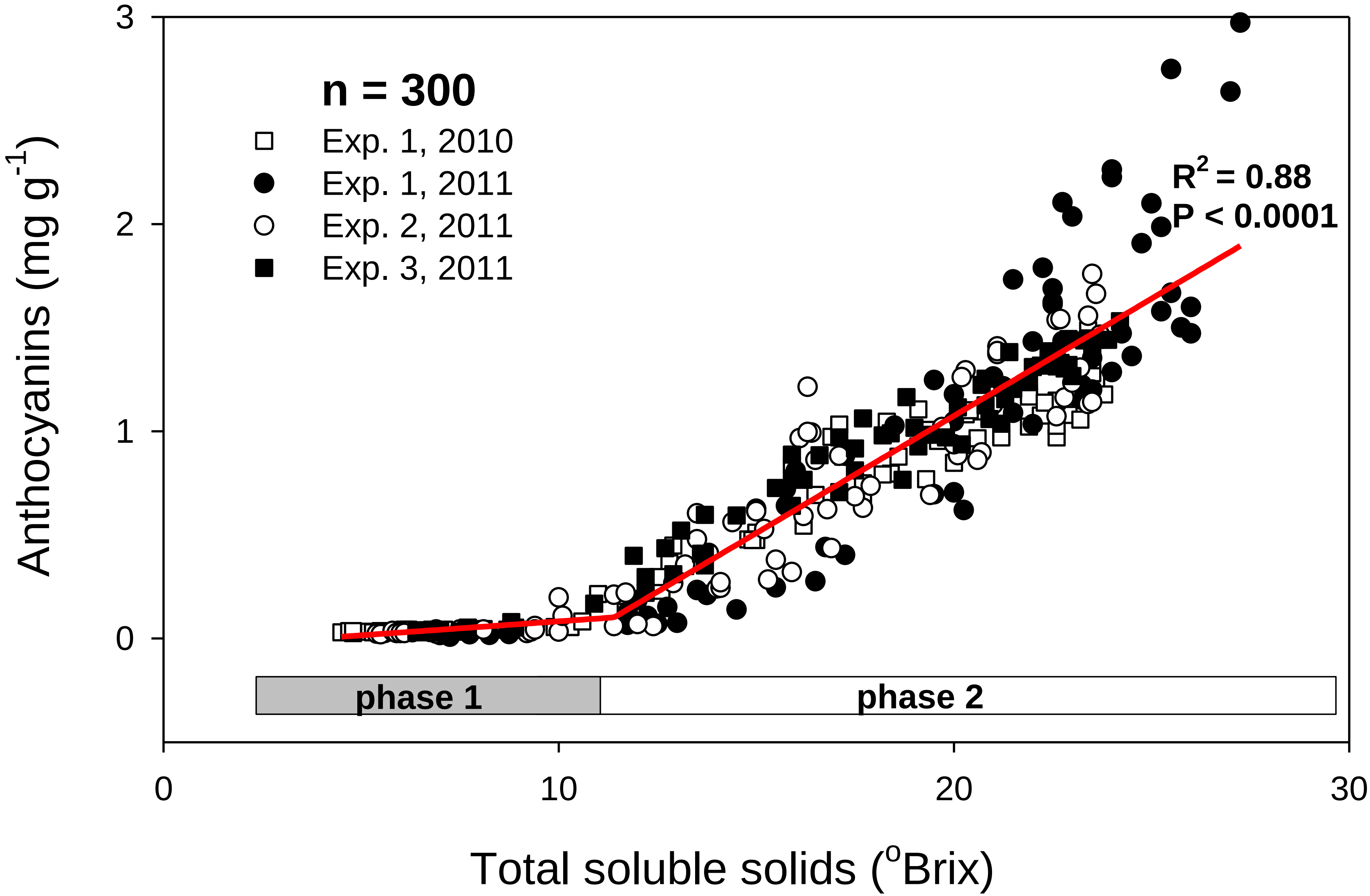
Sugars
Anthocyanins
pH
TA
Flavour compounds

