1st Mediterranean Forum for PhD Students and Young Researchers

Designing Sustainable Agricultural and Food Production Systems
under Global Changes in the Mediterranean
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Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality

Kizildeniz T*[1], Pascual I[1], Irigoyen J J[1], Morales F[2]

[1] Grupo de Fisiología del Estrés en Plantas (Dpto. de Biología Ambiental), Unidad Asociada al CSIC, EEAD, Zaragoza e ICVV, Logroño. Facultades de Ciencias y Farmacia, Universidad de Navarra, Irunlarrea 1, 31008, Pamplona, Spain

[2] Estación Experimental de Aula Dei (EEAD). CSIC. Dpto. Nutrición Vegetal. Apdo. 13034. 50080. Zaragoza, Spain

* Speaker and corresponding author: **tkizildeniz@alumni.unav.es**

1. Introduction

- Climate change
- Effects of climate change
  - Direct
  - Indirect
- Why Grapevine? Why Tempranillo grapevines?
- Effects of climate change in Mediterranean area.
- Aim

2. Materials and Methods

- Climate change scenarios simulation
  - Temperature Gradient Greenhouses (TGG)
- Experimental design
- Parameters:
  - Phenology
  - Yield
  - Berry Must Quality (Technological and Phenolic Maturity)

3. Results and discussion

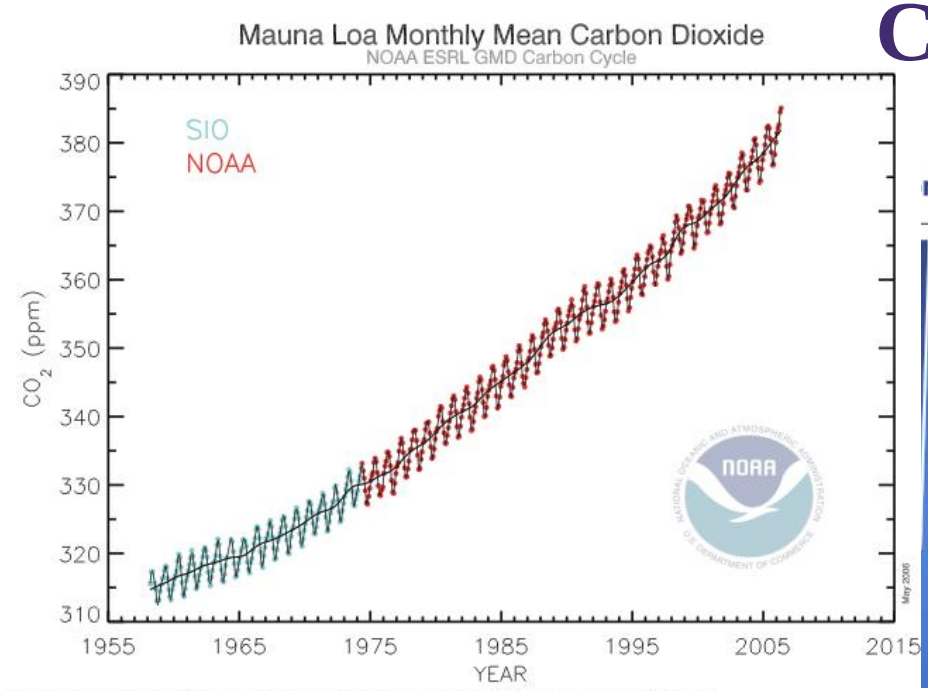
- Phenology-Yield-Berry Quality

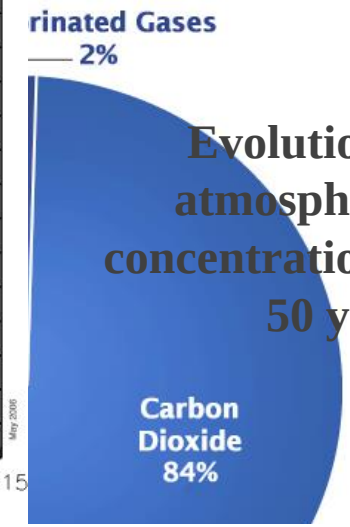
4. Conclusions

Climate Change

- An effect of human activities
- Major ecological, social and economic problem of the planet.
  - Effects:
    - Increasing temperature (1.4 to 5.8°C)
    - Widespread melting of snows and ice
    - Rising global sea levels
    - Decreasing rainfall
    - Changing species distribution
    - Plant vulnerability and mortality
    - Affecting crops, etc.
  - Associated directly and indirectly to:
    - ➢ Elevated CO_2
    - ➢ Temperature increase

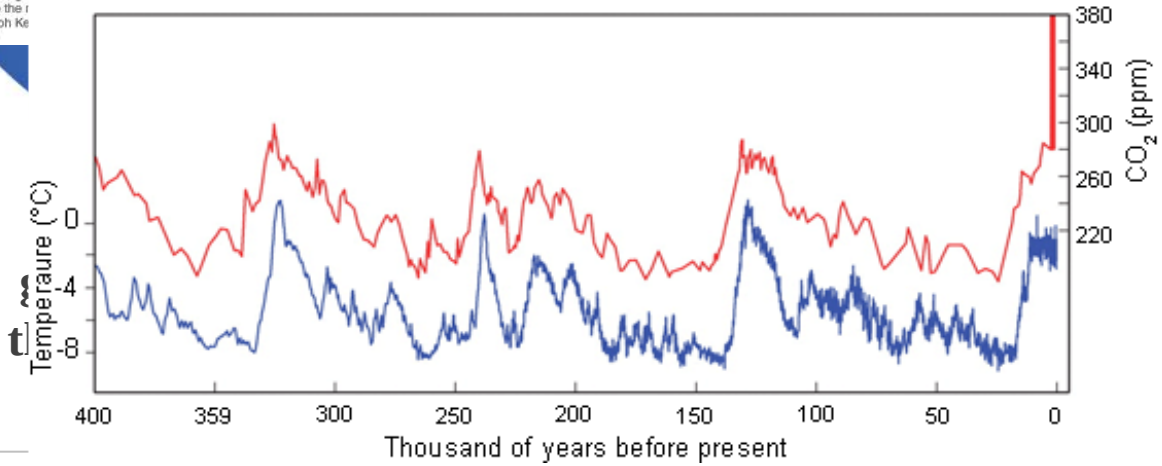
Climate Change





Evolution of the atmospheric CO_2 concentration in the last 50 years

Evolution of the atmospheric CO_2 concentration and temperature during the last 400,000 years (Ice cores, Antartica)

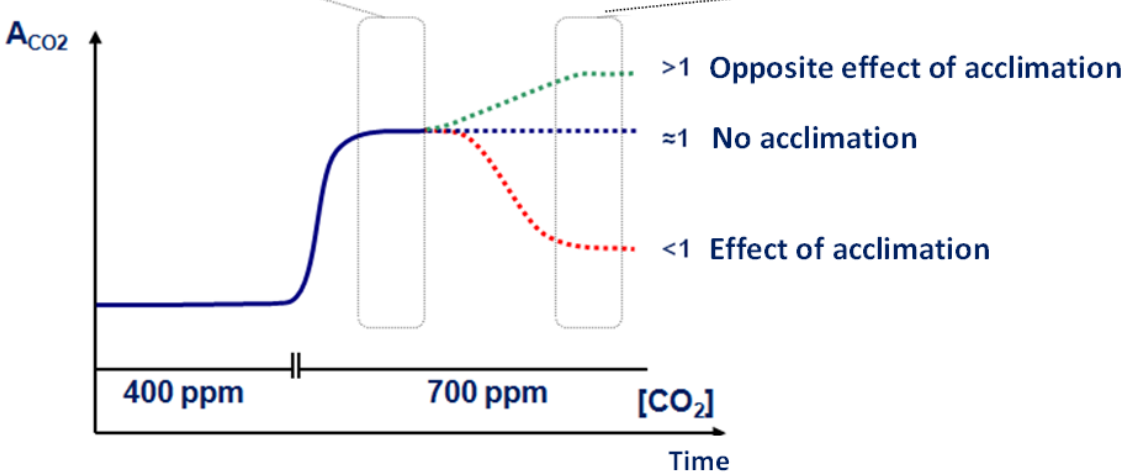


Direct Effects of Elevated CO_2

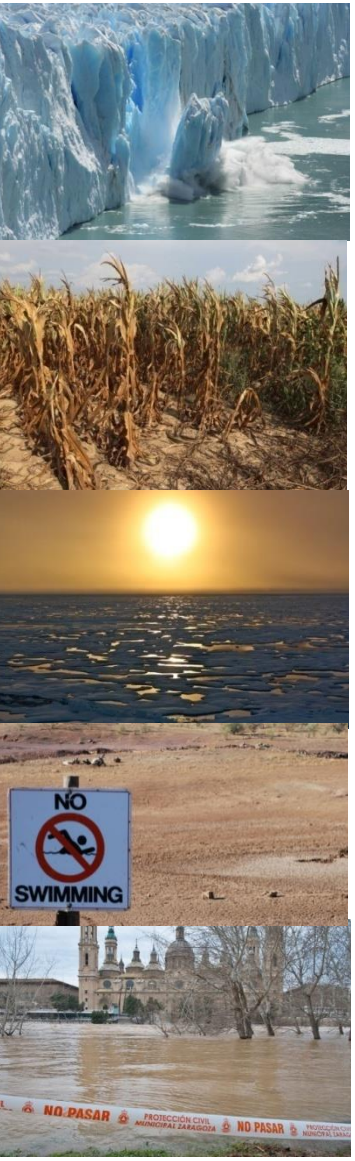
In the short time period: Increasing photosynthesis and growth.

