

The Impact of Water Deficit and High Temperature on
Berry Biophysical Traits and Berry and Wine Chemical
and Sensory Traits

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Table of contents

| | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Abstract | i |
| Declaration | iii |
| Publications | iv |
| Related Publications and Communications Arising During Candidature | v |
| Acknowledgments | vi |
| Dedication | vii |
| Chapter 1: Introduction and Literature Review | 1 |
| 1.1 Overview | 2 |
| 1.2 Greenhouse Gas Emission and Climate Change..... | 3 |
| 1.3 Berry Growth and Development | 4 |
| 1.4 Berry Shrivelling..... | 7 |
| 1.5 Mesocarp Cell Death and Shrivelling – a Linking Hypothesis..... | 8 |
| 1.6 Effects of Elevated Temperature and Water Deficit on Grapevine Composition ... | 9 |
| 1.6.1 Thermal Effects | 10 |
| 1.6.2 Water Effects | 11 |
| 1.6.3 Combined Temperature and Water Effects | 12 |
| 1.7 Summary and Aims of Research..... | 12 |
| 1.8 Linking Statement..... | 13 |
| Chapter 2: Critical Appraisal of Methods to Investigate Temperature Effects on Grapevine Berry Composition | 17 |
| Chapter 3: Effect of Elevated Temperature on the Onset and Rate of Mesocarp Cell Death in Berries of Shiraz and Chardonnay and its Relationship with Berry Shrivel | 43 |
| Chapter 4: Elevated Temperature and Water Stress Accelerate Mesocarp Cell Death and Shrivelling, and Decouple Sensory Traits in Shiraz Berries | 53 |
| Chapter 5: Impact of Elevated Temperature and Water Deficit on the Chemical and Sensory Profiles of Barossa Shiraz Grapes and Wines | 71 |
| Chapter 6: Conclusions and Future Research | 107 |
| References | 112 |

Abstract

Warming and drought associated with climate change are major concerns in grape production worldwide. Our current understanding on the effects of temperature on berries and wines has been indirectly gained from comparisons of thermally contrasting seasons or sites, or from experiments in controlled conditions. Indirect methods, however, cannot prove cause and effect relationships, and extrapolation from controlled environments to field is not warranted. A comprehensive comparison of these methods is discussed. Furthermore, interactions are the main cause of complexity in field experiments; nevertheless, predictions about warmer and drier environments are based on studies that separately addressed these factors. Using direct manipulation of temperature on field growing vines with open-top chambers, the current work is the first combining water and temperature regimes in realistic vineyard conditions. The aims of this research were: (i) to critically assess methods to investigate thermal effect in viticulture; (ii) to measure the effects of elevated temperature on berry shrivelling (BS) and berry mesocarp cell death (MCD) in Shiraz and Chardonnay (exp. 1); and to evaluate the single and combined effects of temperature and water deficit on (iii) BS, MCD and on (iv) berry and wine chemical and sensorial composition in Shiraz (exp. 2).

An increment in background temperature increased both MCD and BS in Shiraz, and increased MCD but had not impact on BS in Chardonnay; MCD seems necessary but not sufficient to explain BS. Similarly, transient water deficit post-veraison increased MCD and BS at harvest in Shiraz. MCD response to temperature was primarily explained by the advance in onset, while the effect of water deficit was traced back to the increment in the rate of MCD post-onset. An interaction between water deficit and temperature was found whereby the onset of berry net water loss was advanced by high temperature under water deficit but not in the irrigated treatments.

MCD during berry senescence has been proposed to enhance berry flavour and aroma. The association between MCD and grape sensory balance was investigated in exp. 2. The balance of berry sensory traits was quantified in terms of offset, which accounts for delay or advance in ripening, and decoupling, which measures the scatter in the response of the different traits. Sensory traits typical of ripened berries were associated with higher MCD; however, warming and water deficit advanced ripening and decoupled berry sensory traits. Thermal effects were larger than water effects; the large decoupling caused by high temperature was mainly associated with differences within

berry parts, whereas water-driven decoupling was mostly associated with a differential response between seed and other berry parts.

