Heat wave mitigation strategies for wine grape production and measures of the impact of heat on berry ripening and wine composition

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Abstract

Loss of berry mass, commonly referred to as berry shrivel, can occur in some cultivars late in ripening. This phenomena is particularly common in Shiraz where it has been linked to a decrease in berry cell vitality (*cell death*) at high sugar concentrations. Moreover, both cell death and loss of mass can be triggered by high temperatures and water stress during berry ripening. Since the mass lost is predominantly water, sugars are concentrated resulting in an increase in the level of alcohol in wine. This increase in alcohol content has been especially evident in red wines in Australia during the last three decades. Global warming evidence and forecasted more intense and longer heatwaves requires that mitigation strategies be investigated that can reduce the high temperature impacts on berry development and in particular loss of berry mass and cell death.

The aims of this research were: (i) develop a more practical and objective technique to detect berry cell death progression based on impedance spectroscopy; (ii) understand grapevine physiology and the ripening process in shaded conditions and to assess various shading options to mitigate heatwaves; (iii) test the use of micro-sprinkler cooling to mitigate heatwaves; (iv) assess if wrapping arms for cordon establishment compromises the vasculature of the cordon, which would represent a progressive stress potentially compounding the effects of heatwave events.

Impedance spectroscopy measurements revealed that berry cell death could be described as a function of berry electrical impedance. The electrical impedance over a range of stimulus frequencies was measured through berry development on Shiraz berries from two locations. From veraison to the onset of cell death, berry impedance was proportional to sugar concentration measured as total soluble solids. Thereafter, impedance decreased in proportion to the level of berry cell death. Changes in berry

cell death were objectively determined by impedance spectroscopy, two models were developed with a high determination coefficient (r^2 >0.83).

Various shade configurations on Shiraz vines at two sites and 3 seasons using a 60% attenuation indicated that an overhead shade system was the most effective. Overhead shade applied from veraison to harvest resulted in maximum temperatures within the canopy being reduced by about 2 °C compared to control vines when temperatures were above 40 °C. This resulted in a 6% decrease in thermal time accumulated and a reduction of around 15 % in the maximum daily VPD. Despite this small difference, shaded vines had a more functional canopy indicated by higher leaf chlorophyll content and photosynthetic rate at saturating light. Lower ψ indicated a different water balance compared to control vines. Berries from shaded vines accumulated sugars at a lower rate, had higher water content and higher total acidity than controls. Berry mass loss under shade was delayed, occurred at a lower rate and berry cell vitality in ripened berries was higher in overhead shade compared to control. The wines corroborated the above trend showing a decrease in the alcohol level at two harvest times, but no difference in anthocyanin, tannins or polyphenols.

A microspray system was installed inside Cabernet Sauvignon canopies and adjusted to activate cyclically for 20 seconds every 10 minutes during berry ripening if the day time temperature was forecast to be higher than 40° C. The mist was able to decrease the air maximum temperature by ~3° C and leaf temperatures were reduced from 4° C in dry leaves to 14° C in wetted areas surrounding the microspray units. Fresh berry mass increased in misted vines, but berry sugar concentration was not altered resulting in higher sugar per berry. The efficiency of cooling was examined relative to the theoretical maximum using certain assumptions, and a suggested index of water

use efficiency calculated that could be compared between studies, and to assist grape growers to achieve optimum cooling for minimal water use.

The hypothesis that wrapping arms on to a cordon wire represents a continuous and progressive stress for the arm vasculature, thus affecting the normal flow of water and nutrients, was tested in a commercial Shiraz block at Barossa. Although, these are preliminary results from just one season, they confirm the hypothesis. Pruning mass was 20 % lower in wrapped vines compared to non-wrapped vines. The arm transversal area decreased more in wrapped vines from the proximal part of the cordon near the trunk to the distal portion. Berry assessment at harvest suggested that non-wrapped vines were exposed to less stress. Since this stress is potentially related to restriction of cordon vasculature, it might compromise the ability of these wrapped vines to deal with heatwaves and water stress. This becomes especially important from a global warming perspective and matches the significant increment in dead arm incidence across Australia.

In summary, in this thesis a robust model to objectively predict berry cell death in Shiraz is presented. This provides a new tool for berry quality assessment. Overhead shade applied from veriason to harvest was effective in heat protection, leading to berries with less sugar, more water and more cell vitality. The vine physiology revealed vines under less stress. Microspray cooling inside the canopy was efficient in protecting the vines from heatwaves using a small volume of water. The wrapping treatment represents an important contribution to the wine industry. It provides a physiological basis to amend this traditional management, which in a global warming context might be best avoided.

Thesis declaration

This work contains no material which has been accepted for award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. The Author acknowledges that copyright of the published works contained within this thesis (as listed below) resides with the copyright holders of those works. I also give permission for the digital version of my thesis to be made available on the Web, via the University's digital research repository, the library catalogue, The Australian Digital Thesis Program (ADTP) and also through wed search engines, unless permission has been granted by the University to restrict access for a period of time.

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Publications

This thesis contains published work:

Chapter 2:
Caravia L, Collins C and Tyerman SD (2015) Electrical impedance of berries correlates with decreasing cell vitality during ripening in Shiraz. Australian Journal of Grape and Wine Research. AJGWR-15-088

Related Publications Arising During Candidature

Chapter 5:
Caravia L, Collins C, Shepherd J and Tyerman SD (2015) Wrapping arms for cordon establishment: is it a stressful practice for grapevine? Wine and Viticulture Journal, Vol. 30, No. 1, Jan/Feb 2015: 48-50.

Caravia L, Collins C, Shepherd J and Tyerman SD (2015) Wrapping arms for cordon establishment could be a stressful practice for grapevine. Wine and Viticulture Journal, Vol. 30, No. 6, Nov/Dec 2015: 46-50.

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Dedication

To my father Luciano who could not see this achievement, but he has been an inspiration for me to go beyond my limitations. To my grandma Betty and my mother Sonia who have inspired me with their life and for their unconditional love.