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GiESCO 2015

Effect of temperature on fruit phenotype and wine

19èmes Journées Internationales de Viticulture GiESCO

19th International Meeting of Viticulture GiESCO

Pech Rouge – Montpellier
31 Mai/*May* - 5 Juin/*June* 2015

JOURNÉE PROFESSIONNELLE
« Viticulture Durable »

PROFESSIONAL DAY
« Sustainable Viticulture »

FINAL REPORT to

AUSTRALIAN GRAPE AND WINE AUTHORITY

Project Number: GWT 1422

Principal Investigator: Victor Sadras

Research Organisation: South Australian R&D Institute

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GiESCO 2015 - EFFECT OF TEMPERATURE ON FRUIT PHENOTYPE AND WINE

Executive summary

This grant partially funded the travel of Victor Sadras to attend the GiESCO 2015 meeting, where he presented a key note paper featuring AGWA-funded research on warming effects and vineyard management. The main themes of the conference were (1) ecophysiology, water and irrigation, (2) climate and terroir, (3) training and cultivation techniques, (4) grape berry and microclimate, (5) new technologies, and (6) rootstock and soil. The professional session on the last day of the conference focused on both big picture issues and case studies with regional relevance under the title *Sustainable viticulture*. A production system is sustainable if it meets four conditions: it is profitable, accounts for the social and environmental expectations, and delivers safe produce. All these factors are related, and failure in one or more of them compromises the system. Sustainability and climate change were the topics of papers by Smart, Schultz, Sadras and Carbonneau. Sustainability however needs to be solved locally. Case studies dealt with specific regional aspects, such as irrigation and the role of organic systems in California, Champagne, Australia, and Switzterland. To communicate the conference to industry, an article summarising the meeting was submitted to the Australian and New Zealand Grapegrower and Winemaker magazine.

Sadras also presented an invited seminar at the Institut de la Science de la Vigne et du Vin (Bordeaux). A joint project has been developed with Prof. Serge Delrot (Bordeaux) that is directly related to our current AGWA projects. The aim is to measure metabolic changes in Cabernet Sauvignon berries in response to elevated temperature, combining our expertise in heating systems and Prof. Delrot expertise in metabolism. The project will also involve AWRI colleagues.

Report

This report includes three parts:

- Summary of GiESCO 2015, submitted for publication to Australian and New Zealand Grapegrower and Winemaker
- Paper presented at GiESCO 2015
- Abstract of seminar presented at Institut de la Science de la Vigne et du Vin (Bordeaux)

Opportunities for collaboration

A joint project has been developed with Prof. Serge Delrot (Bordeaux) that is directly related to our current AGWA projects. Based in our leading work on experimental warming of vineyards, we will receive a French student to work on our heating facilities at Nuriootpa. The aim is to measure metabolic changes in Cabernet Sauvignon berries in response to elevated temperature, combining our expertise in heating systems and Prof. Delrot expertise in metabolism. The project will also involve colleagues at AWRI.

19th International Meeting of Viticulture GiESCO
Pech Rouge – Montpellier, 31 May - 5 June 2015

Submitted to Australian and New Zealand Grapegrower and Winemaker

The main themes of the conference were (1) ecophysiology, water and irrigation, (2) climate and terroir, (3) training and cultivation techniques, (4) grape berry and microclimate, (5) new technologies, and (6) rootstock and soil.

A series of standard papers on management of water dealt with cover crops, wastewater, crop monitoring, yield and fruit responses; these provided little new information. Markus Keller and colleagues presented a highly original and relevant paper entitled "Hydraulic isolation of ripening grape berries: the end of a dogma". They tested with sound experimental systems, the notions that ripening berries become dependent upon phloem water supply because xylem flow into the berries ceases at veraison due to rupture of vessels during rapid berry expansion. Using field-grown vines, they conducted a mass balance on ripening berries to estimate rates of berry growth, transpiration, and phloem flow. Using a modified pressure-chamber technique, they extracted apoplast sap from ripening berries and compared its composition with that of cell sap. Measurements indicated a sudden rise in phloem inflow into berries undergoing veraison on drought-stressed vines. Rewatering accelerated berry expansion by stimulating leaf photosynthesis, but girdling the cluster peduncle prevented this effect. Pressurizing the roots or shoots increased expansion only in preveraison berries, but led to cracking of postveraison berries. Pressurization also restored the normally impeded dye movement into ripening berries. They showed that the phloem generally supplied more water than was needed for berry growth and transpiration. Solute accumulation and changes in pH and osmotic pressure in the berry apoplast differed from that inside the cells and were under developmental control. These results demonstrated that phloem inflow is controlled by sugar demand in the ripening berries and that these berries do not become hydraulically isolated. While xylem flow remains reversible, it is usually from berry to shoot during ripening. They propose a model in which surplus phloem water that osmotically follows the unloaded sugar to the berry apoplast is recycled directly to the xylem or transpired across the skin. Xylem backflow and transpiration may serve as 'overflow valves' for excess phloem water, thus facilitating sugar accumulation and protecting berries from cracking. One of the main corollaries of this study is that the water and carbon economies of berries are closely related, and therefore studies on detached berries would largely miss this link.