**temperature** →

**Decoupled fruit**

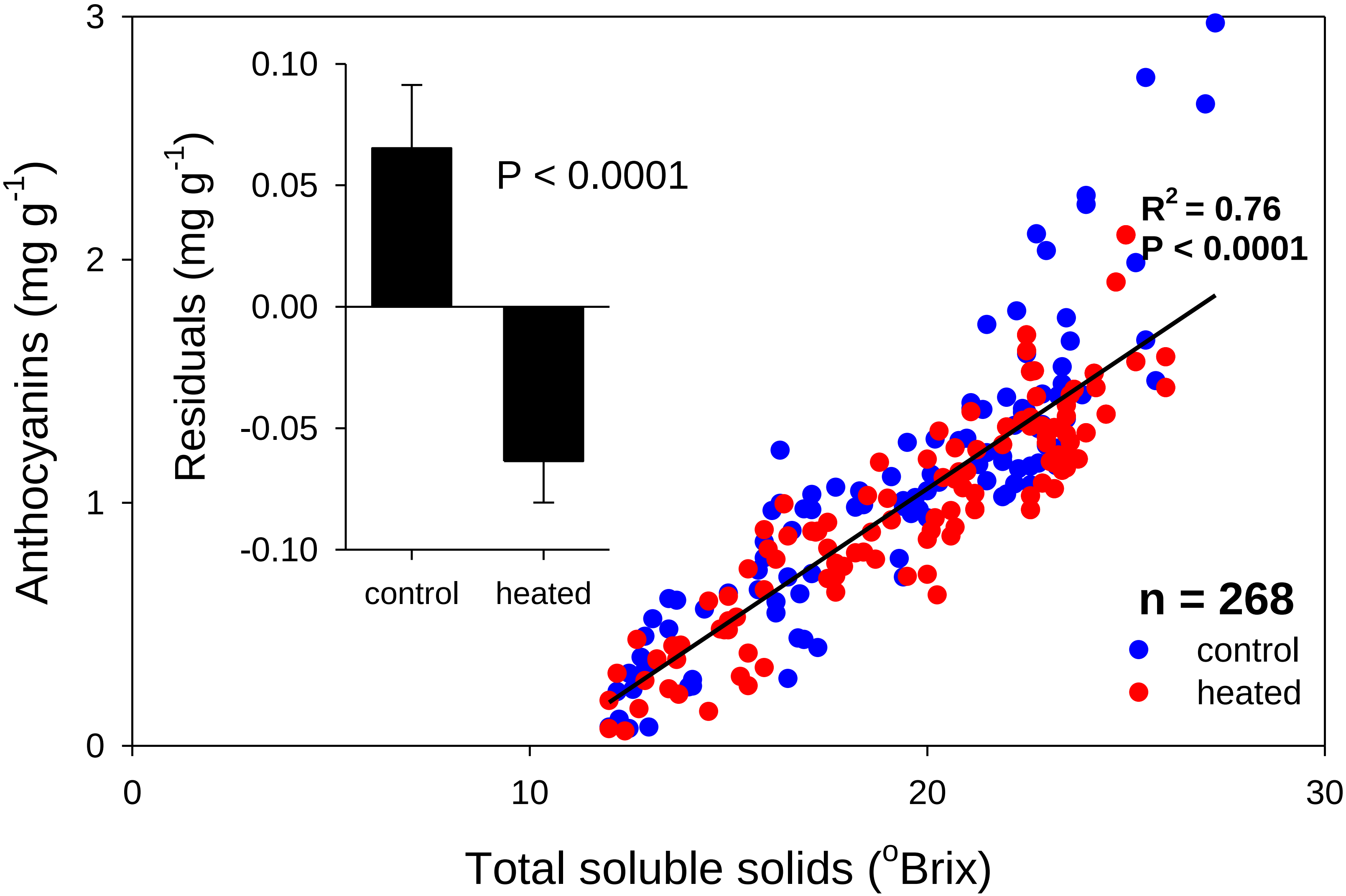
Sugars
Anthocyanins
pH
TA
Flavour compounds