In the long time period: Decline of photosynthesis → Acclimation

$$\text{Effect of acclimation} = \frac{A_{CO2}\ (\text{plants grown at elevated } CO_2 \text{ and measured in elevated } CO_2)}{A_{CO2}\ (\text{plants grown at ambient } CO_2 \text{ and measured in elevated } CO_2)}$$



Bunce *et al.*, 2000



Indirect Effects of Elevated CO_2

- Increasing of :
  - Temperature
  - Plant Metabolism
  - Plant Growth

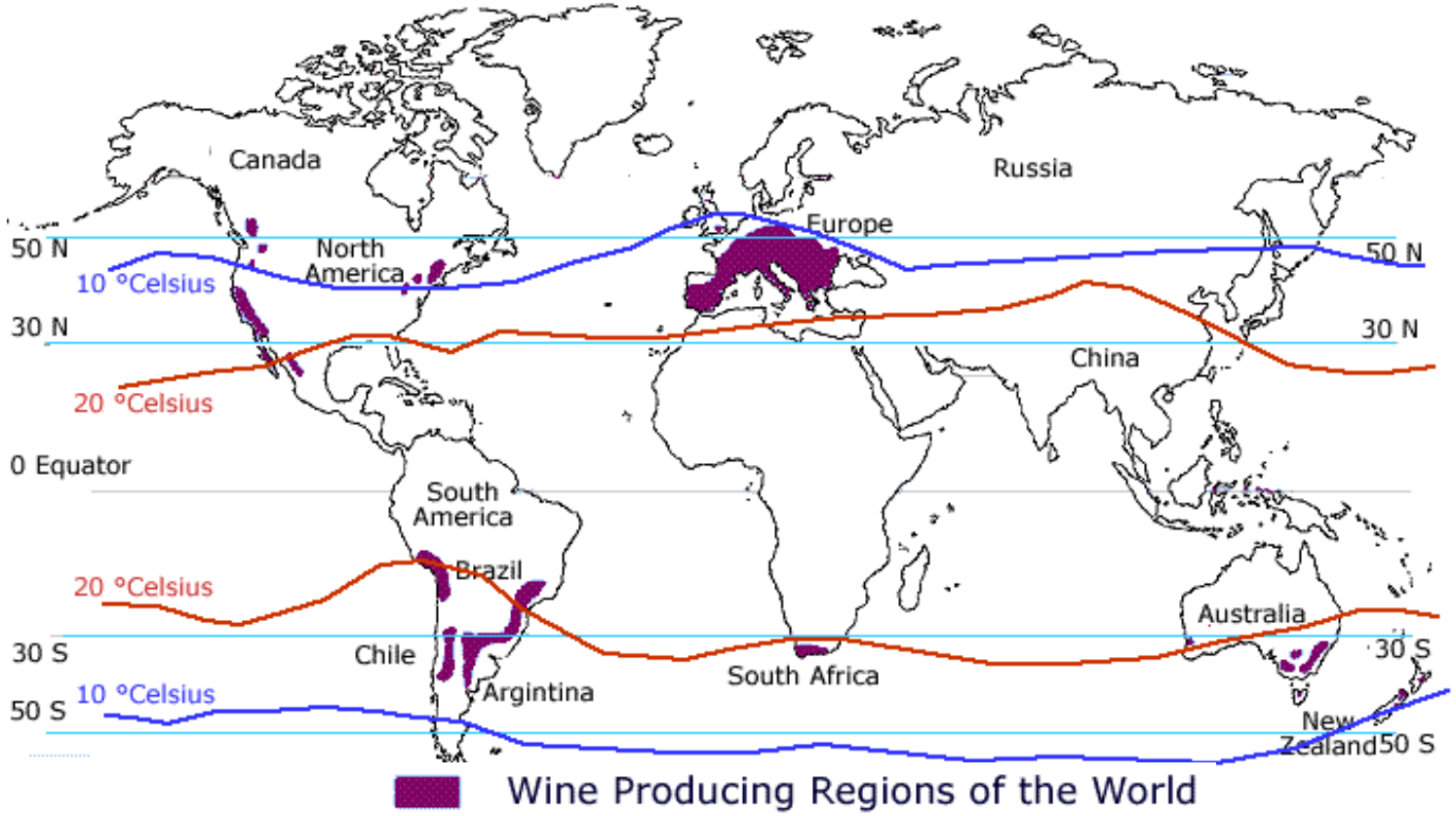
- In the cold areas, the temperature can be close to optimum temperature of growth.

- In the warm areas, temperature increase can exceed the optimum temperature and affect physiological processes.

- Changing the duration of seasons.
- Changing phenology.

Why grapevines?

Grapevine is an economically important crop worldwide that occupies the largest area of cultivated hectares.



OIV 2013

Importance of Red and White Tempranillo grapevines

- Red Tempranillo is one of most commonly grown varieties in the vineyards of many growing areas of Spain, Mexico, New Zealand, South America, South Africa, Australia, Turkey and Canada.

- White Tempranillo is a natural mutant emerged from the red variety, that was found on vines in a vineyard Red Tempranillo Rioja in 1988.

- Therefore it is more widespread in many areas of the planet, so the conclusions that can be obtained from the study will be of great impact on viticulture.

- White wine obtained from the processing of these grapes has been a great interest to the region of La Rioja, Spain.

(Pictures from Juana Martínez, del ICVV, Logroño)

Effects of Climate Change in Mediterranean Area

- In the Mediterranean area, crop **yield** and **quality** changes are occurring due to climate change, associated to **atmospheric CO_2 concentration** increases, enhanced **temperatures** and **scarce water availability** *(Tubiello et al., 2000)*.

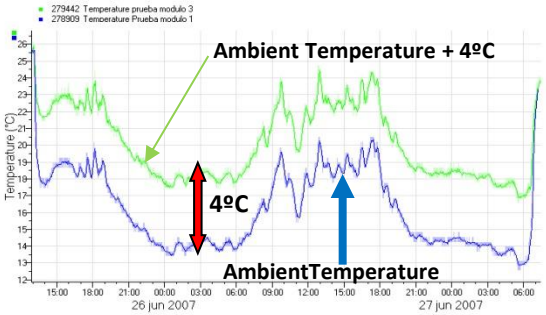
- Previously, we reported, within the three above mentioned factors, **a drastic reduction of vegetative growth** under **drought** conditions in fruit-bearing cuttings of two grapevine (*Vitis vinifera L.)* cultivars (Red and White Tempranillo)*(Kizildeniz et al., 2015)*.

- Therefore, climate change scenarios and the plant responses is a matter that deserves further investigation.

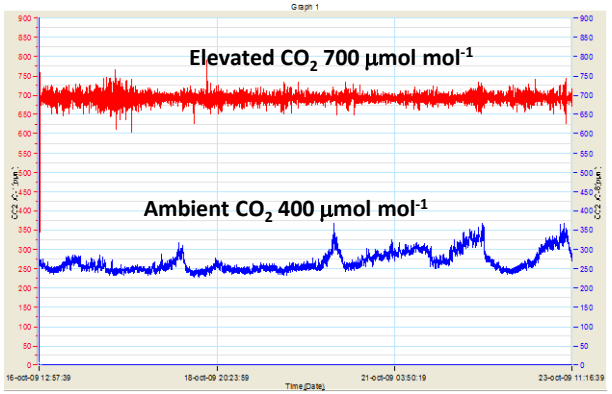
Aim

Assess the effect of climate change factors (elevated CO_2, high temperature and drought) on grapevines (Red and WhiteTempranillo) phenology, yield and berry must quality

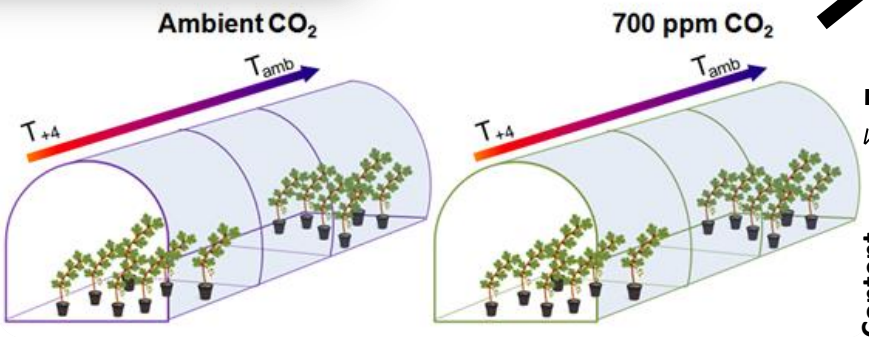
Temperature Gradient Greenhouses (TGG)



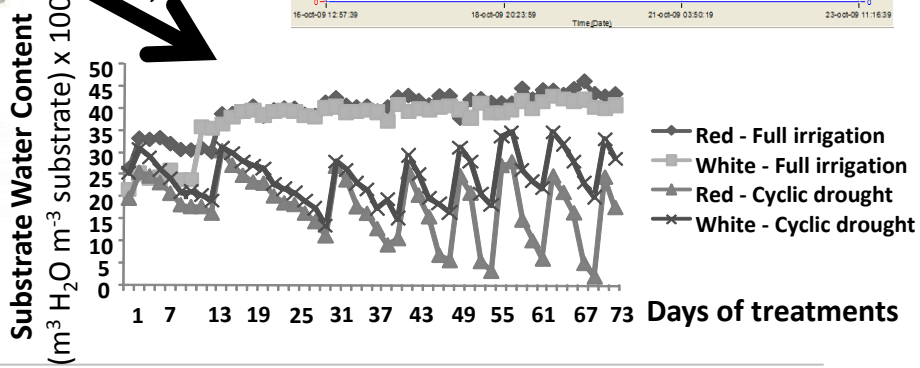
Temperature



CO_2



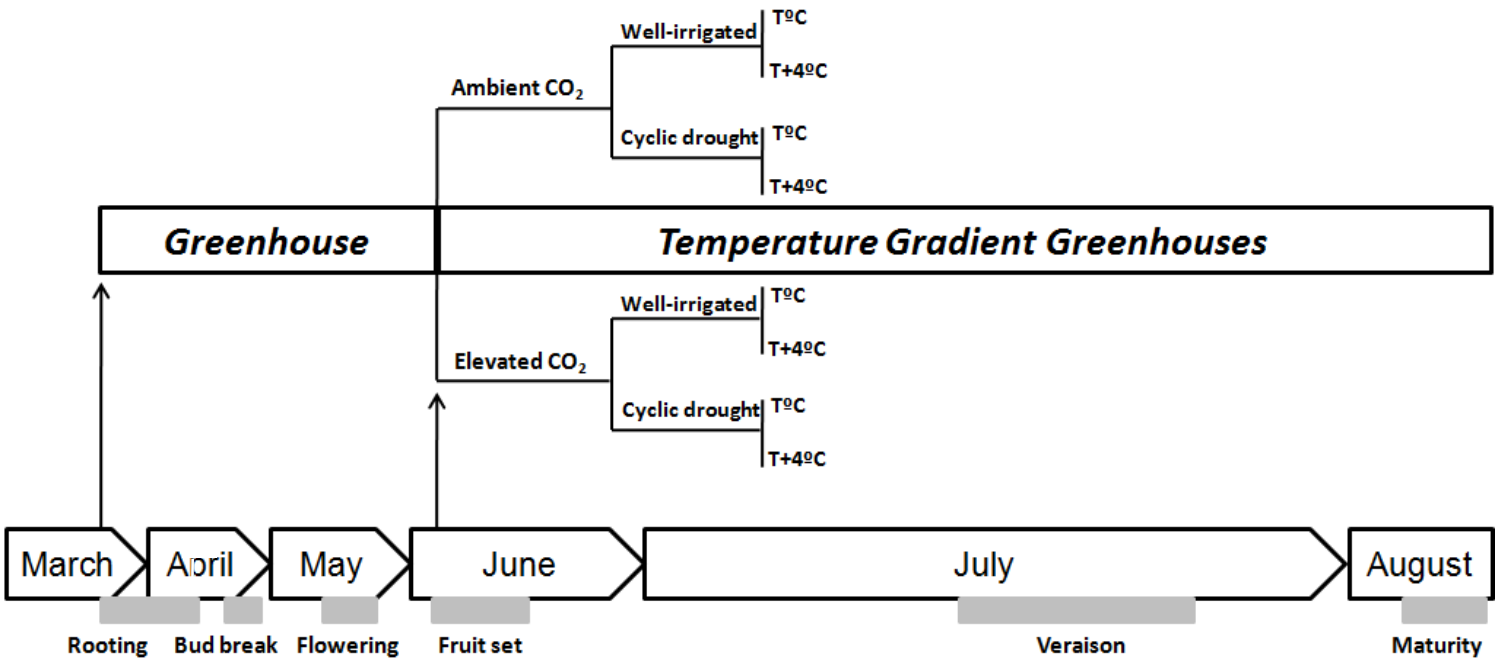
Water availability



Temperature Gradient Greenhouses (TGG)