Climate and terroir comprised 24 papers and berry and microclimate 19. Modelling is a useful approach to integrate otherwise fragmented aspect of grape and wine production, and to extrapolate in space and time from necessarily limited experimental work. Hofmann and Schultz presented their efforts in modelling the transpiration of grapevines on sloped vineyards; accounting for by vineyard geometrical features made it possible to directly compare the relative transpiration of different vineyards. Miranda and colleagues discussed above ground biomass production and partitioning as affected by water status in the context of their vineyard-modelling project VitMod; Luchaire and colleagues used "microvines"to measure aspects of the vine carbon balance as a platform to model the effects of elevated CO_2 and elevated temperature. The work led by Miranda and by Luchaire are examples of how a modelling framework helps to formalise research questions and integrate fragmented information. In the study of Dufourcq and colleagues, irrigation strategies aimed at modulating the aromatic typicality of Colombard and Gros Manseng wines were explored with a combination of modelling soil water content, measuring stem water potential and analysing carbon isotope in sugar at harvest; this illustrates the value of combining modelling and experimental work. Other modelling studies dealing with climate change, terroir and

landscape, prediction of phenology included those by the teams of Quenol, Vinatier , Parker, and Brillante.

Training and cultivation featured 35 papers. An area that is attracting increasing attention in the context of global warming is the manipulation of crop phenology and maturity, and techniques to contribute to balanced fruit. Papers tested growth regulators, canopy/fruit ratio treatments, e.g. defoliation to favour anthocyanin:sugar ratio, minimum pruning, and nitrogen input. New technologies included 23 papers. Many of these were related to spatial variation; how to measure it and exploit it in the vineyard. Boatto and colleagues presented an economic evaluation of alternative technologies for chemical spray, which included innovative fixed systems to reduce drift in environmentally-sensitive areas (Table 1). Rootstocks and soils comprised 14 papers. Rootstocks were typically evaluated for their impact on shoot growth and water status, berry traits, and nutrient uptake.

Table 1. Economic comparison of alternative spraying systems in Conegliano Valdobbiadene DOCG. Source: Vasco BOATTO, Luigi GALLETTO, Gianni TEO, Luigino BARISAN, GiESCO 2015.

Costs:	**Current prototype (A)**	**Fixed system "realistic model" (B)**	**Fixed system "in series model" (C)**	**Helicopter *(*) (**)* (D)**
	(€/Ha)			
Average fixed costs (CF/N):				
1) Fixed part	3.594	2.994	2.516	-
2) Mobile part	253	253	253	-
3) Maintenance	600	600	600	50
4) Reintegrates & interest tractor /sprayer	-	-	-	80
Total Fixed Costs (CF)	**4.447**	**3.847**	**3.369**	**130**
Avarage Variable costs (cv):				
5) Carburant e lubricant	500	500	500	250
6) Labor (*)	405	405	405	840
7) Cost of plant protection products (*)	900	900	900	400
8) Helicopter Tariff	-	-	-	2.480
Total Variable Cost	**1.805**	**1.805**	**1.805**	**3.970**
Total Cost per unit	**6.252**	**5.652**	**5.174**	**4.100**

The professional session on the last day of the conference focused on both big picture issues and case studies with regional relevance under the title “Sustainable viticulture”. A production system is sustainable if it meets four conditions: it is profitable, accounts for the social and environmental expectations, and delivers safe produce. All these factors are related, and failure in one or more of them compromises the system. Sustainability and climate change were the topics of papers by Smart, Schultz and Carbonneau. As usual, these authors asked sharp questions, and presented an invaluable long-term perspective. Sustainability however needs to be solved locally. Case studies dealt with specific regional aspects, such as irrigation and the role of organic systems in California (Sanchez), Champagne (Garcia), Australia (Collins), and Switzterland (Spring).