# elevated temperature decoupled anthocyanins and sugars in Shiraz and Cab franc



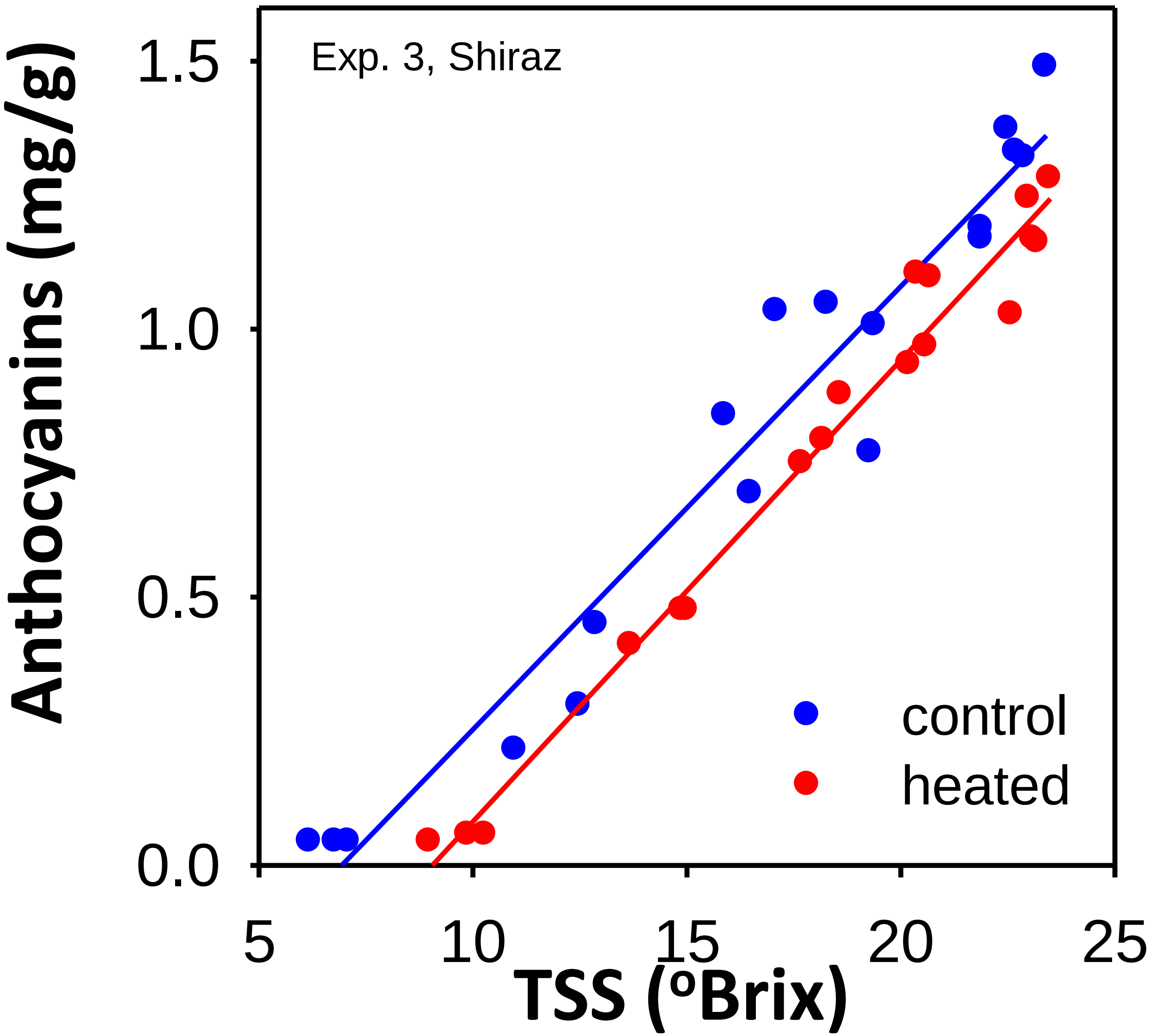

Sadras & Moran 2012 Austr J Grape & Wine Res 18, 115