-Ambient T and Ambient T+ 4ºC
-CO_2 Control (400 and 700 mmol mol^{-1})
-Control of water availability (cyclic drought and full irrigation)
-Ilumination (natural intensity and photoperiod)

Experimental Design

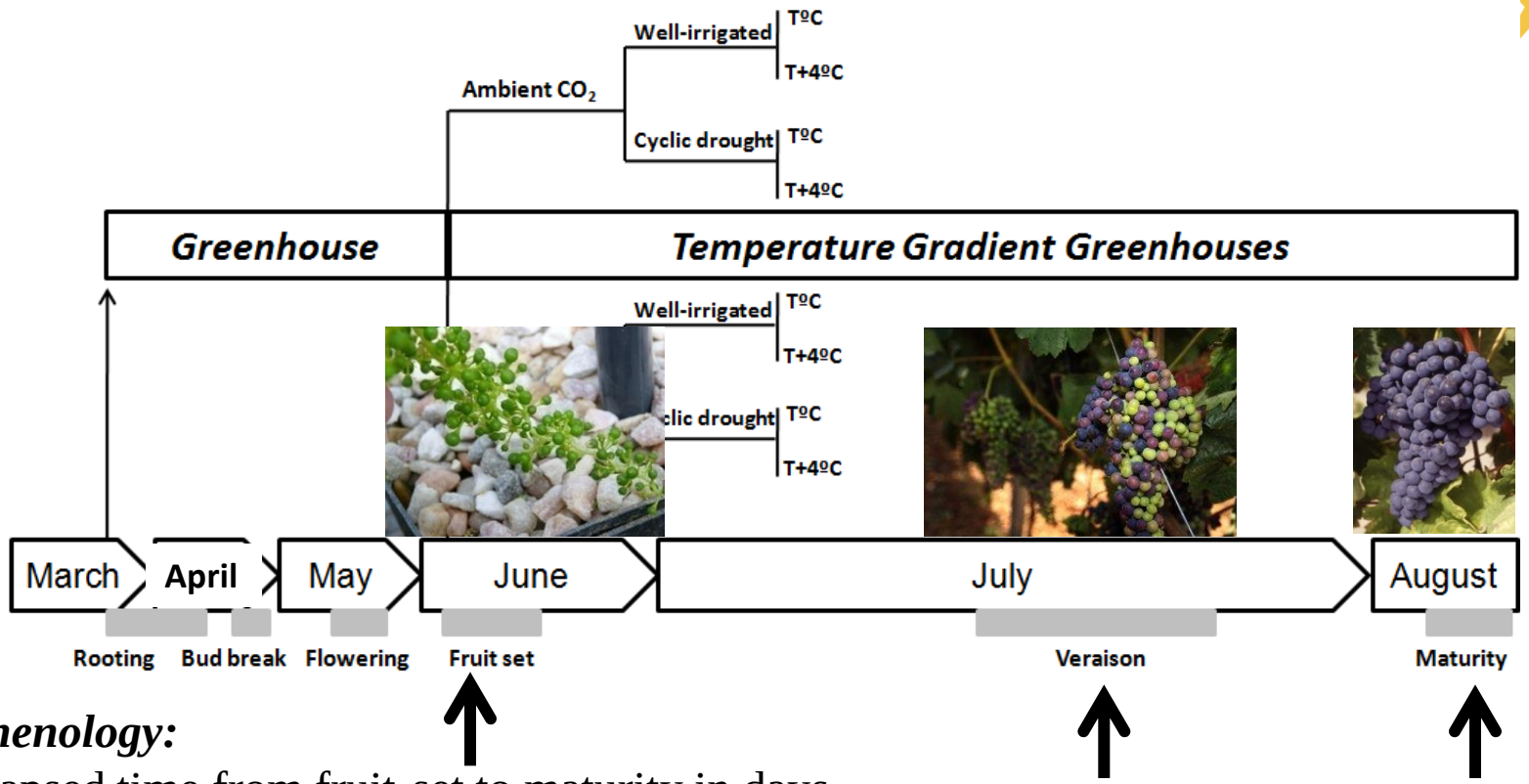


First experiment in 2013

Second experiment (repetition) in 2014

Third experiment (repetition) in 2015

Phenology-Yield-Berry Quality



Phenology:

Elapsed time from fruit-set to maturity in days,
monitoring both the period from fruit-set to veraison and from veraison to maturity.

Yield:

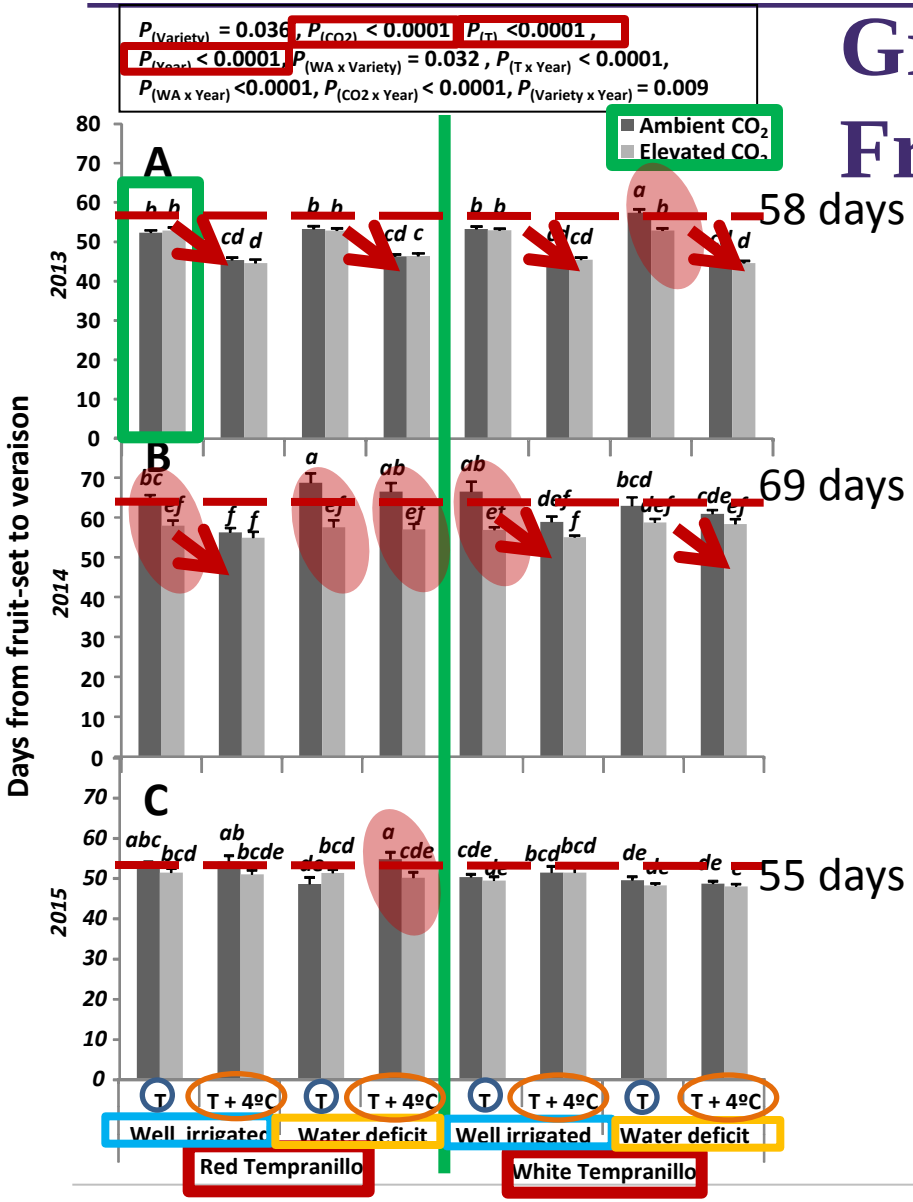
Bunch fresh weight in maturity stage (21-23ºBrix).

Berry quality:

Technological and phenolic maturity parameters were evaluated in maturity stage.

Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality

Grapevine phenology Fruit-set to Veraison



Elevated CO_2 and temperature tented to shorten fruit-set to veraison phenological period (although many changes were not significant).