Australian scientists presented a series of papers: Peter Clingeleffer (*Thompson seedless berry collapse*), Vinay Pagay (*The influence of soil moisture deficits on Riesling shoots in a cool, humid climate; Severe leaf removal improves vine source-sink balance and composition of merlot grapes and wine*), Fiona Kerslake (*Pinot noir yield prediction in a variable cool climate*), Markus Müller (*Comparison of vineyard nitrogen application practices and winery nitrogen management*), Roberta De Bei (*Linking canopy architecture to grape quality using the laicanopy app*), Richard Smart (*Changes to viticulture in the last forty years. are these tendencies sustainable?*), Cassandra Collins (*The relative sustainability of organic, biodynamic and conventional viticulture)*, Victor Sadras (*Wine as G x E :effect of temperature on vine and fruit phenotype*). Browsing the proceedings of the conference, the strong influence of *The Australian Journal of Grape and Wine Research* became evident, reinforcing the world-leading position of the ASVO journal.

WINE AS G x E:

EFFECT OF TEMPERATURE ON VINE AND FRUIT PHENOTYPE

G X E DU VIN:

EFFETS DE LA TEMPERATURE SUR LA VIGNE ET LE RAISIN

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Abstract

A production system is sustainable if it meets four conditions: it is profitable, accounts for environmental and social expectations and ensures product safety. The challenges for sustainability in the vineyard and winery overlap partially. The latest Australian Wine Industry Environment Conference highlighted four aspects relevant to sustainability: profitability, water, energy and warming climate. In this paper, we narrow our focus to warming and its implications for yield and fruit traits as drivers of profit. Sustainability challenges and opportunities have a strong regional component as the likelihood of negative (or positive) impact of warming increases (decreases) from cool to hot regions; here we concentrate on the Barossa Valley of Australia, a region with median growing season temperature of 19.0 ^{o}C (1970-2000).

We are interested in growing grapes, making wine and selling it. Viticulture, oenology and marketing provide theories and practices to support each of these activities. The concepts of "vintage" and "terroir" are useful in marketing but unsuitable to understand grapes. A phenotype-based framework is advanced that helps to understand environmental and technological influences on vine and fruit traits relevant to wine.

The phenotype comprises all components of an organism other than its DNA. Root depth, stomatal conductance and berry anthocyanins are all aspects of the vine's phenotype and therefore depend on the genotype (G), the environment (E) and their interaction (GxE). Vineyard management (M) can affect the phenotype directly, e.g. pruning that shapes the canopy, or indirectly through modification of the environment, e.g. irrigation that changes soil water content. Likewise, the sense of smell or her approach to wine making are aspects of the winemaker's phenotype that result from G and E, where E is defined in the widest sense as to include personal and social history, culture, education and so forth. Wine is hence the result of two interacting phenotypes, the fruit's and the winemaker's; wine is GxE twice. This could be extended by making explicit the phenotypes of the microorganisms involved in winemaking, which are also the result of G, E and M and their interactions.

Ambient temperature is a component of the environment that influences vine and fruit phenotypes. Against the backdrop of climate change, we make the distinction between gradual, long-term warming at typical rates of 0.01-0.02 ^{o}C/yr and heat stress events. Here we summarise a 6-yr project where we compared vines exposed to elevated temperature (approx. 2^{o}C above ambient) with untreated controls in the Barossa Valley. The concept of

phenotypic plasticity, derived from our framework, is applied to elucidate the effect of warming on juice pH and acidity. Warming was mostly neutral for yield and its effect smaller than expected for time of maturity. Elevated temperature decoupled sugars and anthocyanins in Syrah and Cabernet Franc; this was due to the shift in the onset of colouring on a TSS scale under elevated temperature. Elevated temperature also decoupled berry sensory traits. Adaptive viticultural and winemaking technologies to preserve the identity of Syrah would contribute to the sustainability of the wine sector in the Barossa Valley.

Keywords: *sustainability, warming, Syrah, yield, phenology, wine balance, phenotype, terroir*

Résumé

Alors que les concepts de millésime et de terroir sont précieux au marketing du vin, ils sont peu adaptés à la compréhension du comportement de la vigne ou du vin, notamment du fait que les vignes n'ont pas de capteurs sensibles à nos concepts de « sols », « années » ou « sites ». Définir un cadre d'analyse se basant sur le phénotype de la vigne et du vin peut aider à mieux comprendre les effets environnementaux observés.