The extraction of the major phenolics classes in fully ripe fruit and their contribution to the final wine chromatic characteristics, phenolic composition and sensory attributes were determined in exp. 2. The effect of temperature on berry composition was larger than the effect of water but no interactions were found between these factors. Significant, previously unrecorded interactions were found for grape and wine phenolics, and wine sensory traits. Wines from control temperature and water deficit treatments had higher total phenolics, tannin concentration, colour density, non-bleachable coloured compounds and a higher proportion of polymeric pigments than the other combinations of temperature and water regimes. These wines were also characterised by attributes such as cooked fruit flavour, berry flavour, tannin structure and higher red tones and colour saturation. Therefore, the effect of water deficit leading to colourful, flavoursome and phenolic-rich wines may not hold under high temperature.

Scientifically, this thesis provides unequivocal answers to questions of berry physiology under elevated temperature in contrast to indirect methods and accounts for previously unknown interactions with water deficit in realistic vineyard conditions. From the perspective of the industry, this study represents a novel contribution as it answers the question of how warmer and drier conditions during ripening would affect grape and wine attributes and established the bases for new research aiming at counteracting the effects of climate change.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certified that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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Publications

This thesis is a collection of manuscripts that were published or submitted for publication in refereed journals, and has been prepared according to the University of Adelaide's specifications for 'Thesis by publication' format.

Each manuscript is displayed as a separate chapter in the thesis in the published or submitted format required by the specific journal. References for the submitted manuscripts, and the introduction and general discussion sections, have been incorporated into a single consolidated reference list at the rear of the thesis. A Statement of Authorship listing individual contributions and signatures of authors precedes each chapter.

The following peer-reviewed publications form the basis of the thesis:

Chapter 2. Bonada, M. and Sadras, V.O. (2014) Critical appraisal of methods to investigate temperature effects on grapevine berry composition. *Australian Journal of Grape and Wine Research* [Accepted].

Chapter 3. Bonada, M., Sadras, V.O. and Fuentes, S. (2013) Effect of elevated temperature on the onset and rate of mesocarp cell death in berries of Shiraz and Chardonnay and its relationship with berry shrivel. *Australian Journal of Grape and Wine Research* 19, 87–94.

Chapter 4. Bonada, M., Sadras, V.O., Moran, M.A. and Fuentes, S. (2013) Elevated temperature and water stress accelerate mesocarp cell death and shrivelling, and decouple sensory traits in Shiraz berries. *Irrigation Science* 31, 1317–1331.

Chapter 5. Bonada, M., Jeffery, D.W., Petrie, P.R., Moran, M.A. and Sadras, V.O. (2014) Impact of elevated temperature and water deficit on the chemical and sensory profiles of Barossa Shiraz grapes and wines. *Australian Journal of Grape and Wine Research* [Submitted manuscript].

Related Publications and Communications Arising During Candidature

Publications in peer-reviewed journals

Fuentes, S., Mahadevan, M., Bonada, M., Skewes, M.A. and Cox, J.W. (2013) Night-time sap flow is parabolically linked to midday water potential for field-grown almond trees. *Irrigation Science* 31, 1265-1276.

Sadras, V.O., Moran, M.A. and Bonada, M. (2013) Effects of elevated temperature in grapevine. I Berry sensory traits. *Australian Journal of Grape and Wine Research* 19, 95–106.

Publications in industry journals

Bonada, M. (2013) Grapevine research leads PhD candidate to South America. *Australian & New Zealand Grapegrower and Winemaker* September, p. 38.

Bonada, M., Sadras, V.O. and Fuentes, S. (2013) Effects of elevated temperature on mesocarp cell death and shrivelling in Shiraz and Chardonnay berries. *Australian & New Zealand Grapegrower and Winemaker* February, p. 35-36.

Conferences and seminars

Bonada, M. Maintaining wine quality under elevated temperatures. SARDI Waite Seminar Series, 22 August 2013 Adelaide, Australia. [Oral presentation].

Moran, M.A., Sadras, V.O., Petrie, P.R. and Bonada, M. Effect of elevated temperature on vine phenology, physiology and berry composition. The Australian Wine Industry Trade Exhibition (WineTech), 13-18 July 2013 Sydney, Australia. [Poster].

Bonada, M., Sadras, V.O., Moran, M.A. and Fuentes, S. Elevated temperature and water deficit accelerated berry mesocarp cell death and shrivelling, and decoupled sensory traits in Shiraz berries. IX International Symposium on Grapevine Physiology and Biotechnology, 21-26 April 2013 La Serena, Chile. [Oral presentation].

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Dedication

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