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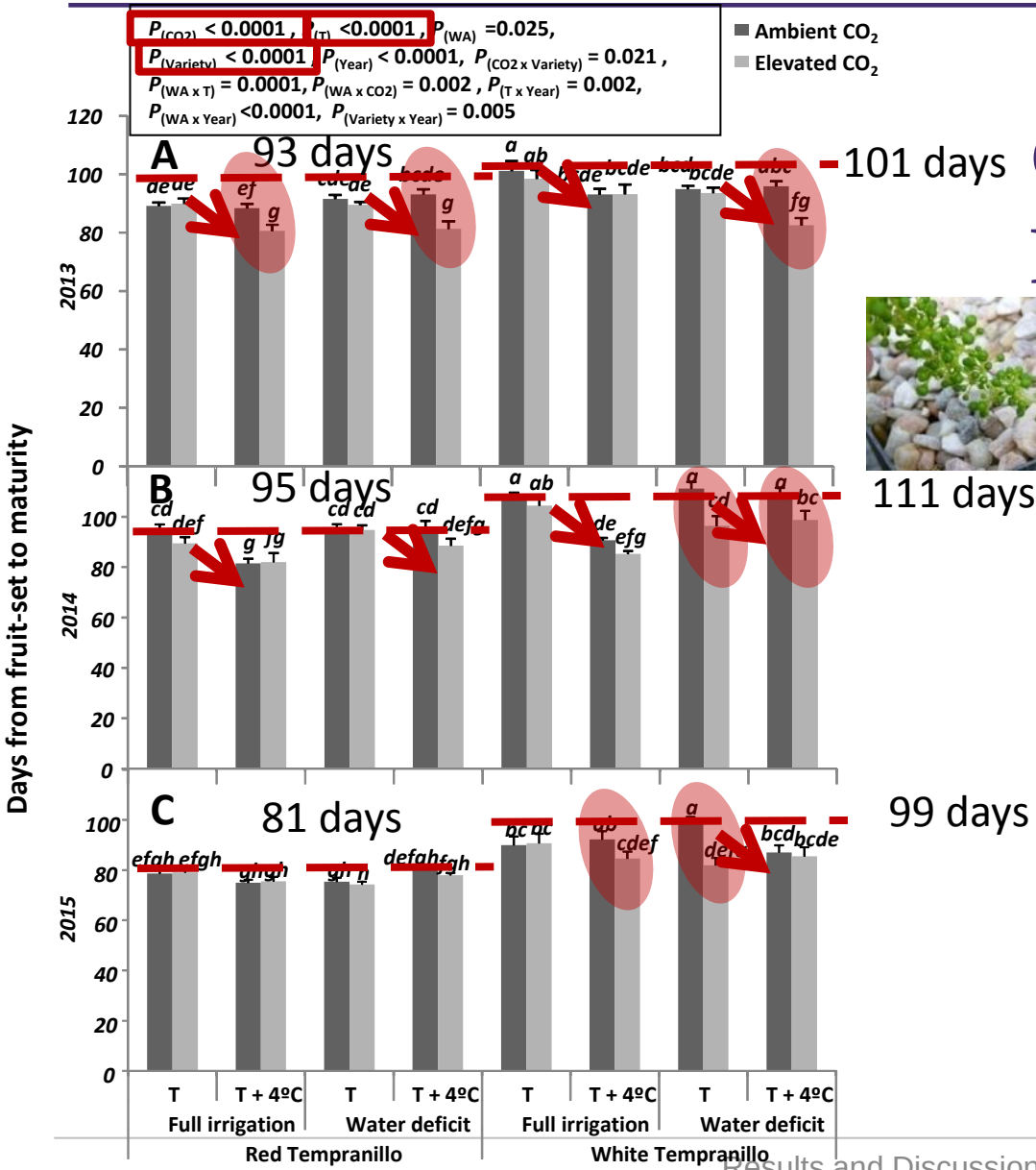
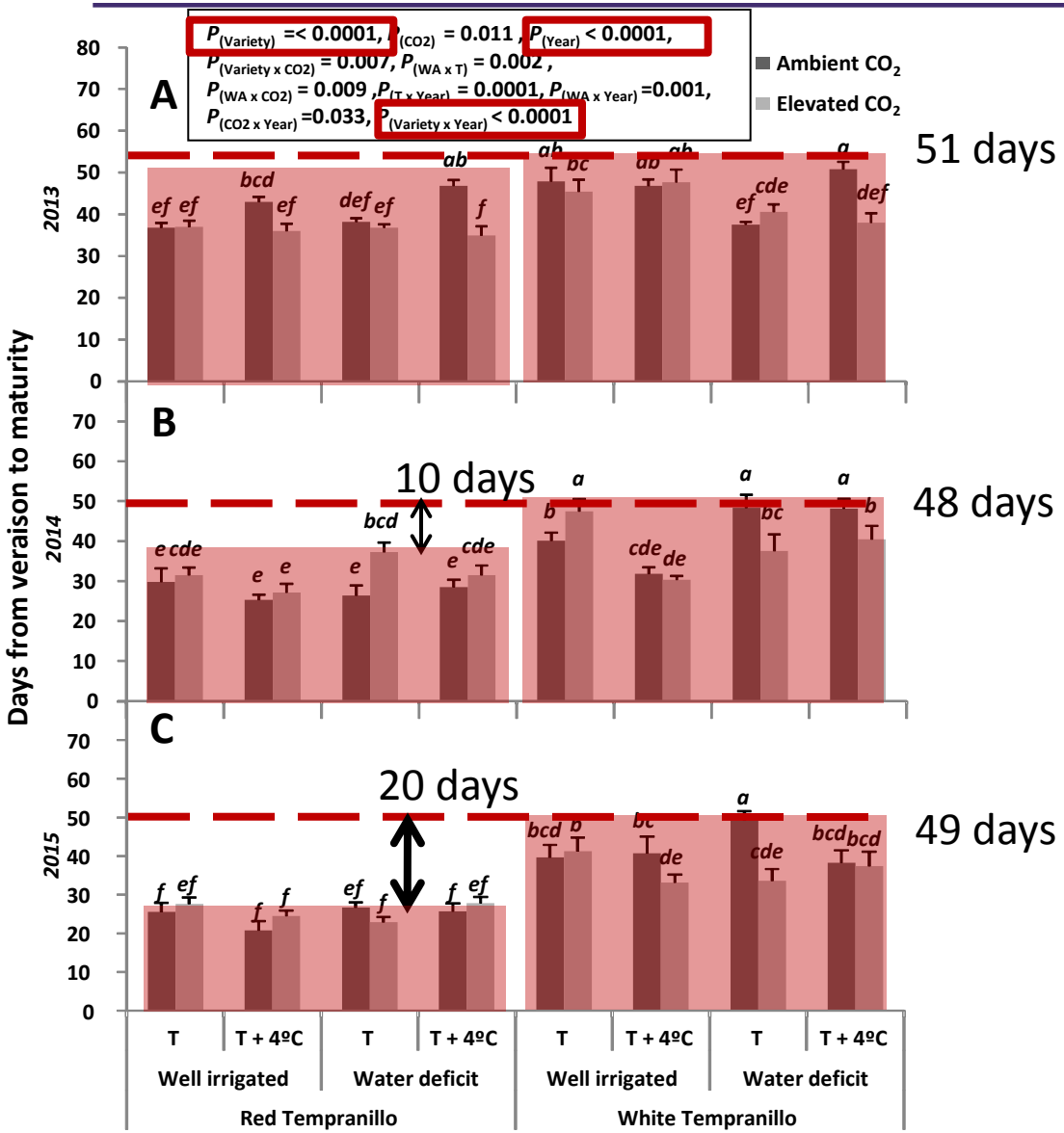


Grapevine phenology Fruit-set to Maturity

Red Tempranillo had consistently shorter phenology than the White one.

Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality



Grapevine phenology Veraison to Maturity

Red Tempranillo had shorter veraison to maturity phenological period than White Tempranillo.

Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality

Grapevine Phenology – ANOVA -

ANOVA P value	Factors	Fruit set to veraison	Veraison to maturity	Fruit set to maturity
Individual effects	*P* (T)	<0.0001 ***	ns	<0.0001 ***
	P (CO_2)	<0.0001 ***	0. 011 **	<0.0001 ***
	P (WA)	ns	ns	0.025 *
	P (Variety)	0.036 *	<0.0001 ***	<0.0001 ***
	P (Year)	<0.0001 ***	<0.0001 ***	<0.0001 ***
Interacting effecs	*P* (Variety x T)	ns	ns	ns
	P (Variety x CO_2)	ns	0.007 **	0.021 **
	P (Variety x WA)	0.032 *	ns	ns
	P (Variety x Year)	ns	<0.0001 ***	0.005 **
	P (T x CO_2)	ns	ns	ns
	P (T x WA)	ns	0.002 **	0.0001 ***
	P (T x Year)	<0.0001 ***	0.0001 ***	0.002 **
	P (CO_2 x WA)	ns	0.009 **	0.002 *
	P (CO_2 x Year)	<0.0001 ***	0.033 *	ns
	P (WA x Year)	<0.0001 ***	0.001 **	<0.0001 ***

Temperature and CO_2 had influences in almost all phenological phases.

Phenology depended on variety and year.

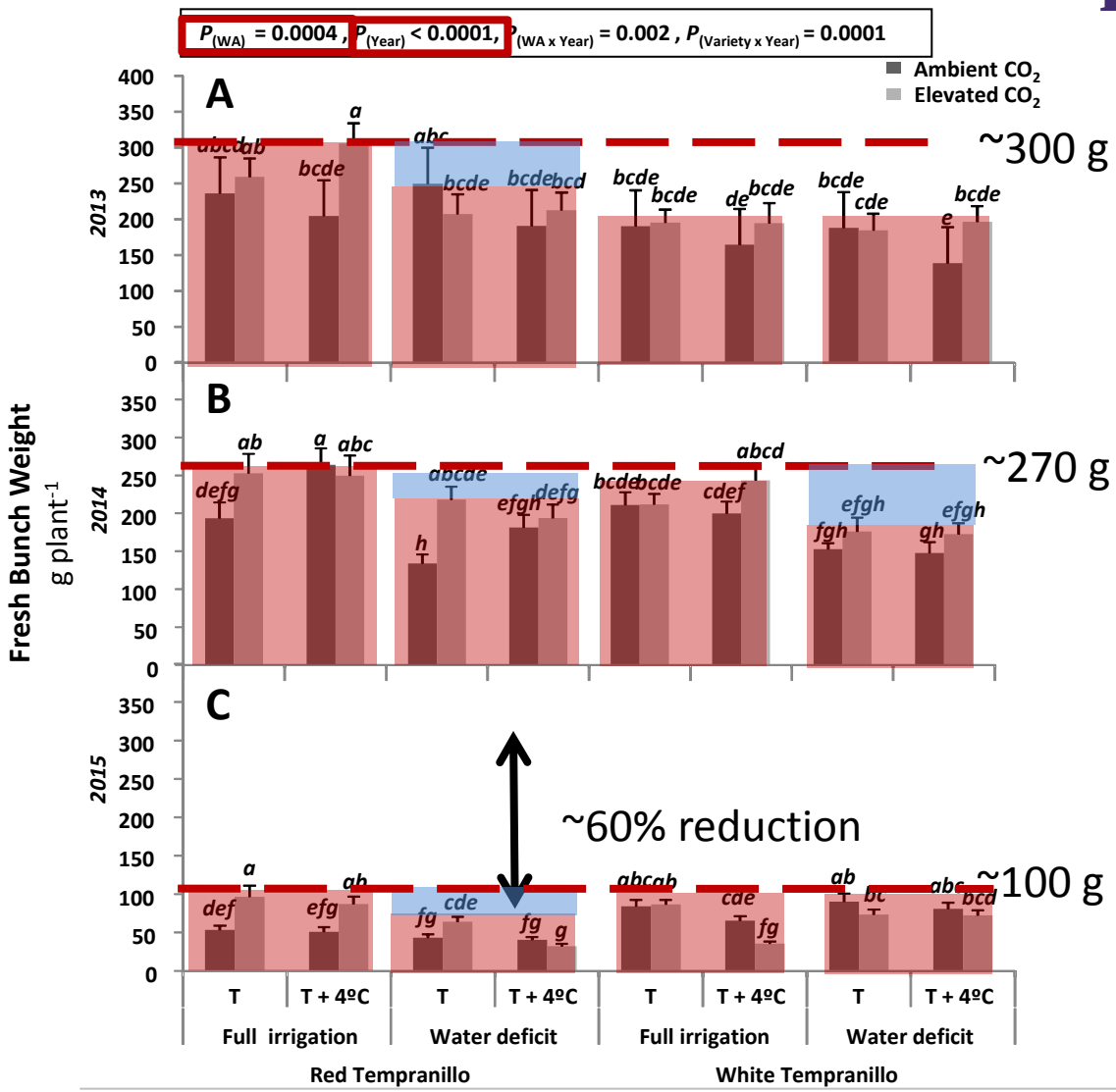
Year factor had influence almost in all parameters.