Le phénotype d'un organisme englobe toutes les composantes de cet organisme à l'exception de son ADN. Des caractères comme la profondeur d'enracinement, la conductance stomatique ou la concentration en anthocyanes font tous partis du phénotype de la vigne et dépendent du génotype (G), de l'environnement (E) et de leur interaction (GxE). La conduite d'un vignoble (M) influence également le phénotype directement, par ex. via une taille, ou indirectement, par ex via une irrigation. Similairement, l'odorat ou le type de vinification choisi par un œnologue résultent de G et E, où E inclut le passé culturel et social de l'individu. Le vin est donc le produit de l'interaction de deux phénotypes, celui du fruit et celui de l'individu, et résulte donc d'une double interaction GxE. Ce postulat peut d'ailleurs être élargi aux micro-organismes impliqués dans la vinification, dont le phénotype dépend également de G, E et M et leurs interactions.

La température ambiante est un facteur influençant le phénotype du raisin comme du vin. Dans un contexte de changement climatique, il faut distinguer le réchauffement progressif, à long-terme de 0.01-0.02 ^{o}C/an, des stresses thermiques, plus ponctuels. Durant 6 ans, nous avons comparé des vignes exposées a des températures surélevées (environ + 2^{o}C) à des témoins (température ambiante) dans la vallée de la Barossa en Australie. Dans notre cadre d'analyse, le concept de plasticité phénotypique est utilisé pour élucider les effets d'un échauffement sur le pH du jus de raisin. Dans notre étude, l'élévation de température n'a globalement pas eu d'effet sur le rendement, et a moins touché la date de maturité qu'initialement prévu. Le réchauffement a cependant découplé les sucres des anthocyanes pour le Syrah et le Cabernet Franc et a dissocié les caractères sensoriels du raisin.

***Mots clés**: réchauffement, Syrah, rendement, phénologie, équilibre du vin*

1. Introduction

Here we define sustainability in terms of economic, social, environment and food safety dimensions, and touch on current issues for the Australian wine sector, including climate change. The concepts of vintage and terroir are discussed from two angles: their field of application and alternative perspectives. The core of the paper is a summary of our recent work on the effects of elevated temperature on vine phenology, yield, fruit traits and wine attributes in a context of realised and projected warming.

2. Sustainability is, at least, 4-dimensional

A production system is sustainable if it meets four conditions: it is profitable, protects the integrity of natural resources, improves the quality of life of individuals and communities, and ensures the nutritional value and safety of food (Sadras et al., 2009). Often sustainability is reduced to its environmental component (McManus, 2008). However, all four aspects of sustainability are related and all are important; failure in any of these dimensions would turn a production system unsustainable.

The Australian Wine Industry Environment Conference in 2014 highlighted four aspects relevant to sustainability: profitability, water, energy and warming climate. Profitability of the Australian wine sector is challenged by both contingent factors, such as a high exchange rate, and structural issues including a production model relying on high volume and relatively low price; the share (by volume) of Australian wines below AU$5 per litre was 90% in the year ended November 2013 (Australian & New Zealand Grapegrower & Winemaker, Dec 2013). Profitability and water are closely linked in grower's perception and management practices in vineyards (Ambrosio et al., 2008) as well as in the water market (Bjornlund and Rossini, 2007), management of wastewater in wineries (Mosse et al., 2011) and the aggregated output of the national agriculture (Figure 1).

In this paper, we narrow our focus to warming and its implications for yield and fruit traits as drivers of profit. Sustainability challenges and opportunities have a strong regional component as the likelihood of negative (or positive) impact of warming increases (decreases) from cool to hot regions; this paper concentrates on the Barossa Valley of Australia, a region with median growing season temperature of 19.0 ^{o}C (1970-2000). In the next section, we outline a phenotype-based conceptual model to capture the primarily biological effects of temperature on vines and fruit.

3. Wine is GxE, at least twice

We are interested in growing grapes, making wine and selling it. Viticulture, oenology and marketing provide theories and practices to support each of these activities. The concepts of "vintage" and "terroir" are useful in marketing but unsuitable to understand grapes and their attributes relevant to wine.