# elevated temperature decoupled anthocyanins and sugars

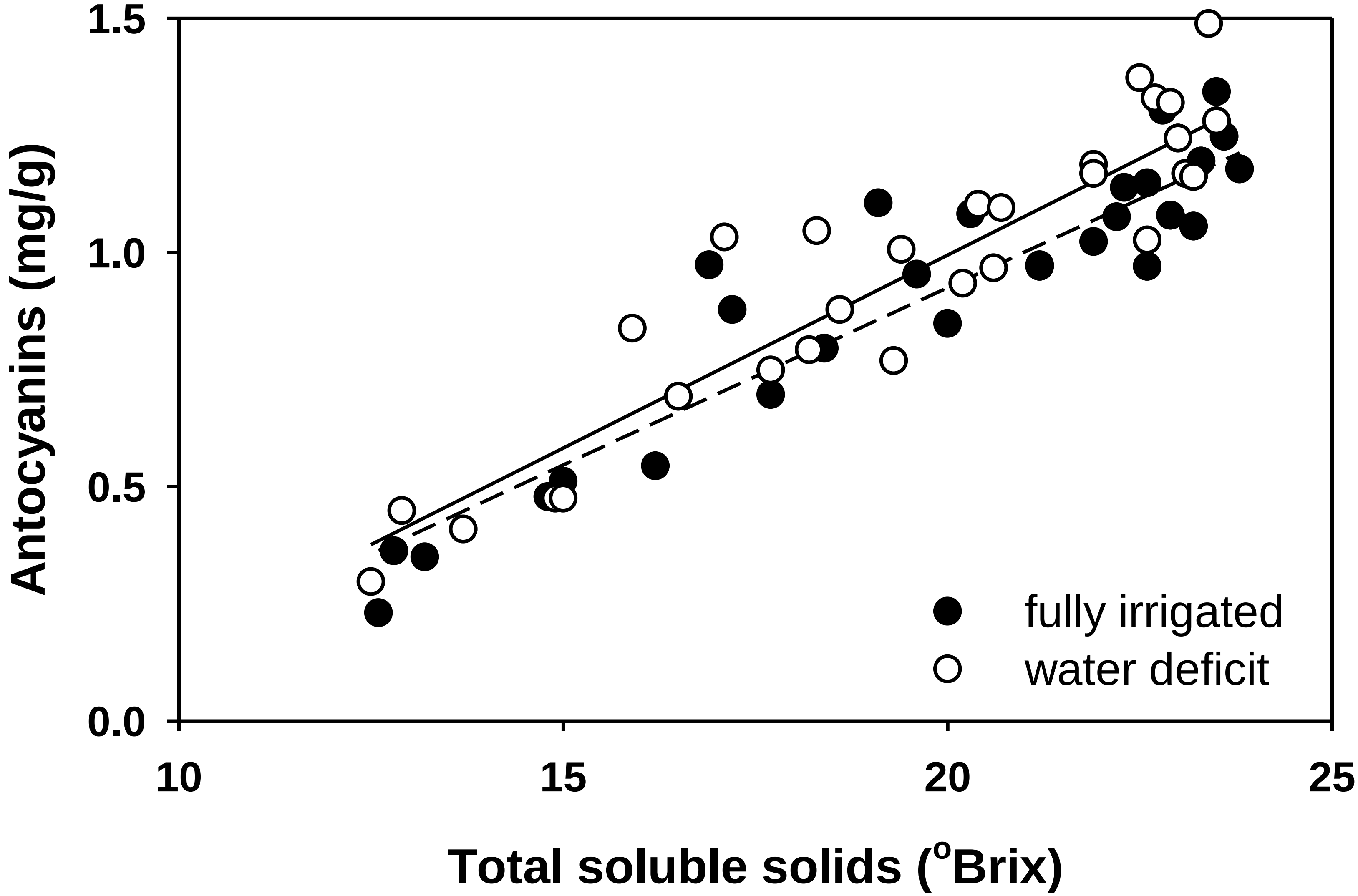



Sadras & Moran 2012 Austr J Grape & Wine Res 18, 115

**elevated temperature decoupled anthocyanins and sugars by delaying