Water availiablity did not have so huge influence alone.

However it had influence with T and CO_2 after veraison.

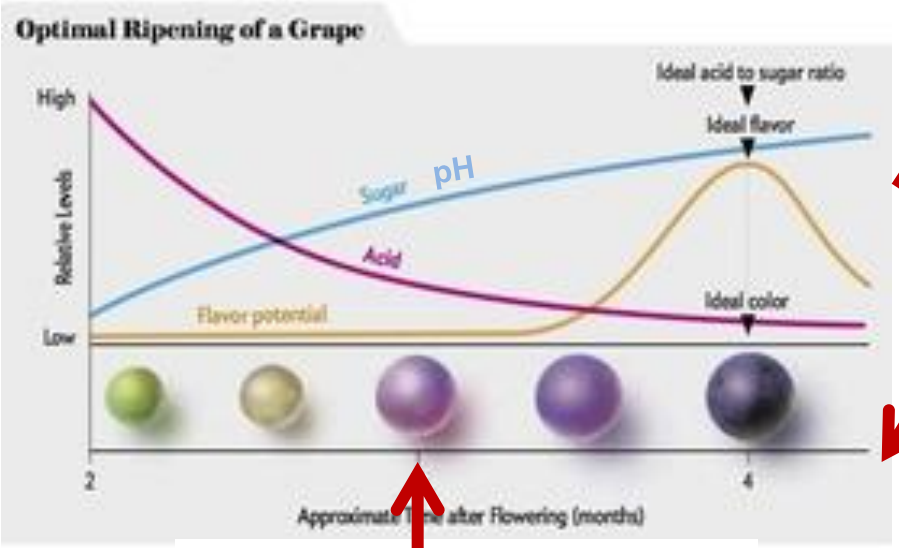
Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality

Grapevine yield

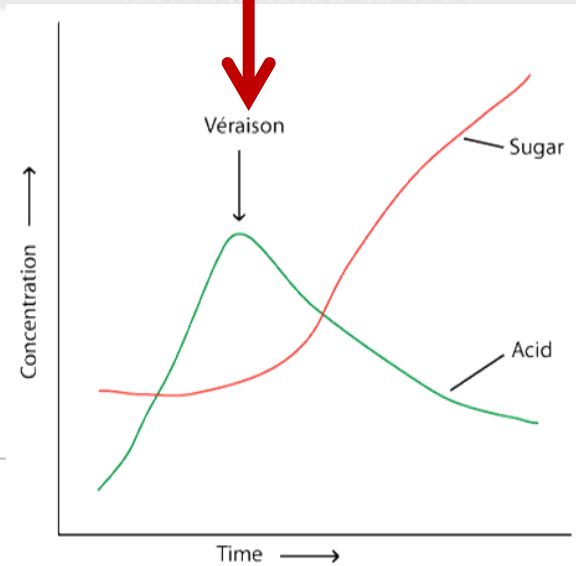


Yield was impacted by drought and year, specially in 2015 due to July heat shocks with a 60%, reduction.

What occurs during the evolution of berry in the quality parameters?



- Sugar and pH
- Acid
(Tartaric and Malic acids)

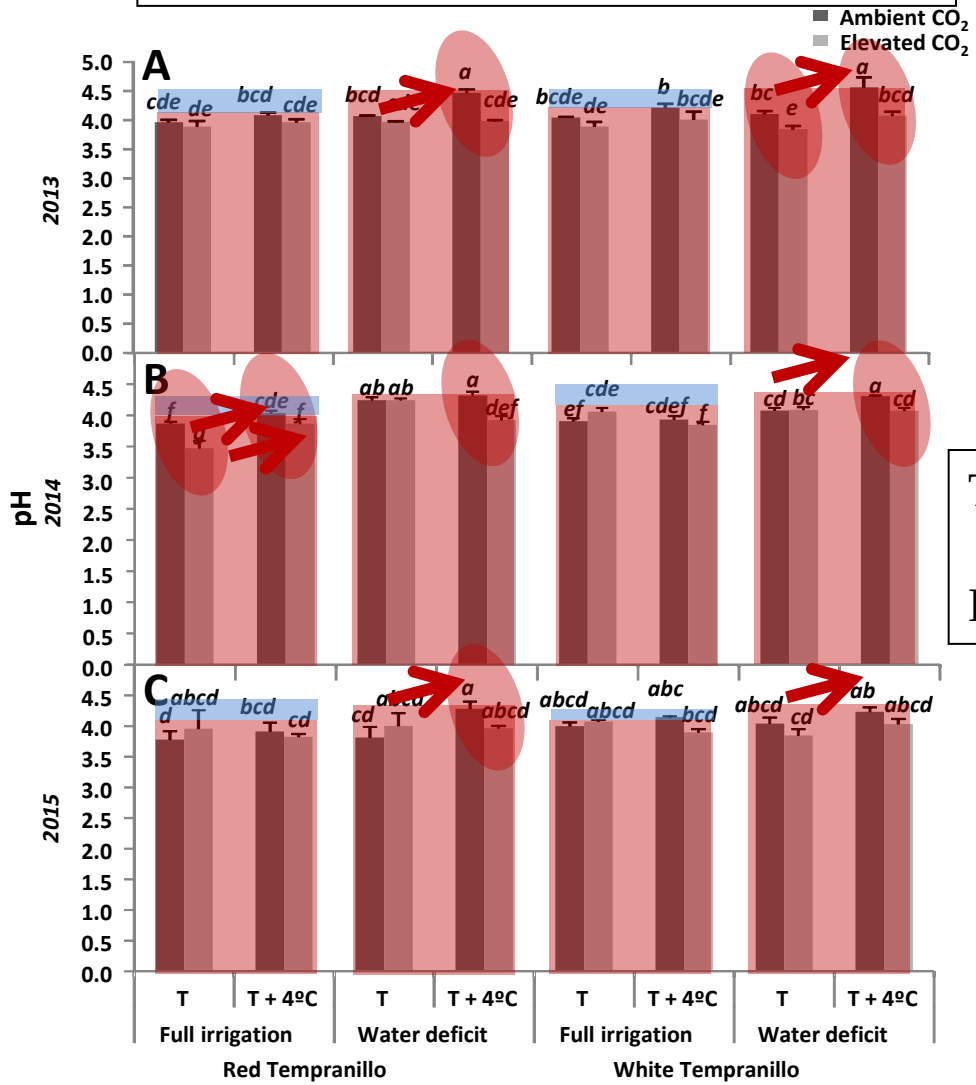


Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality

$P_{(T)} < 0.0001$, $P_{(CO2)} < 0.0001$, $P_{(WA)} < 0.0001$, $P_{(Variety)} = 0.042$, $P_{(WA \times Variety)} = 0.041$, $P_{(T \times CO2)} = 0.0004$, $P_{(WA \times Year)} = 0.01$

pH

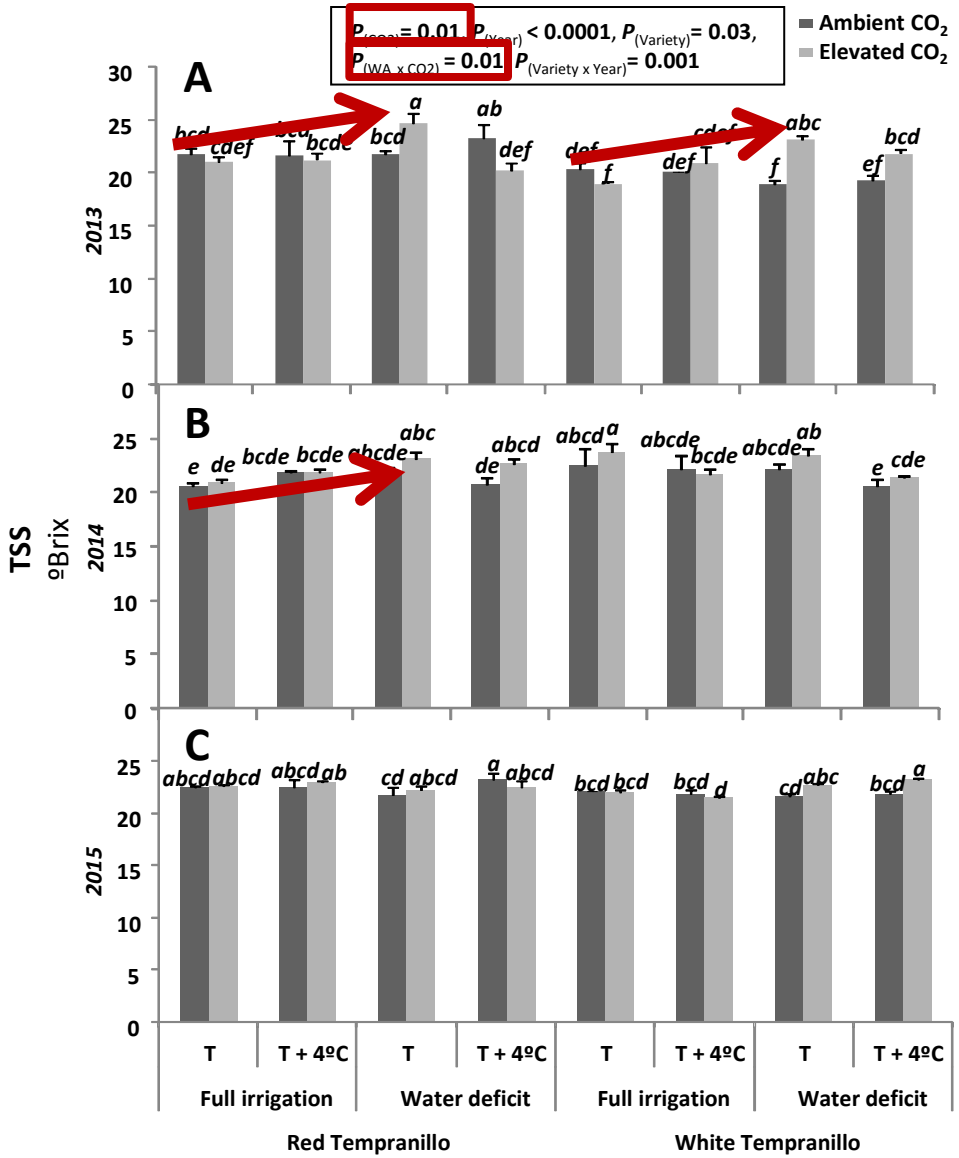
Technological Maturity



Temperature and drought increased must pH.