Consider the two water fleas in Fig. 2a; both are the same genotype. The one on the right grows in a non-stressful environment, and allocates a large proportion of resources to reproduction. The one on the left grows in a stressful environment, say with predators, and develops a protective helmet at the expense of reproduction. We can legitimately say this is an effect of terroir. Is this perspective useful? Frank Ribéry scores an average 0.34 goals per match playing for Bayern Munich and 0.19 goals per match playing for France. This can be interpreted in terms of terroir but we will show that a phenotype perspective is superior.

All organisms, including water fleas, grapevines and humans (including football players and winemakers), have two components. The genome, defined as the full complement of DNA in a cell, and the rest; the rest is the phenotype (West-Eberhard, 2003). Hormones, enzymes, root depth, stomatal conductance, fruit yield, berry size, skin anthocyanins, seed tannins, flavour compounds are all phenotypic traits. Likewise, the sense of smell, perspectives on wine style and so forth belong to the winemaker's phenotype. Phenotypic traits of humans including psychological responses to landscape (Ballard, 1965) and ideological inclinations (Smith et al., 2011) are beyond the scope of our work. Phenotypic traits of plants depend on the genotype (G), the environment (E), management practices (M) and the interaction among these factors. Wine is therefore the result of G x E twice (Figure 3), once for the grapevine and a second time for the winemaker. This could be extended further to include the phenotype of the yeasts and other microorganisms involved in fermentation.

"Vintage" and "terroir" are useful marketing concepts; however, they can only be understood from a G x E perspective, and associated concepts such as phenotypic plasticity, defined as the production of multiple phenotypes (e.g. skin anthocyanin concentration) by a single genotype (Bradshaw, 1965). For example this perspective has allowed us to untangle G x E effects on juice pH and titratable acidity (TA), thus identifying varieties with high (Chardonnay) and low (Shiraz) phenotypic plasticity in response to temperature (Sadras et al., 2013b). Reaction norms demonstrated the enhanced stomatal size and conductance in leaves developed under high temperature (Sadras et al., 2012), which were consistent with an augmented capacity for water transport as reflected in higher density of wider xylem vessels (Galat Giorgi et al., 2013).

4. Warming effects on vine phenology, yield, fruit and wine attributes

4.1. Effect of temperature on vine development and harvest time

Analysis of time series combined with robust theory supports a link between phenological shifts of grapevines and increasing ambient temperature in Europe, North America and Australia (Duchêne et al., 2010; Jones and Davis, 2000; Petrie and Sadras, 2008; Wolfe et al., 2005). Unrelated time series in Australia and Italy returned comparable rates, between 7 and 9 days early maturity per 1 ^{o}C increase in ambient temperature (Petrie and Sadras, 2008; Tomasi et al., 2011). Whereas the direction of the response is clear (i.e. early maturity) time series and experiments do not agree quantitatively. There are two sources for the discrepancy: complex interactions among multiple drivers in the observational data and experimental artefacts. Both sources are likely to be important, and they are not mutually exclusive. However, we are inclined to conclude that time-series over estimated warming effects in our experiments (Sadras and Moran, 2013b). In common with Webb et al. (2012), we suggest that the trends for earlier harvest in time series are only partially related to warming.

Irrespective of the cause, one of the consequences of shifts in maturity is compressed harvests. Compressed harvests are having direct implications for the logistics of fruit processing in the winery, and management tools to at least partially "decompress" harvest are required.

4.2 Effect of temperature on fruit yield

Figure 4 summarises the effect of warming on fruit yield in the Barossa Valley; the data set covers a wide range of factors including varieties, seasons, water regimes, fruit loads and pruning time. Most points are close to the y = x line, thus indicating lack of temperature effect. Few cases show yield reductions (i.e. points below the line) and a few show large yield improvements associated with warming (i.e. points above the line). This variation in responses is partially associated with the background conditions. We conclude that warming by about 2 ^{o}C is likely to be neutral for yield of grapevine in locations similar to Nuriootpa, with positive impact in seasons where the background temperature is at the cool end of the records, and negative impact in seasons at the hot end. Of particular interest, the conclusion of an overall neutral effect of warming held for an experiment where Shiraz has been exposed to both warming and severe water deficit during four consecutive years (blue points in Fig. 4).

4.3 Effect of temperature on berry and wine attributes

The effect of elevated temperature was measured and reported for berry sugar accumulation, TA, pH, antocyanins, organic acids and sensory traits (Bonada et al., 2015; Bonada et al., 2013; Sadras and Moran, 2012; Sadras et al., 2013a; Sadras et al., 2013b; Sweetman et al., 2014) and for chemical and sensory wine attributes (Bonada et al., 2015; Sadras et al., 2013b). Here we illustrate some of these findings.