pigment development in a brix scale**

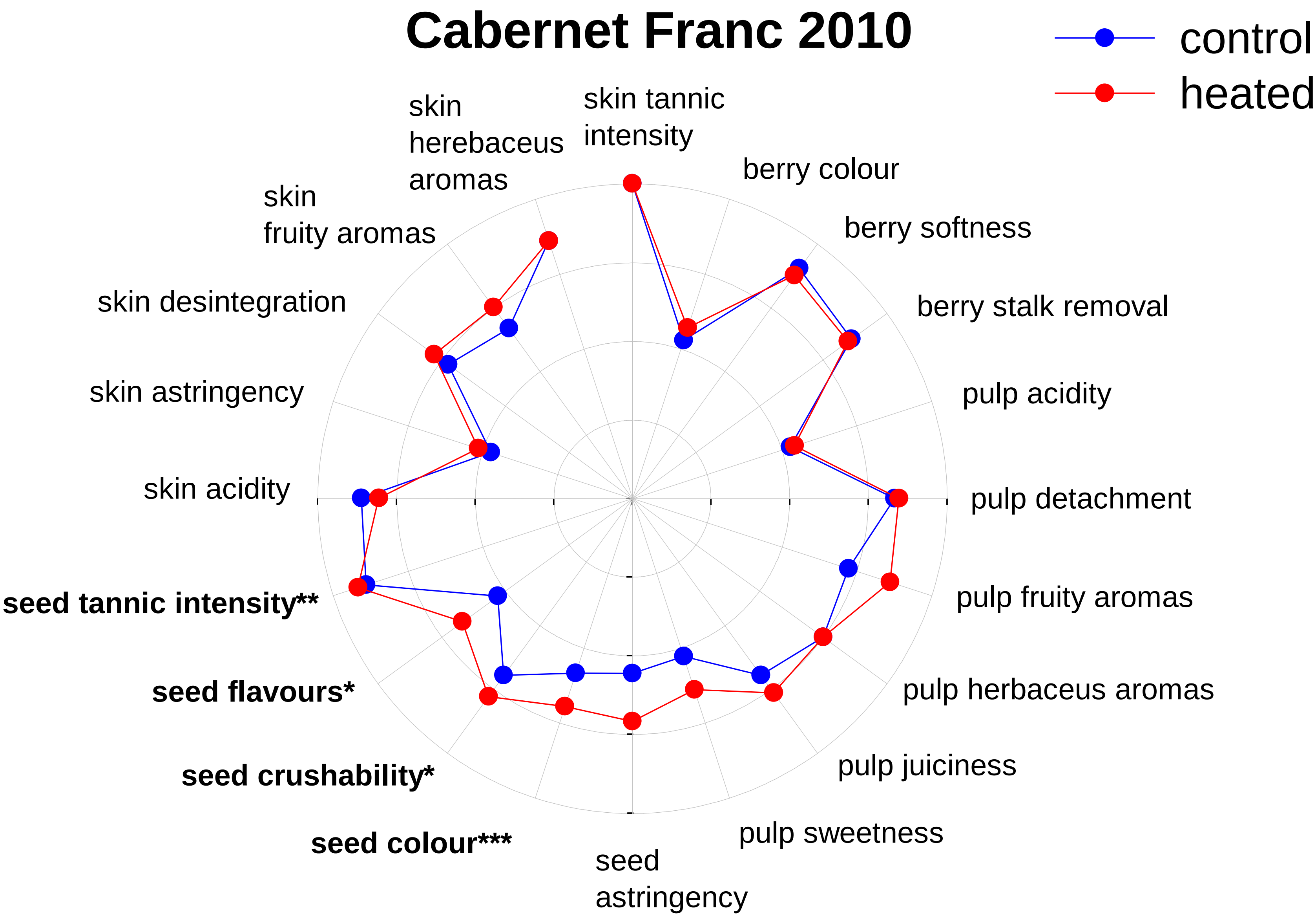


# water deficit partially restored the anthocyanin : sugar balance




Sadras & Moran 2012 Austr J Grape & Wine Res 18, 115