By the contrary, elevated CO_2 decreased pH.

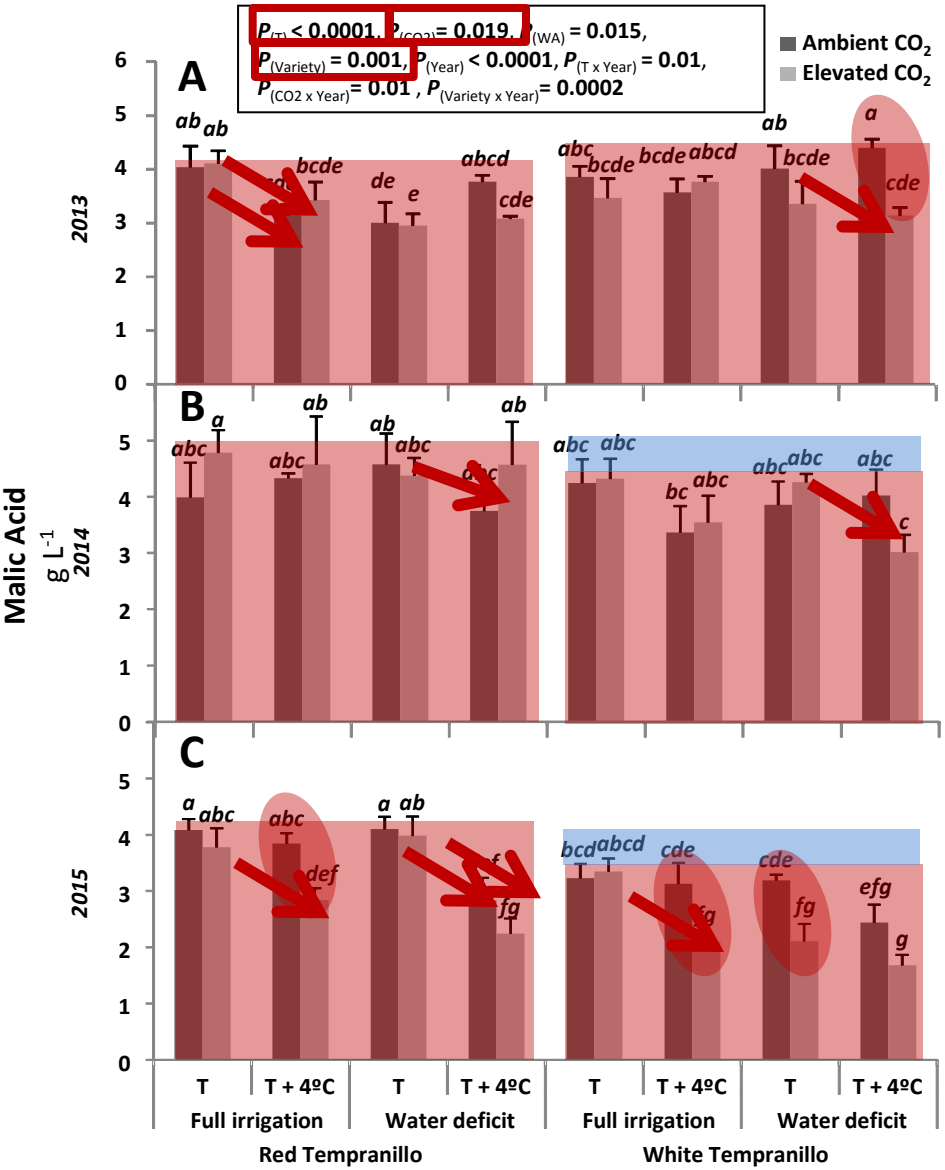
Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality



Technological Maturity Total Soluble Sugars (TSS-°Brix)

TSS were increased by both: only elevated CO_2(**) and elevated CO_2 - drought interaction (**).

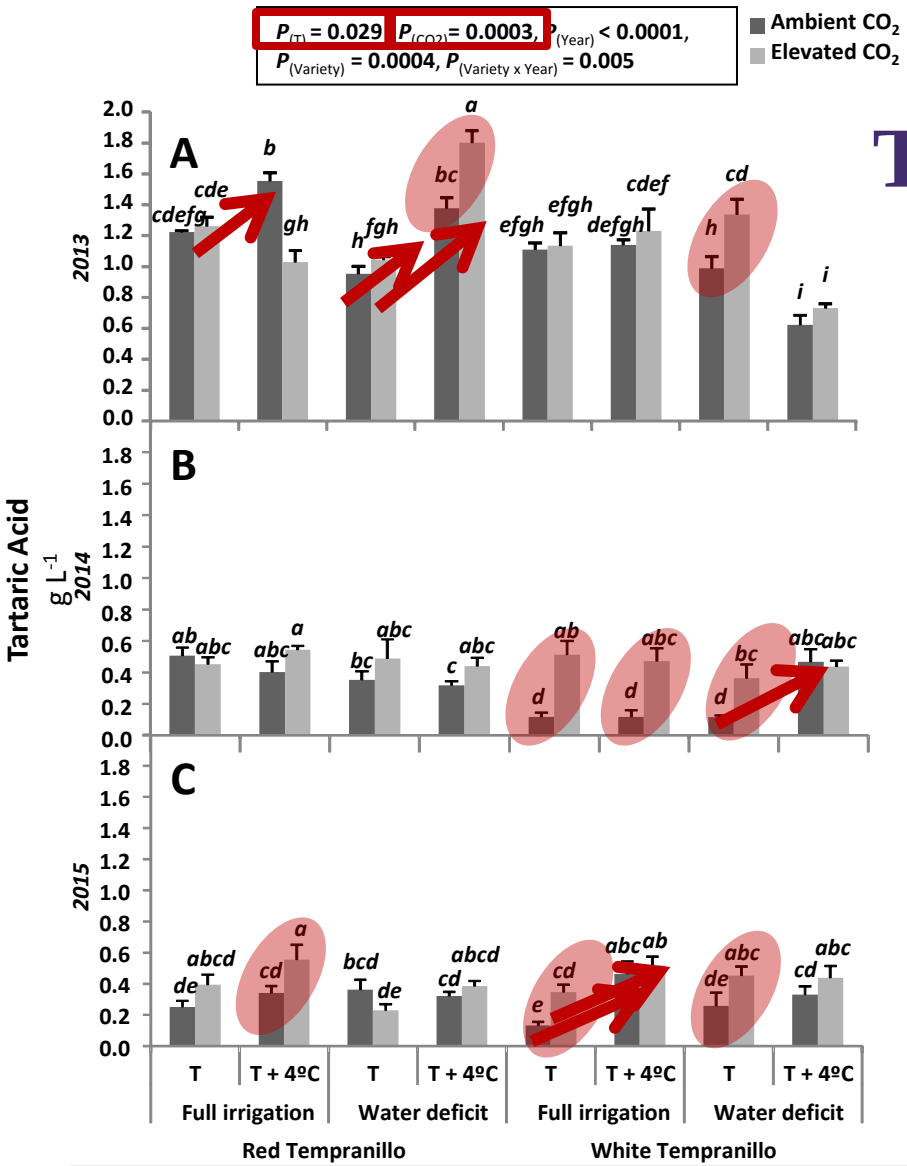
Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality



Malic Acid Technological Maturity

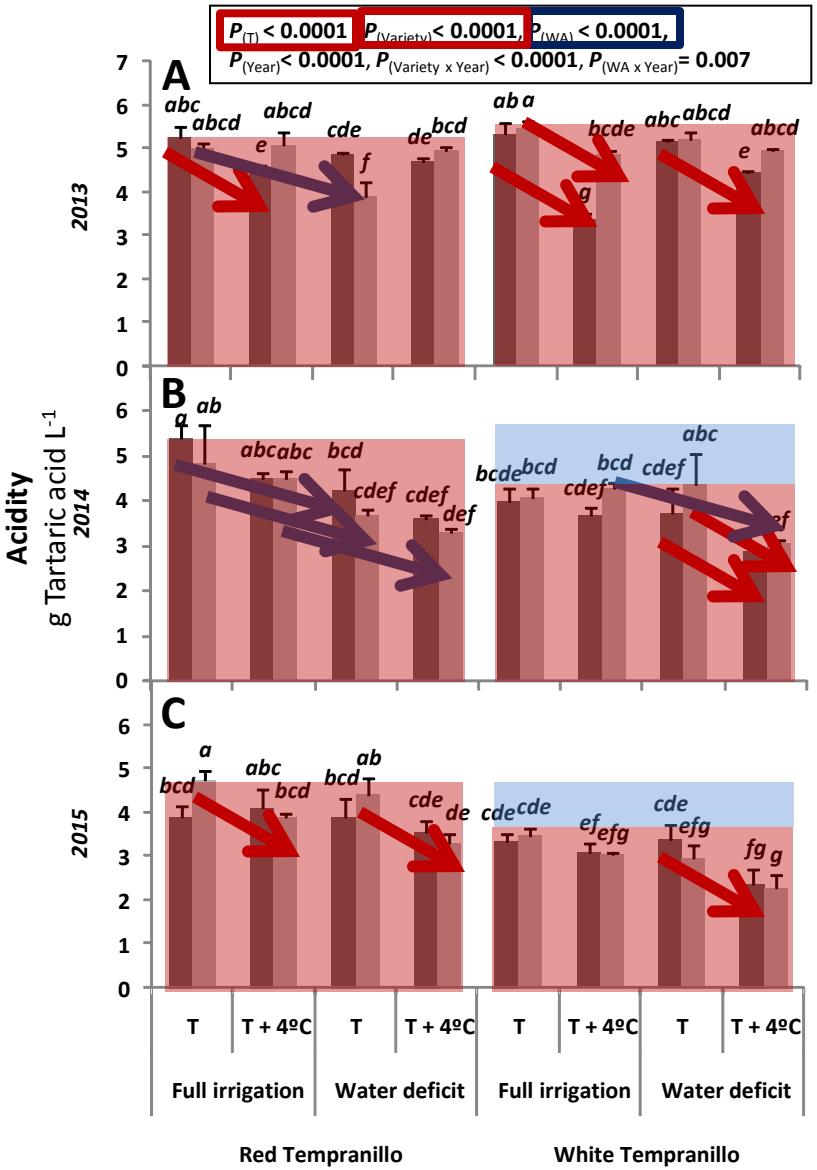
Malic acid decreased significantly by temperature increase (***) and less significantly by elevated CO_2 (*).