Malate content in berries

Elevating maximum temperatures (4-10°C above controls) during véraison and ripening reduced malate content in Shiraz berries. However, malate did not respond when minimum temperatures were also raised (4-6°C). Changes in malate content were proportional to daily thermal amplitude. Regulation of malate metabolism may differ during the day and night (Sweetman et al., 2014), hence the need to revise the general assumption of reduced malate with high temperature.

Thermal decoupling of berry traits

Temperature is likely to have differential effects on particular traits, and these differential effects lead to decoupling in berries, with consequences for wine balance. The most significant and consistent decoupling recorded in our studies was between anthocyanins and sugars in berries of Shiraz and Cabernet Franc (Fig. 5). At the same sugar content, elevated temperature reduced the concentration of anthocyanins. This thermal decoupling partially explains the systematic increase in alcohol of red wine varieties over the last two decades (Godden and Gishen, 2005). Water deficit after veraison can in part restore the balance between anthocyanins and sugars (Sadras and Moran, 2012). However, water deficit can increase heat damage; this is an important trade-off that needs to be solved locally.

Mesocarp cell death

The breakdown of cell membranes during the ripening of normally senescing fruits has been linked with the development of flavours and aroma (Tilbrook and Tyerman, 2008). This is consistent with practices such as extended ripening or ‘hang time’ seeking to enhance these quality traits. We found that traits typical of ripened berries were associated with lower percentage of mesocarp cell viability. However, warming and water deficit hastened the onset and rates of mesocarp cell death and shrivelling but not necessarily improved the sensory balance of berry traits in pulp, skin, seeds and whole-berry (Bonada et al., 2015; Bonada et

al., 2013). We conclude that the positive association between berry aromas and flavours and mesocarp cell death may not hold when high temperature accelerates cell death in water stressed berries.

Wine phenolic compounds and sensory attributes

Significant, previously unrecorded interactions were found between temperature and cultivar (Sadras et al., 2013b) and between temperature and water (Bonada et al., 2015) for sensory and compositional features of wines. Elevated temperature consistently reduced green and citrus aromas, and enhanced rich mouth feel and tropical flavours in Semillon. Thermal effects on sensory traits of Shiraz and Cabernet Franc, however, were strongly season-dependent.

Our study on Shiraz revealed trade-offs between warming and water deficit on the phenolic composition of wines. One year-old wines from vines exposed to both elevated temperature and water deficit had lower colour density, polymeric pigments and total tannins. In agreement with the reduced phenolic composition, these wines were chromatically and sensorially less intense; wines were lighter and with less overall colour and red tonnes. Wines were discriminated by panellist due to their low tannin structure and berry flavours. We thus conclude that the generalised perception that water deficit leads to more intensely coloured, flavoursome and phenolic rich wines may not hold under high temperature. These findings highlight the dominant effect of temperature driving grape and wine composition, and provide industry with indications of shifts in wine profiles that would require technological innovations in the vineyard and winery to maintain the identity of Barossa Shiraz, the flagship of the Australian wine industry.

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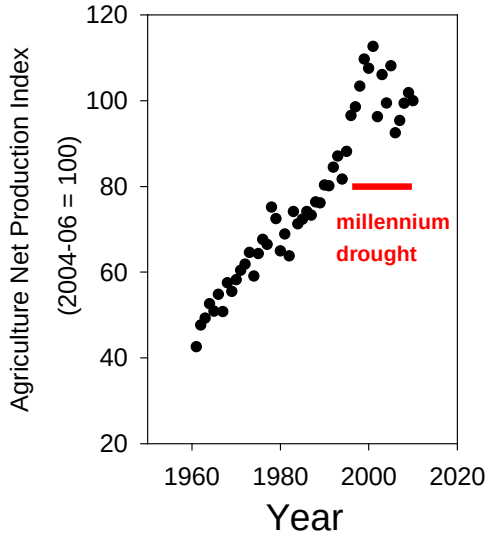


Figure 1 Time trend in FAO's Net Production Index in Australia highlighting the sustained increase in productivity and the disruption caused by drought in south-eastern Australia, where rainfall between 1997 and 2009 was 73 mm below average since the start of the 20th century.

