THE EFFECT OF PARTIAL ROOTZONE DRYING ON THE PARTITIONING OF DRY MATTER, CARBON, NITROGEN AND INORGANIC IONS OF GRAPEVINES

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Declaration

I hereby declare that this thesis contains no material that has been accepted for the award of any other degree or diploma at any University. To the best of my knowledge and belief, no material described herein has been previously published or written by any other person, except where due reference is made in the text.

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Publications

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Summary

Partial rootzone drying (PRD) is an irrigation management technique designed to reduce water use in grapevines without a decline in yield, thereby increasing water–use efficiency (measured as t/ML) (WUE). The principle of PRD is to keep part of the root system at a constant drying rate to produce soil-derived signals to above-ground plant organs to induce a physiological response. Major PRD effects include a reduced canopy size and greatly increased WUE with possible improvements in fruit quality. Although we have a good understanding of the hormonal physiology of PRD, little is known on the effect of PRD on partitioning of C, N and inorganic ions such as K. This thesis broadens our knowledge on the effects of PRD on grapevine field performance, growth and dry matter accumulation as well as its effects on physiology and biochemistry. In field experiments over 3 seasons, PRD reduced water use in grapevines without a significant decline in yield. PRD effects included reduced shoot growth and greatly increased WUE. Field-grown Cabernet Sauvignon, where the PRD grapevines were irrigated at half the control rate, and Shiraz where the PRD grapevines were irrigated at same rate as controls, confirmed that PRD is not simply an irrigation strategy that applies less water, rather it alters the way in which the plant responds to its environment, e.g. PRD alters the sensitivity of the stomatal response to atmospheric conditions and significantly influence enzymes that regulate nutrient accumulation and partitioning. PRD did not change the total amount of carbon and nitrogen on a whole plant basis. However, it caused a significant partitioning of carbon and nitrogen towards trunk, roots and fruit at the expense of shoot growth. This change in partitioning occurred as a result of altered activity of the enzymes controlling the assimilation of carbon and nitrogen. PRD significantly reduced nitrate reductase (NR) activity in grapevine leaves, which catalyses the first step in the assimilation of nitrate irrespective of the amount of water applied. The reduction in NR activity is correlated with the development of the PRD cycle and the associated reduction in stomatal conductance.

PRD also significantly altered grapevine sucrolytic enzyme activity that regulate source:sink relationships. PRD showed transient increases in leaf sucrose phosphate synthase (SPS) activity (formation of sucrose) compared to control, but significantly reduced leaf neutral invertase (sucrose cleavage) and leaf starch content in both field and potted experiments. This may indicate an increased photosynthetic capacity and a reduction in its sink strength for sucrose in favor of organs such as fruit and roots. This hypothesis was reinforced by the fact that berries showed significantly higher levels in glucose and fructose early in the season. Berry sugar content and Brix at harvest however was unaffected. Although PRD had no significant effect on berry characteristics at harvest such as Brix and pH, it occasionally reduced per berry K^+ content and increased total amino acid concentration that may lead to positive outcomes for wine quality.

PRD-treated grapevine roots on the ‘wet’- and ‘drying’-sides differed greatly in enzyme activity and osmolality. PRD significantly increased osmolality in both wet and drying roots by increasing total osmolyte concentration that may facilitate the movement of water from wet to dry roots. The increases in osmolality were also associated with increased free polyamine production (spermidine and spermine) in PRD roots that may be related to increased root growth and density.

List of Abbreviations

ABA	abscisic acid
ADC	arginine decarboxylase
AI	acid invertase
GWRDC	Australian Grape and Wine Research Development Corporation
*C*i	intracellular CO_2 concentrations
CK	cytokinins
CSIRO	Commonwealth Scientific & Industrial Research Organization
°C	degrees Celsius
ET_o	evapotranspiration
FAA	free amino acid
FAN	free amino nitrogen
GDD	growing degree days
GOGAT	glutamine synthase/glutamate synthase
g_s	stomatal conductance
GS	glutamine synthase
IRGA	infrared gas analysis instrument
LA	leaf area
NADPH	nicotinamide adenine dinucleotide phosphate
NCCs	nitrogen-containing compounds
NI	neutral invertase
NR	nitrate reductase
PAR	photosynthetic active radiation
PAs	polyamines
Pn	photosynthesis
PRD	partial rootzone drying
RH	relative humidity
RuBP	ribulose- 1,5- bisphosphate
s.e.	standard error of the mean
SPS	sucrose phosphate synthase
SucSy	sucrose synthase
TDR	time domain reflectometry
TSS	total soluble solids
VSP	vertical shoot positioning
WUE	water use efficiency
Ψ_L	leaf water potential

Table of contents

List of figures

List of tables