## temperature decoupled sensory berry traits




**Sadras et al. 2012 Austr J Grape & Wine Res 19, 95**

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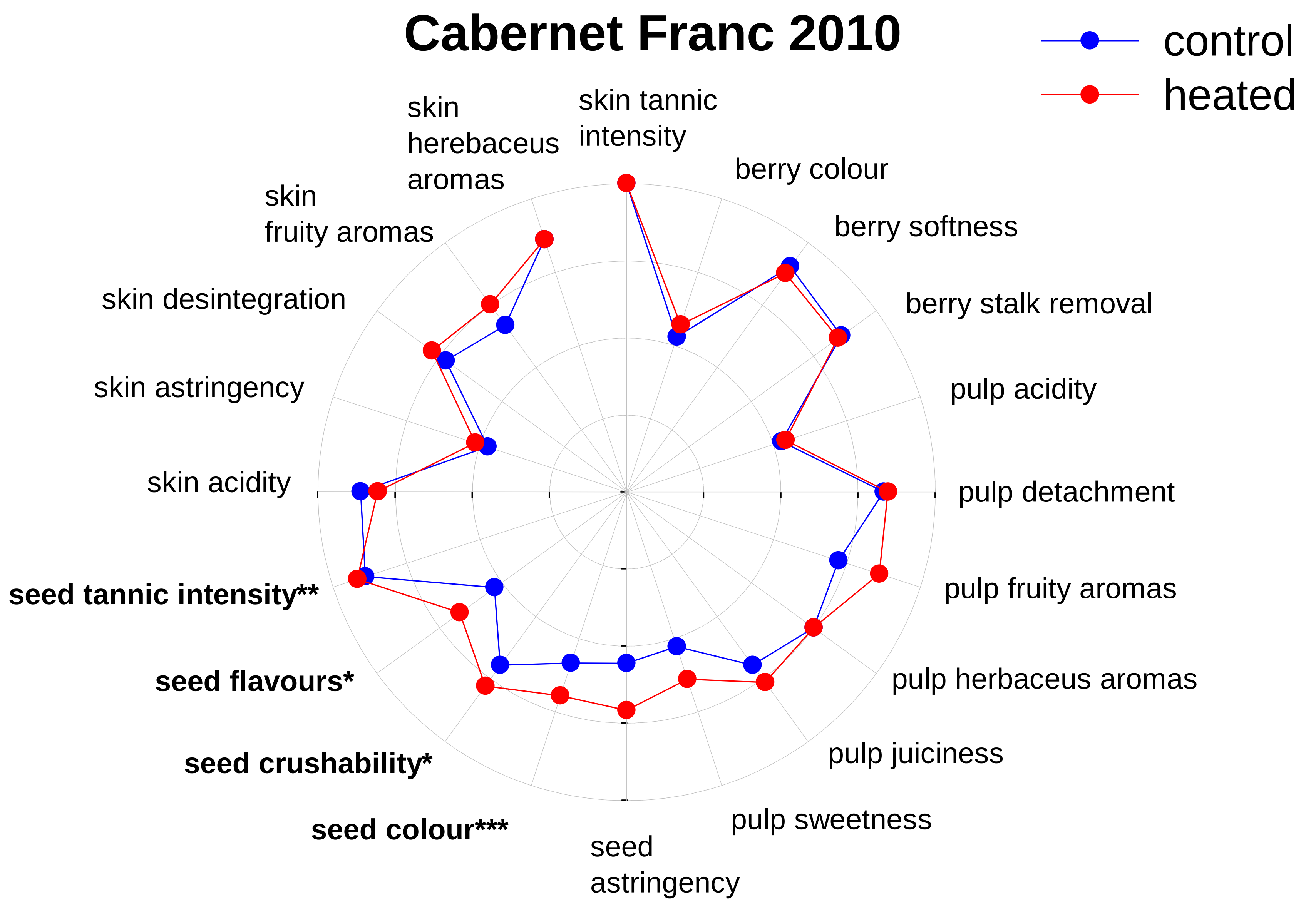