Tartaric Acid Technological Maturity



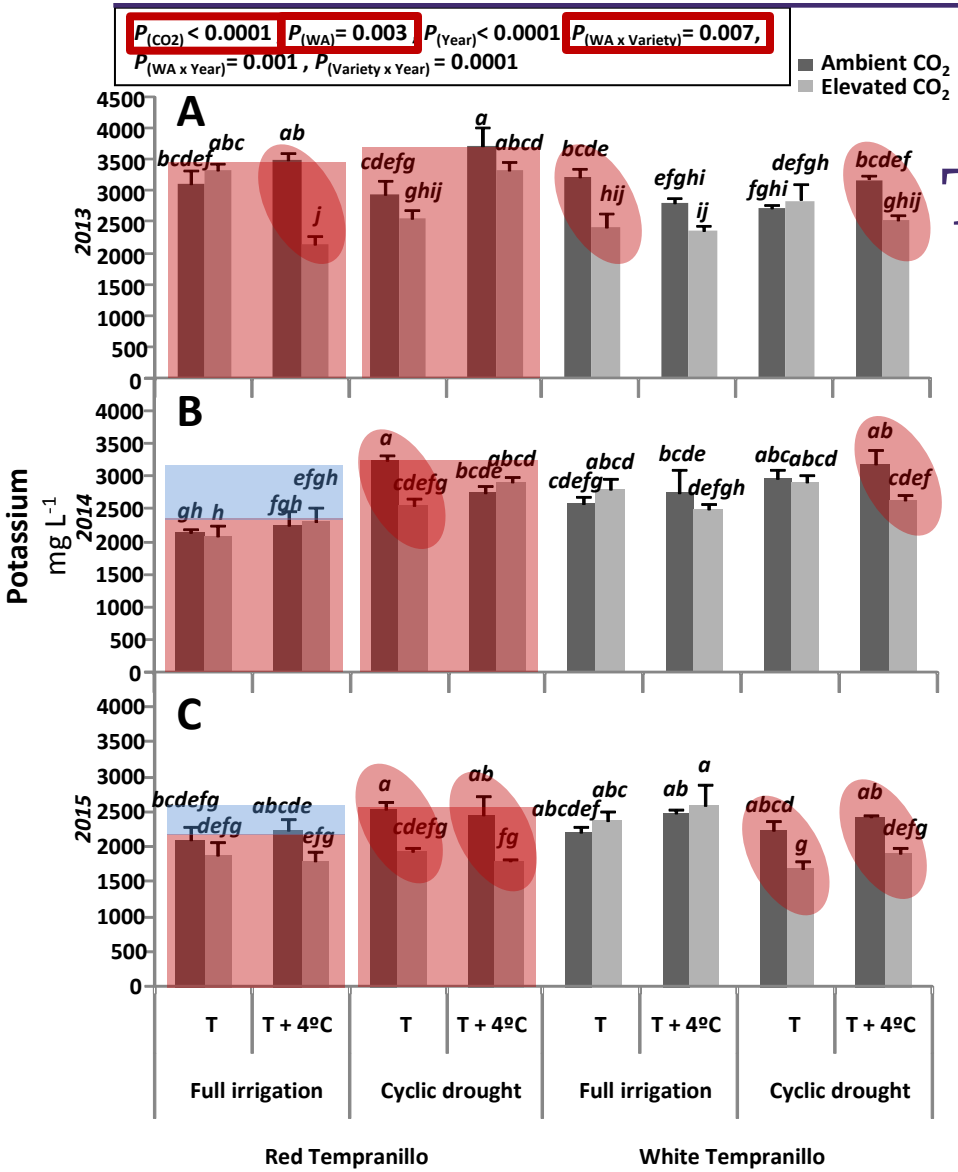
Tartaric acid increased significantly by elevated CO_2 and less significantly by elevated temperature.

Titratable Acidity
Technological Maturity



Acidity decreased significantly by elevated temperature and drought, having White Tempranillo less acidity than Red one.

Climate change scenarios simulated in temperature gradient greenhouses (TGGs) affect grapevine phenology, yield and berry quality



Potassium Technological Maturity

Potassium decreased significantly by elevated CO_2 (***).

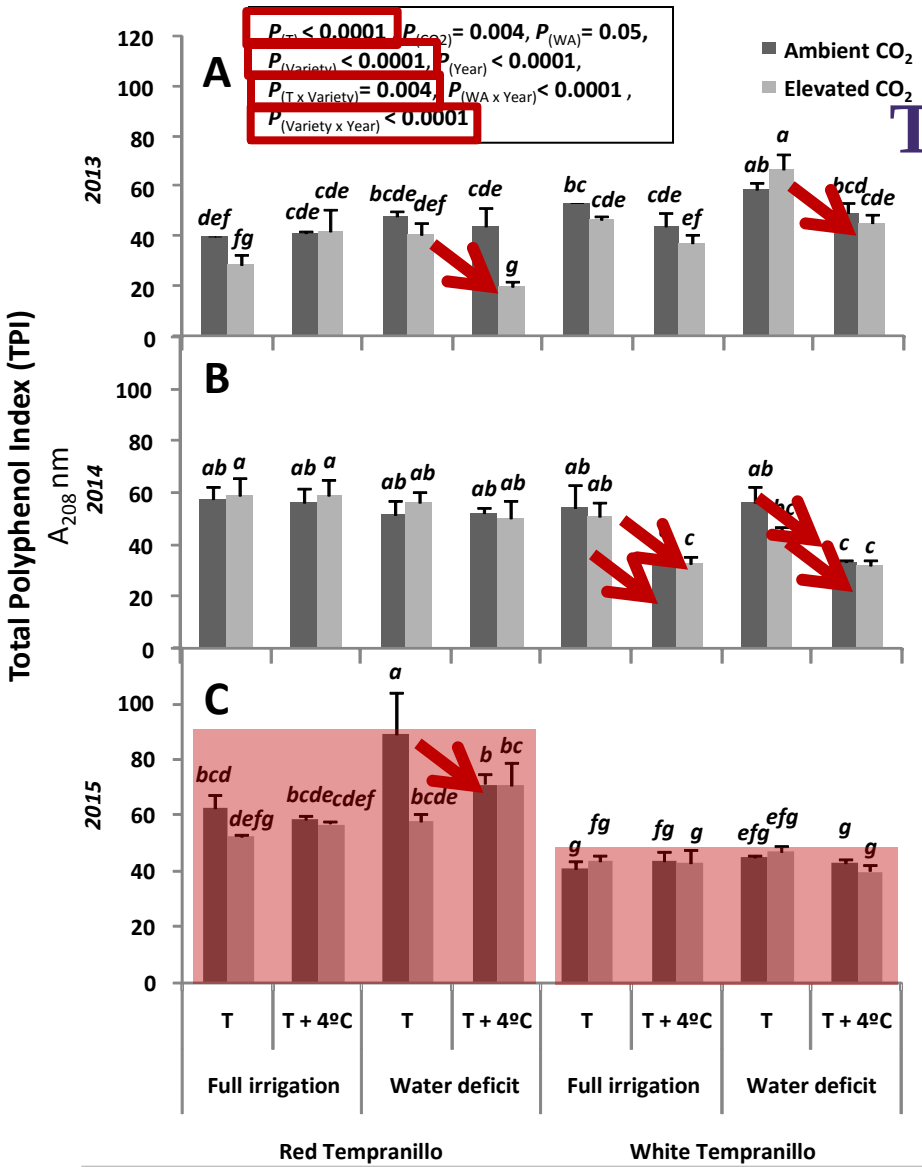
Drought (**), especially in Red Tempranillo, incresed potassium.

Technological maturity – ANOVA-

ANOVA *P* value	Factors	Brix	pH	Acidity	Tartaric acid	Malic acid	Potassium
Individual effects	**P** (T)	ns	**<0.0001**	**<0.0001**	**0.029**	**<0.0001**	ns
	P (CO2)	**0.01**	**<0.0001**	ns	**0.0003**	**0.019**	**<0.0001**
	P (WA)	ns	**<0.0001**	**<0.0001**	ns	**0.015**	**0.003**
	P (Variety)	**0.03**	**0.042**	**<0.0001**	**0.0004**	**0.001**	**<0.0001**
	P (Year)	**< 0.0001**	ns	**<0.0001**	**<0.0001**	**<0.0001**	ns
Interacting effecs	**P** (Variety x T)	ns	ns	ns	ns	ns	ns
	P (Variety x CO2)	ns	ns	ns	ns	ns	ns
	P (Variety x WA)	ns	**0.041**	ns	ns	ns	**0.007**
	P (Variety x Year)	**0.001**	ns	**<0.0001**	**0.005**	**0.0002**	**0.0001**
	P (T x CO2)	ns	**0.0004**	ns	ns	ns	ns
	P (T x WA)	ns	ns	ns	ns	ns	ns
	P (T x Year)	ns	ns	ns	ns	**0.01**	ns
	P (CO2 x WA)	**0.01**	ns	ns	ns	ns	ns
	P (CO2 x Year)	ns	ns	ns	ns	**0.01**	ns
	P (WA x Year)	ns	**0.01**	**0.007**	ns	ns	**0.001**

