INFLUENCE OF SUSTAINED DEFICIT IRRIGATION ON PHYSIOLOGY AND PHENOLIC COMPOUNDS IN WINEGRAPES AND WINE

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ABSTRACT

Wine grape production in the semi-arid regions of Australia is successful due to the availability of irrigation water. Whilst water is a natural resource it is also becoming extremely valuable. In the hot and semi-arid regions of Australia, the prospect of water restrictions from drought and intensifying horticultural and domestic competition for water has prompted the grape and wine industry to implement strategic deficit irrigation practices to try and maintain sustainable wine grape production. Sustained deficit irrigation (SDI) differs significantly in its management to partial rootzone drying and regulated deficit irrigation and is a technique that could potentially be easily adopted across the winegrape industry if water allocations were reduced. With SDI, the water deficit is not created by withholding water, but rather, by applying a lesser volume of water at each irrigation event for the entire irrigation season.

This study aimed to understand the physiological behaviour of wine grape cultivars to SDI and how this deficit irrigation strategy would influence yield and composition of the grapes and wine. The trials were conducted during 2003-2006 on the cultivars Cabernet Sauvignon and Shiraz grafted to 140 Ruggeri (*V. berlandieri* x *V. rupestris*) rootstock and grown in the Murray-Darling region of Australia. Furthermore, while Cabernet Sauvignon and Shiraz are the main red winegrape varieties grown in the Murray-Darling region, anectodally they are observed to respond differently to hot, dry conditions when managed under similar irrigation regimes. The vines were drip irrigated providing 100% of estimated ET_c (control) and three graded sustained water deficits (Cabernet Sauvignon 70%, 52% and 43% of the control; Shiraz 65%, 45% and 34% of the control). For each season, the volume of actual water applied (ML/ha) was calculated for each irrigation treatment and varied depending on seasonal and vineyard conditions. To further explore vine responses to water deficit, glasshouse studies on four own-rooted *Vitis vinifera* L. cultivars, including Cabernet Sauvignon, Shiraz, Grenache and Tempranillo were also conducted.

Deficit irrigation management, whilst controlling vegetative growth and manipulating berry composition, may not always produce consistent outcomes among grapevine varieties. This has lead to the observation that deficit irrigation management strategies may need to be tailored to individual grape cultivars. Consequently, an understanding as to how certain

grapevine varieties respond to water deficit, particularly in relation to physiological responses, could assist with linking any impacts that water deficits may have on grape and wine composition. Field-grown Cabernet Sauvignon and Shiraz exposed to approximately 50% SDI experienced significant reductions in leaf water potential and stomatal conductance compared to the control. By contrast, xylem sap abscisic acid (ABA) levels increased significantly for the SDI-treated vines compared to the control that is probably related to root to shoot signals and canopy-derived ABA. Under field situations, Cabernet Sauvignon displayed physiological responses more typical of an isohydric-like (drought avoiding) vine, compared to the anisohydric-like (drought tolerant) responses of Shiraz. These responses may also be supported by the pattern of xylem sap [ABA] production. The differences in canopy development (leaf area index and pruning weights) for Cabernet Sauvignon and Shiraz may be a reflection of the isohydric-like and anisohydric-like responses of these grape varieties to water deficit, thereby influencing carbohydrate dynamics and long-term viability of vine health under SDI.

After three seasons, the SDI treatments significantly reduced yield of the field-grown vines, primarily due to a reduction in berry weight that tended to occur from the beginning of veraison through to harvest. SDI reduced yield (t/ha) by up to 30% in Cabernet Sauvignon and Shiraz, when applied at approximately 50% of the control irrigation (ML/ha). Irrespective of the yield reductions, water use efficiency was improved between 40-50% for the SDI-treated Cabernet Sauvignon and Shiraz, compared to the control. The lighter berries from SDI-treated vines tended to have increased pH and decreased titratable acid levels than the control. The SDI treatments applied at approximately 50% of the control increased the concentration of total anthocyanins in Cabernet Sauvignon and Shiraz berries by 22% and 15% respectively. As less water was applied there was an increase in total malvidin concentration for both varieties, with less effect on delphinidin, peonidin, petunidin and cyanidin for Cabernet Sauvignon and peonidin, petunidin, delphinidin and cyanidin for Shiraz. The increase in total anthocyanin and total phenolic concentrations for the SDI treatments than the control is attributed more to factors such as water deficit, canopy light penetration and/or changes in phenolic synthesis, than to differences in berry size (skin surface area to pulp volume ratio).

Differences in grape anthocyanins and phenolics between the irrigation treatments were not the same as those measured in the wine. A decrease in berry weight did not alter the skin weight to berry weight ratios, and were therefore unlikely to be the cause of the altered composition of SDI wines. The increases in wine colour with SDI treatment may be the result of biochemical changes in the flavonoid pathway as a result of altered grapevine physiology responses to the SDI. Alternatively, the increases in red wine colour could possibly be due to a change in chemical properties of the anthocyanins to copigmented forms that may have influenced extractability efficiency during the winemaking or ageing process.

This research showed that an SDI of approximately 50% less water could be applied over one or two seasons with improvements in water use efficiency (t/ML) and berry composition compared to fully irrigated vines. Furthermore, for Cabernet Sauvignon exposed to 70% and 52% SDI there tended to be improvements in the overall wine composition and sensory ranking than the control. However from an economic perspective, net returns were not largely affected by using SDI based on the current grape prices. If water becomes a more highly valued resource and priced accordingly, then a larger increase in net return will result from SDI. Additionally, wineries would need to offer price incentives to produce lower yields that may result from adopting SDI. Overall, if the wine industry was faced with reductions in water allocations of 50% or more in a particular season, then the adoption of SDI may be a feasible solution to maintaining winegrape production for the short-term. Through understanding the translation of grape composition into wine, these findings should be able to provide additional knowledge to the Australian grape and wine industry as to how SDI can be used to manipulate grape composition for the production of sustainable wine styles.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma 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.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signed: ……………………………………………………. Date:……………………

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LIST OF ABBREVIATIONS

ABA	abscisic acid
au	absorbance units
^{o}C	degrees Celsius
CE	catechin equivalents
cm	centimetres
CS	Cabernet Sauvignon
df	degrees of freedom
Epan	pan evaporation
ET_c	crop evapotranspiration under
ET_o	reference crop evapotranspiration (grass reference crop)
g	grams
g_s	stomatal conductance
GC-MS	gas chromatography/mass spectroscopy
GDD	growing degree days
GR	Grenache
h	hour
ha	hectare
HCl	hydrochloric acid
HPLC	high performance liquid chromatography
kg	kilograms
kPa	kilopascals
L	litre
LAI	leaf area index
LSD	least significant difference
LWP	leaf water potential
m	metre
mg	milligram
mm	millimetres
min	minute
mL	millilitre
ML	megalitre

MPa	megapascals
n	number of samples
ng	nanogram
nm	nanometre
ns	not significant
NSW	New South Wales
P	probability for data
pH	-log[H^+]
ppm	parts per million
PRD	partial rootzone drying
r	correlation coefficient
r^2	coefficient of determination
RDI	regulated deficit irrigation
rpm	revolutions per minute
s	second
SC	stomatal conductance
SDI	sustained deficit irrigation
s.e.	standard error of the mean
SHZ	Shiraz
t	tonnes
TA	titratable acidity (g/L tartaric acid)
TE	Tempranillo
TSS	total soluble solids (^{o}Brix)
μL	microlitre
UV	ultra-violet
Vic	Victoria
VPD	vapour pressure deficit
WUE	water use efficiency
Ψ_l	leaf water potential

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