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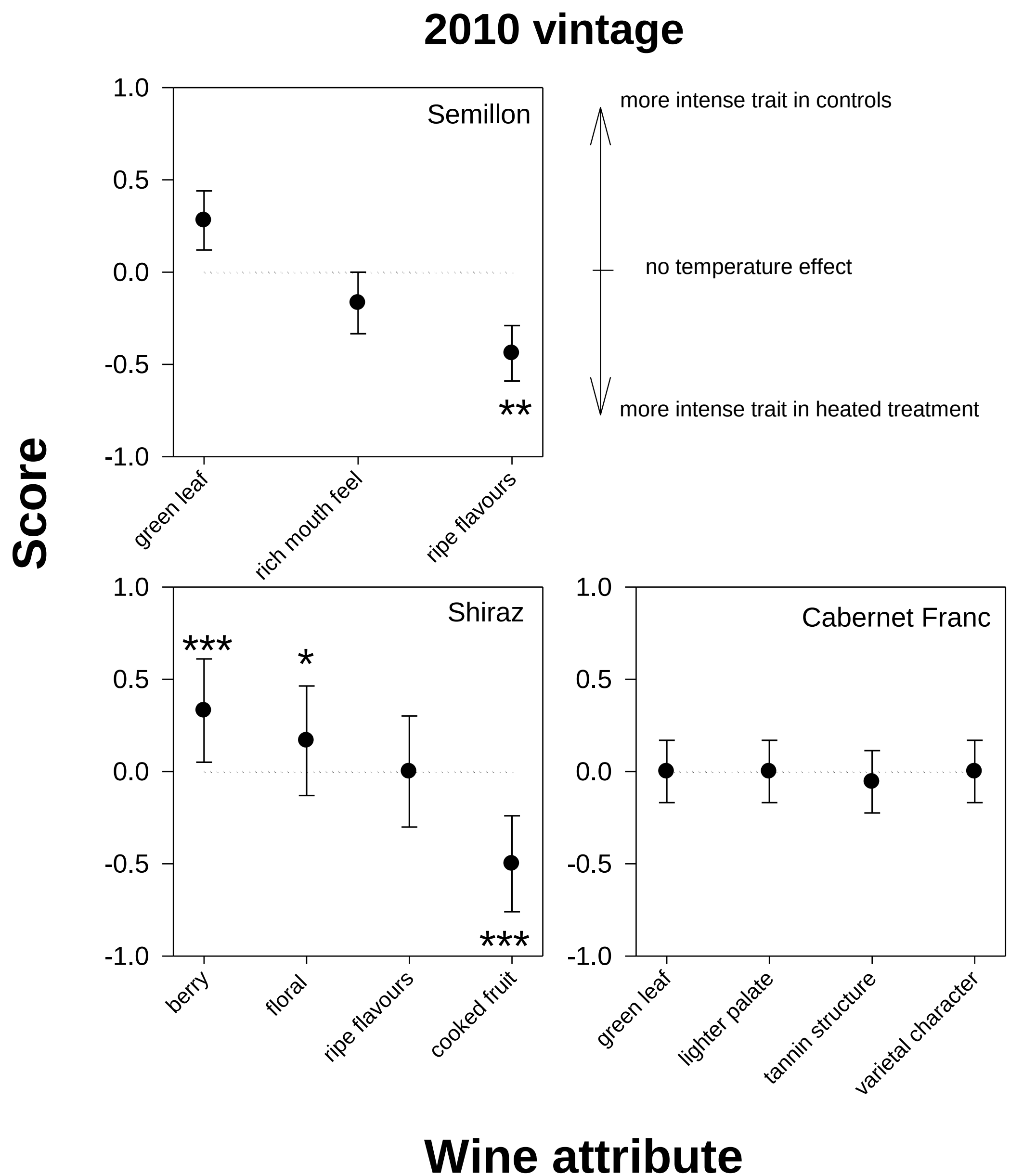
# strong variety x season x temperature effect on wine sensory traits




**Sadras et al. 2012 Austr J Grape & Wine Res 19, 107**

# Conclusions

# In a warmer Barossa

**Nonlinear effect on phenology**

**Smaller than expected effect on maturity (3 days per ºC)**

**Asymmetric effect on yield mediated by bunch number**
46% reduction to 177% increase

**Apparent depletion of starch in trunks?**

**Larger, more open stomata; ↑ leaf transpiration and photosynthesis per unit leaf area**

**Variety-dependent responses (pH, TA)**

**Decoupling of berry traits and wine attributes**

# Can we shift phenology and restore berry and wine balance with late pruning?

By Paul Petrie, this meeting

# questions, comments, report:
## victor.sadras@sa.gov.au

**A window into hotter and drier futures:**

**phenological shifts and adaptive practices**

**Final Report to Grape and Wine**

**Research & Development Corporation**

**Project Number: SAR 0901**

**1 July 2009 – 30 June 2012**

**Victor Sadras, Martin Moran and Paul Petrie**

December 2012

# Thank you