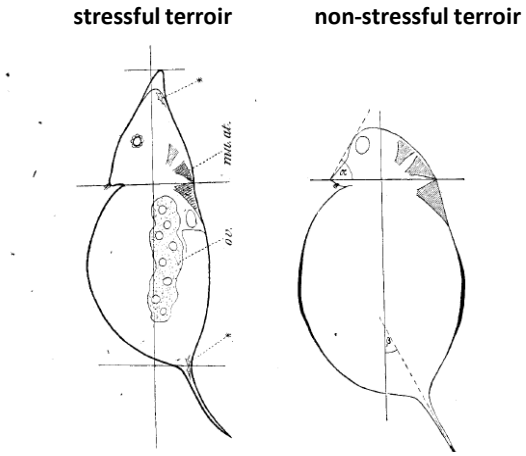


Figure 2. Effect of terroir on water flea morphology. Source: Woltereck (1909).

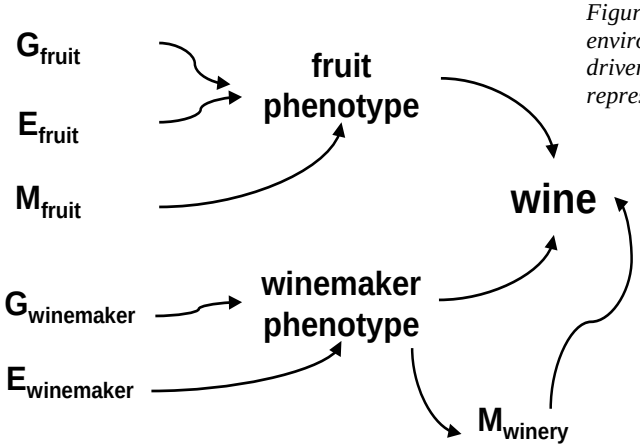


Figure 3. Wine is G x E twice. G is genotype, E is environment, and M is management. Subscripts emphasise drivers of fruit and winemaker phenotype, whereas M_{winery} represents the winemaking technology.

