INTEGRATED IRRIGATION AND CANOPY MANAGEMENT STRATEGIES FOR *VITIS VINIFERA* CV. SHIRAZ.

A thesis submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy at The University of Adelaide

By

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Rachel Margaret Ashley
15 September 2004

Dedicated to the memory of Eve Cottral.

SUMMARY

Modern canopy management practices and irrigation strategies have improved the economic and environmental sustainability of Australia's wine industry, in terms of increased production and improved wine quality for minimal production cost and environmental impact. This study tested the hypothesis that partial rootzone drying (PRD) integrated with low input, minimal pruning practices can improve sustainability of winegrape production in warm-climate, irrigated vineyards. The bi-factorial experiment investigated three conventional pruning practices; hand spur pruning (SPUR), mechanical hedging (MECH) and minimal pruning (MIN) integrated with standard drip (SD) and PRD irrigation strategies. The sustainability of winegrape production of field-grown cv. Shiraz grapevines was determined by examining yield, fruit composition, wine composition and quality, vine physiology and susceptibility of bunches to Botrytis bunch rot.

Winegrape production was strongly influenced by pruning level and the resultant bunch number per vine. Increased node retention at pruning of minimal pruned vines resulted in 4-fold more bunches per vine than spur pruned vines. Mechanical hedged vines had an intermediate number of bunches per vine. Yield generally reflected the trend in bunch number per vine. However, minimally pruned and mechanically hedged vines compensated for greater carbohydrate partitioning between reproductive sinks by producing smaller bunches with fewer berries per bunch. Partial drying of the grapevine rootzone had a detrimental effect on yield relative to SD irrigation (18%). The additive effect of SD combined with light pruning treatments resulted in few statistically significant interactions for the measured yield components. Berry weight was the only parameter influenced by the interaction between irrigation and pruning during the three experimental seasons; PRD + MIN reduced berry weight by 36% compared to SD + SPUR, in response to lower irrigation inputs and higher bunch number. A 2-fold increase in water use efficiency (tonnes per megalitre) was found by the reduced irrigation inputs of PRD combined with the high crop levels of MIN vines compared to SD + SPUR vines.

Fruit and wine composition was also largely unaffected by combined irrigation and pruning treatments, as a result of the additive effect of PRD and MIN. However, light pruning levels (MIN and MECH) and their associated small berry size and high bunch exposure, reduced

pH and increased titratable acidity, and anthocyanin and phenolic concentrations of berry juice compared to SPUR. Minor pruning level effects on wine composition can be directly correlated with those observed on fruit composition. PRD had minimal effect on basic fruit composition but strong effects on wine spectral parameters: density, hue, total anthocyanin and phenolic concentration and ionised anthocyanin concentration, possibly as a result of co-pigmentation of anthocyanin compounds with exocarp tannins. Berry size was strongly correlated with fruit and wine quality. Small berries (i.e. from PRD and MIN) had lower pH and higher anthocyanin and phenolic concentrations in the juice and produced wine that was more acidic, brighter and had higher colour density and anthocyanin (total and ionised) and phenolic concentrations than all other treatments.

Midday and diurnal leaf gas exchange were manipulated by partially drying the rootzone. PRD reduced midday stomatal conductance, photosynthesis and transpiration compared to SD. Stomatal limitation on photosynthesis and transpiration was probable, given the strong positive relationship with stomatal conductance and reduced carbon isotope discrimination by PRD. Transpiration efficiency was improved for PRD irrigated vines compared to SD irrigated vines. Leaf water potential and osmotic potential were measured diurnally, in conjunction with leaf gas exchange to investigate the response of PRD irrigated vines to increasing vapour pressure deficit. Diurnally, stomatal conductance was reduced by PRD compared to SD, which maintained leaf water potential, while no osmotic adjustment occurred. Therefore, PRD irrigation maintained hydraulic water status by hydrating half of the rootzone, whilst dehydration of the other half of the rootzone resulted in the partial closure of stomata. Pruning treatment effects on vine physiology were less pronounced. Minor gas exchange effects showed that pruning level influenced carboxylation efficiency and not stomatal limitations, as photosynthesis was not directly correlated with stomatal conductance.

Bunches were least resistant to infection by Botrytis when fully developed and at maximum maturity. The development of bunches into tighter clusters as berry size increased from veraison to harvest and the increase in sugar content may have encouraged development of Botrytis. The distinct bunch architecture resulting from the combined pruning and irrigation treatments influenced the incidence and severity of Botrytis bunch rot. Light pruning combined with PRD irrigation produced small, loose bunches in season 2001-02, which

were less susceptible to Botrytis bunch rot development compared to the large, compact bunches produced on SD + SPUR vines. However, low bunch numbers and high fruit-set on MIN and MECH vines in season 2002-03 led to a significant change in bunch architecture. As a consequence of the increased compactness of bunches in season 2002-03, no pruning effects on Botrytis development were observed.

Long term economic and environmental sustainability of winegrape production is dependent on continual improvement in fruit and wine quality, preservation of yield, reduced water and chemical usage. This study has shown partial drying of the rootzone combined with light pruning techniques improved yield, fruit and wine composition, water use efficiency and transpiration efficiency and reduced the incidence and severity of Botrytis bunch rot compared to SD and severe pruning levels. Therefore, over the three experimental seasons, PRD combined with minimal pruning was determined as the preferred strategy to enhance the sustainability of winegrape production of Shiraz cv. in warm-climate, irrigated vineyards.

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LIST OF ABBREVIATIONS

Abbreviation	*Explanation and Units*
PRD	Partial rootzone drying
SD	Standard commercial practice drip irrigation
SPUR	Hand spur pruning
MECH	Mechanical hedging
MIN	Minimal pruning
PAR	Photosynthetically active radiation ($\mu mol.s^{-1}.m^{-2}$)
DAB	Days after budburst
DAF	Days after flowering
DAI	Days after irrigation
AEDT	Australian Eastern Daylight Savings Time
LSD	Least significant difference
θ_v	Volumetric soil-water content (%)
T	Temperature (°C)
RH	Relative humidity (%)
VPD	Vapour pressure deficit (kPa)
SGR	Shoot growth rate ($cm.day^{-1}$)
LA	Leaf area per vine (m^2)
LA:F	Leaf area to fruit ratio ($m^2.g.vine^{-1}$)
WUE	Water use efficiency ($t.ML^{-1}$)
TSS	Total soluble solids (°Brix)
TA	Titratable acidity ($g.L^{-1}$)
α	Percentage of anthocyanin ionisation (%)
g_s	Stomatal conductance ($m\ mol.m^{-2}.s^{-1}$)
A	Net leaf photosynthesis ($\mu mol.m^{-2}.s^{-1}$)
T	Net leaf transpiration ($\mu mol.m^{-2}.s^{-1}$)
A/T	Transpiration efficiency ($\mu mol.mmol^{-1}$)
Ci	Internal leaf carbon dioxide concentration ($\mu mol.mol^{-1}$)
Ca	Atomospheric carbon dioxide concentration ($\mu mol.mol^{-1}$)
Δ	Carbon isotope discrimination
Ψ_L	Leaf water potential (MPa)
Ψ_S	Osmotic potential (MPa)
SS	Surface sterilisation
NS	Non-surface sterilisation

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