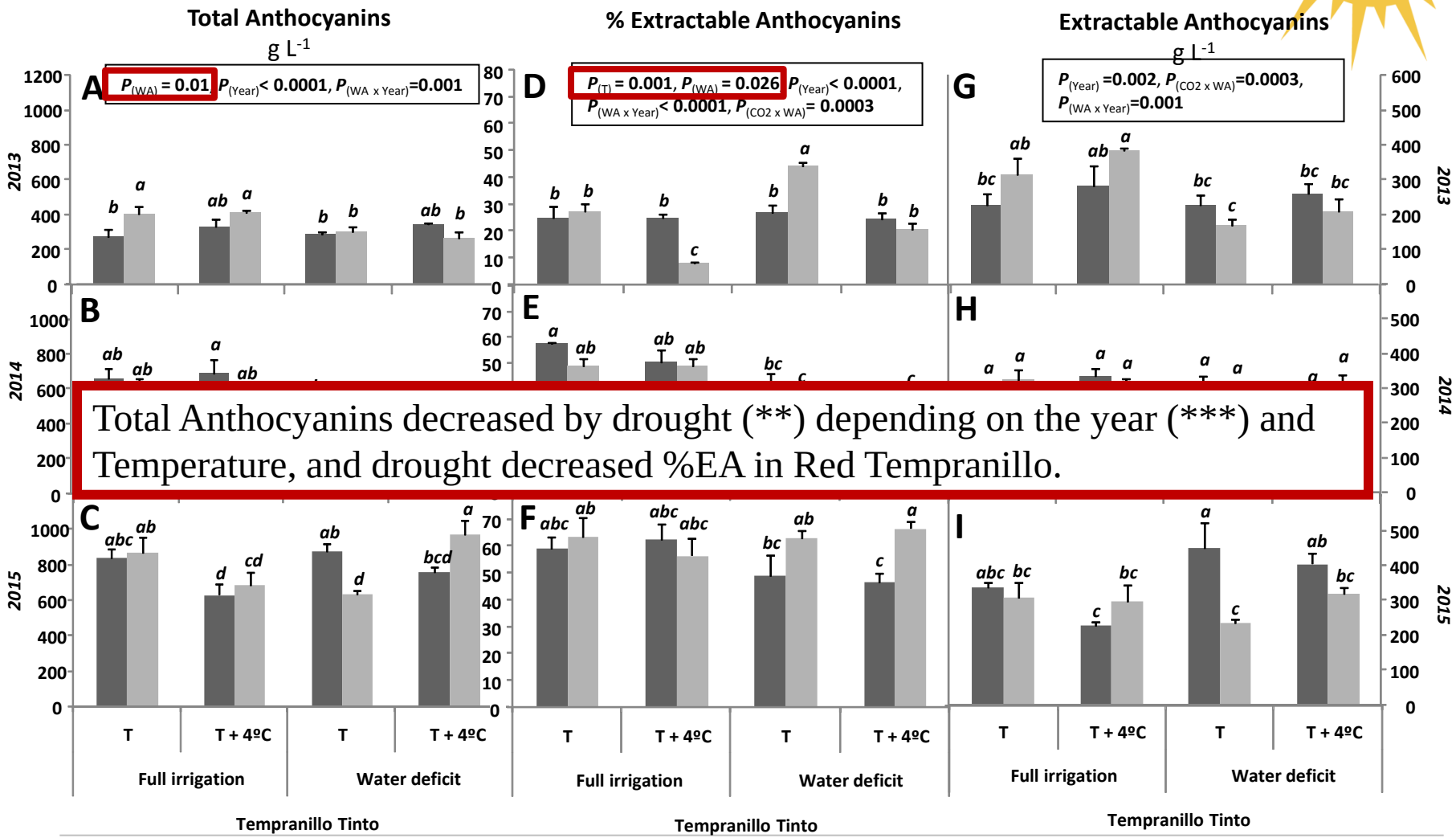
Individual effects have more influence on primary metabolites.

Phenolic Maturity
Total Polyphenol Index (TPI)



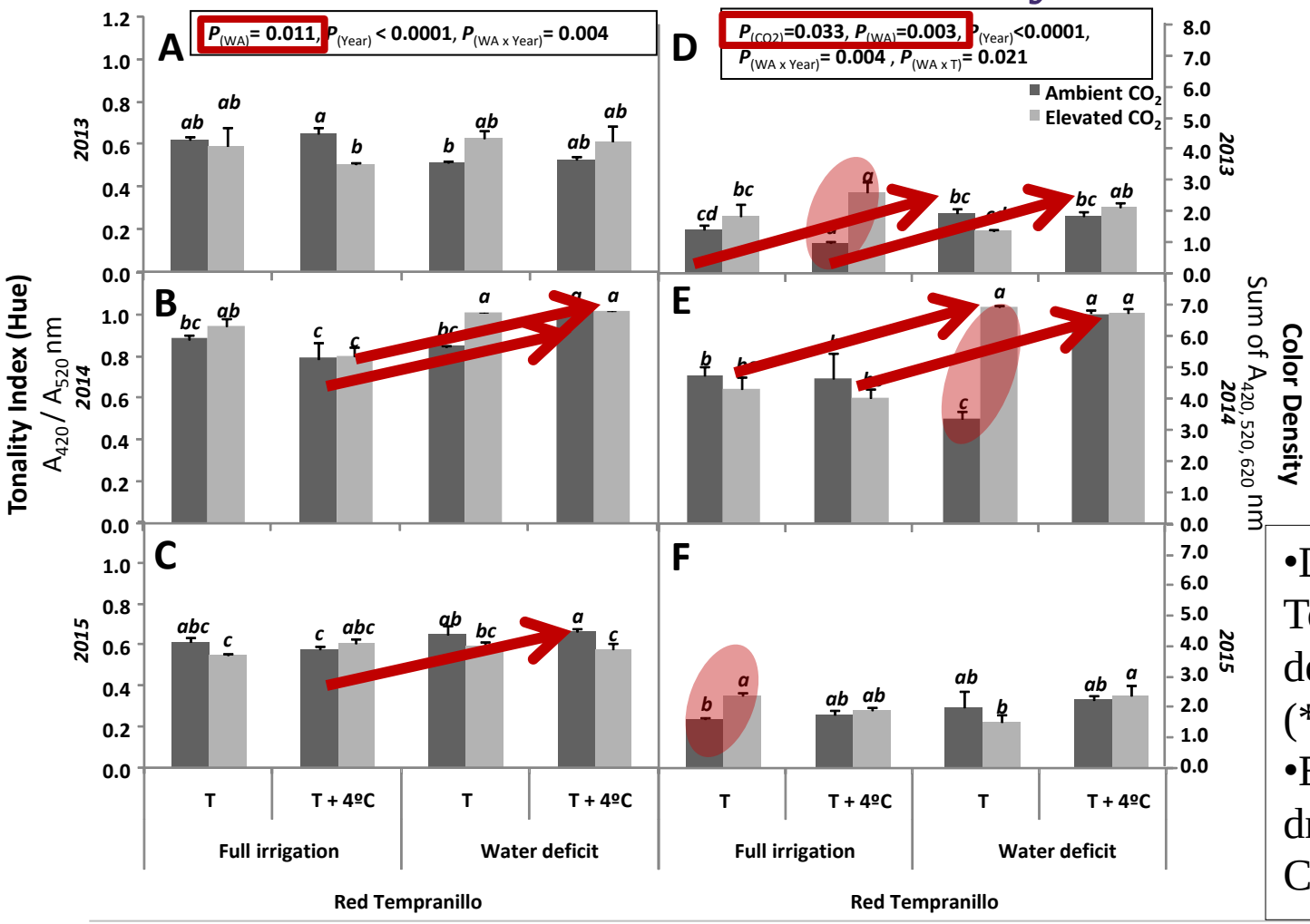
TPI decreased significantly by elevated temperature and also depends on variety and year.

Total Anthocyanins-% Extractable Anthocyanins (EA)- EA Phenolic Maturity



Total Anthocyanins decreased by drought (**) depending on the year (***) and Temperature, and drought decreased %EA in Red Tempranillo.

Tonality Index (Hue) & Color Density Phenolic Maturity



- Drought increased Tonality index (**) depending on year (***).
- Elevated CO_2 (*) and drought (*) increased Color density.

Phenolic Maturity – ANOVA -

ANOVA *P* value	Factors	TPI	Total Anthocyanins	Extractable Anthocyanins	% EA	Color density	Tonality Index (Hue)
Individual effects	**P** (T)	**<0.0001**	ns	ns	**0.001**	ns	ns
	P (CO2)	**0.004**	ns	ns	ns	**0.033**	ns
	P (WA)	ns	**0.01**	ns	**0.026**	**0.003**	**0.011**
	P (Variety)	**<0.0001**	ns	ns	ns	ns	ns
	P (Year)	**<0.0001**	**<0.0001**	**0.002**	**<0.0001**	**<0.0001**	**<0.0001**
Interacting effecs	**P** (Variety x T)	**0.004**	ns	ns	ns	ns	ns
	P (Variety x CO2)	ns	ns	ns	ns	ns	ns
	P (Variety x WA)	ns	ns	ns	ns	ns	ns
	P (Variety x Year)	**<0.0001**	ns	ns	ns	ns	ns
	P (T x CO2)	ns	ns	ns	ns	ns	ns
	P (T x WA)	ns	ns	ns	ns	**0.021**	ns
	P (T x Year)	ns	ns	ns	ns	ns	ns
	P (CO2 x WA)	ns	ns	**0.0003**	**0.0003**	ns	ns
	P (CO2 x Year)	ns	ns	ns	ns	ns	ns
	P (WA x Year)	**<0.0001**	**0.001**	**0.001**	**<0.0001**	**0.004**	**0.004**

- Water availibility alone and with year factor have more influence on secondary metabolites.
- Generaly, secondary metabolites are less influenced than primary metabolites by environmetal factors.

Conclussions

Within the three climate change-related factors investigated, drought and temperature (heat shocks) reduced the grapevine production of Red and White Tempranillo.

Regarding the hot topic of climate change effects on plant phenology, this study concludes that grapevine phenology is affected by three climate change related factors: elevated CO_2, high temperature and water deficit.

Elevated CO_2 and high temperature accelerated the phenology and reduced the number of days to reach a certain phenological stage such as veraison or maturity.

On the contrary, drought slowed down grape development, and increased the number of days to reach veraison and maturity.

Conclussions

The period from fruit set to veraison was mainly affected by elevated CO_2, while the veraison to maturity period was more impacted by elevated temperature.

Red Tempranillo has a shorter phenological period than White between fruit-set and maturation due to the veraison to maturation period is shorter in Red Tempranillo.

Three year analyses of the berry quality reflect that climate change factors (elevated CO_2, elevated temperature and drought) affected in a greater extend the technological maturity parameters (primary metabolism), whereas the phenolic maturity (secondary metabolism) was less impacted.

The response of grape quality (technological and phenolic maturity) to climate change-related factors (elevated CO_2, elevated temperature and drought) was highly variable and depended on the year, probably do to the variability of the climate and the interactions among factors defining the climate (temperature, humidity, sunlight etc.).

Acknowledgements

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