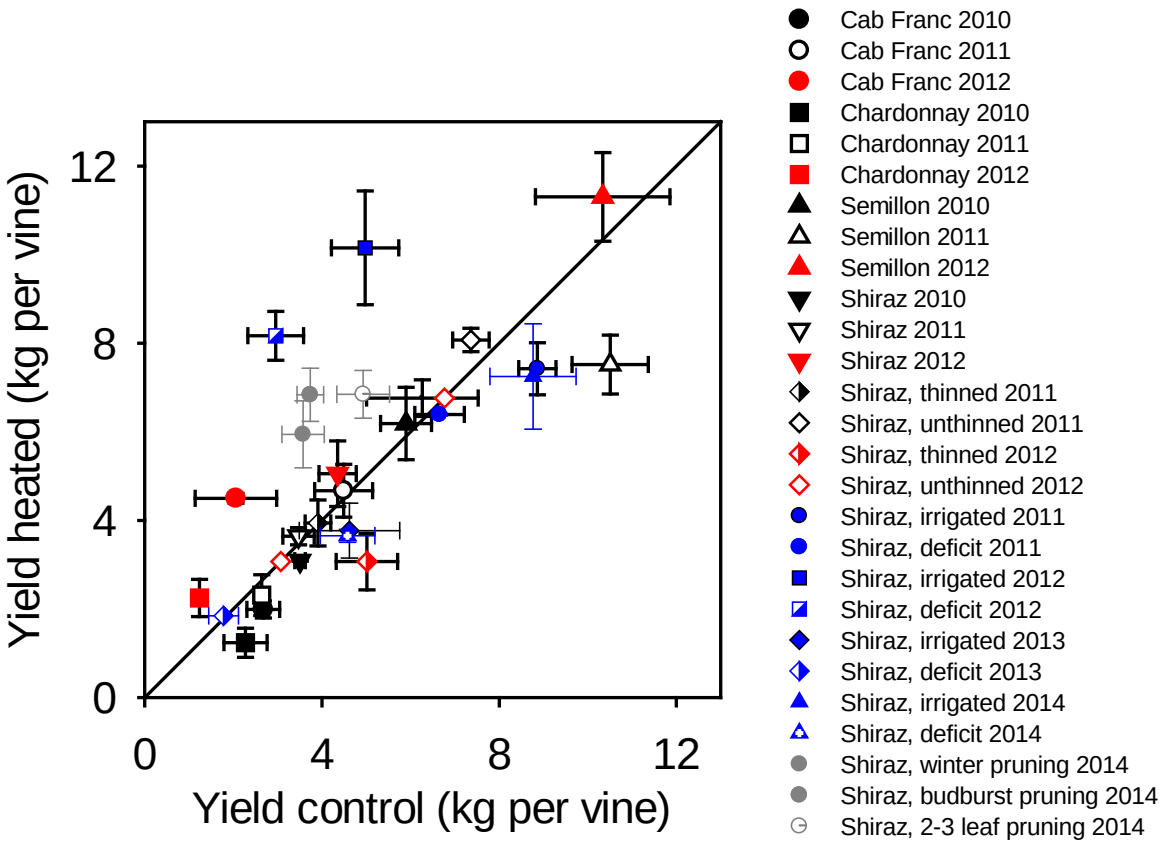


Figure 4. Warming (approx. 2°C) is mostly neutral for fruit yield in the Barossa Valley. Most observations are close to the line (y = x) that indicates lack of difference between heated and control vines. Bars are two standard errors of the mean. Sources: 2010-12 (Sadras and Moran, 2013a), 2013-14 (Sadras and Moran, unpublished).

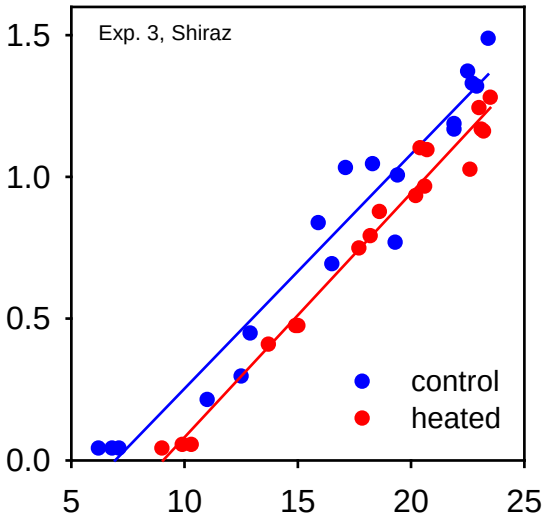


Figure 5. Elevated temperature decouples anthocyanins and sugars. Source: Sadras and Moran (2012).



université de BORDEAUX / ISVV INSTITUT DES SCIENCES DE LA VIGNE ET DU VIN BORDEAUX AQUITAINE

SEMINAIRE RECHERCHE

"Wine as G x E. effect of temperature on vine and fruit phenotype."

Lundi 8 juin 2015 à 14h – Amphithéâtre de l'ISVV

Résumé :

We are interested in growing grapes, making wine and selling it. Viticulture, oenology and marketing provide theories and practices to support each of these activities. The concepts of "vintage" and "terroir" are useful in marketing but unsuitable to understand grapes. A phenotype-based framework is advanced that helps to understand environmental and technological influences on vine and fruit traits relevant to wine.

The phenotype comprises all components of an organism other than its DNA. Root depth, stomatal conductance and berry anthocyanins are all aspects of the vine's phenotype and therefore depend on the genotype (G), the environment (E) and their interaction (GxE). Vineyard management (M) can affect the phenotype directly, e.g. pruning that shapes the canopy, or indirectly through modification of the environment, e.g. irrigation that changes soil water content. Likewise, the sense of smell or her approach to wine making are aspects of the winemaker's phenotype that result from G and E, where E is defined in the widest sense as to include personal and social history, culture, education and so forth. Wine is hence the result of two interacting phenotypes, the fruit's and the winemaker's; wine is GxE twice. This could be extended by making explicit the phenotypes of the microorganisms involved in winemaking, which are also the result of G, E and M and their interactions.

Ambient temperature is a component of the environment that influences vine and fruit phenotypes. Against the backdrop of climate change, we make the distinction between gradual, long-term warming at typical rates of 0.01-0.02 oC/yr and heat stress events. Here we summarise a 6-yr project where we compared vines exposed to elevated temperature (approx. 2oC above ambient) with untreated controls in the Barossa Valley. The concept of phenotypic plasticity, derived from our framework, is applied to elucidate the effect of warming on juice pH and acidity. Warming was mostly neutral for yield and its effect smaller than expected for time of maturity. Elevated temperature decoupled sugars and anthocyanins in Syrah and Cabernet Franc; this was due to the shift in the onset of colouring on a TSS scale under elevated temperature. Elevated temperature also decoupled berry sensory traits. Adaptive viticultural and winemaking technologies to preserve the identity of Syrah would contribute to the sustainability of the Barossa Valley.



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