
Grapevine root hydraulics: The role of aquaporins

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Abstract

Hydraulic conductance of roots of the grapevine cultivar, Chardonnay, varies diurnally, peaking at 1400 h. The diurnal amplitude of hydraulic conductance between 600 and 1400 h was not altered when potted grapevines were water-stressed by withholding water for 8 days. However, the diurnal change was greatly reduced for water-stressed Grenache. If the diurnal change in root hydraulic conductance is a result of changes in aquaporin gene expression or activity, it suggests that aquaporins respond differently in water-stressed Chardonnay and Grenache roots. Both Chardonnay and Grenache demonstrated a reduction in hydraulic conductance in response to water stress, with Grenache exhibiting a larger reduction. Suberisation of the roots increased in response to water stress, with complete suberisation of the endodermis occurring closer to the root tip of Grenache compared to the more drought sensitive Chardonnay. The drought sensitive rootstock, 101-14 (*V. riparia* × *V. rupestris*) demonstrated a similar reduction in hydraulic conductance to Chardonnay, while drought tolerant 1103 Paulsen (*V. berlandieri* × *V. rupestris*) had a non-significant reduction when water-stressed compared to the large reduction observed for drought tolerant Grenache. Therefore, in this study the degree of reduction in hydraulic conductance did not relate to the drought tolerance of the four varieties examined.

The impact of partial drying (watering only half the root system) on hydraulic conductance also differed between Chardonnay and Grenache. There was no change in the conductance of the whole root system of Chardonnay due to an increase in conductance of the roots in the wet half which compensated for the reduction on the dry side. In contrast, Grenache did suffer a reduction measured over the whole root system due to a much larger reduction on the dry side compared to Chardonnay. There was an increase in hydraulic conductance on the wet side but this could not compensate for the large reduction on the dry side.

Two aquaporins (*VvPIP1;1* and *VvPIP2;2*) were cloned from the roots of grapevine cultivar Chardonnay. The genes were expressed in *Xenopus* oocytes to determine their osmotic permeability. As has been shown in a number of plant species,

VvPIP1;1 was only slightly permeable to water, whereas VvPIP2;2 did transport water. However, when VvPIP1;1 was injected into the oocytes with VvPIP2;2, there was a substantial increase in the osmotic permeability. There was no significant variation in the diurnal expression of *VvPIP2;2*, whereas *VvPIP1;1* showed a peak in expression at 1000 h prior to the peak in hydraulic conductance and peaked again at 1800 h. *VvPIP2;2* did not vary in transcript level in response to water stress or rewatering in Chardonnay or Grenache roots. The level of *VvPIP1;1* doubled in water stressed Chardonnay roots and declined again when the vines were rewatered 24 h previously. This response to water stress did not occur in Grenache roots. The roots used were from the apical 5 cm. Similar roots were used to measure the water permeability of the cortical cell membranes using the cell pressure probe. Changes in cell membrane permeability in response to water stress corresponded to changes in *VvPIP1;1* expression.

An experiment to determine if shoot topping had an effect on root hydraulic conductance revealed a significant 50% decline. This response was also observed in soybean (*Glycine max* L.) and maize (*Zea mays* L.). A range of experiments have been performed to determine the reason for the decline. Possibilities included a response to final leaf area and reduced transpirational demand; loss of a carbohydrate sink; or hormonal signals such as abscisic acid, auxin and ethylene. At this stage the nature of the positive or negative signal that causes the change in root hydraulic conductance remains elusive. However, the signal did cause a reduction in the transcript level of *VvPIP1;1*, indicating the involvement of aquaporins in the response.

The root hydraulic conductance of grapevines is variable and dependent on factors such as time of day, water-stress, transpiration rate and unknown signals from the shoot. A proportion of this variability is due to changes in aquaporin number or activity. There are also genotypic differences which may be beneficial for future breeding efforts to improve water use efficiency of grapevines.

Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution. 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 has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being made available in all forms of media, now or hereafter known.

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List of Abbreviations

ABA	abscisic acid
E	transpiration rate per unit leaf area ($\text{mmol.m}^{-2}.\text{s}^{-1}$)
ε	cell volumetric elastic modulus (MPa)
g_s	stomatal conductance ($\text{mmol.m}^{-2}.\text{s}^{-1}$)
HCFM	hydraulic conductance flow meter
l	cell length (μm)
L_l	root hydraulic conductance normalised to leaf area ($\text{kg.s}^{-1}.\text{MPa}^{-1}.\text{m}^{-2}$)
L_o	root hydraulic conductance normalised to root dry weight ($\text{kg.s}^{-1}.\text{MPa}^{-1}.\text{g}^{-1}$)
L_p	root hydraulic conductivity normalised to root surface area ($\text{m.s}^{-1}.\text{MPa}^{-1}$)
L_{pcell}	cell membrane hydraulic conductivity ($\text{m.s}^{-1}.\text{MPa}^{-1}$)
Ψ_{leaf}	leaf water potential (kPa)
Ψ_{stem}	stem water potential (kPa)
MIP	major intrinsic protein
NIP	NOD26-like intrinsic protein
P	turgor pressure (MPa)
PD	partial drying
PIP	plasma membrane intrinsic protein
PRD	partial rootzone drying
RDI	regulated deficit irrigation
r	cell radius (μm)
SIP	small basic intrinsic protein
SWC	gravimetric soil water content (g.g^{-1})
$T_{1/2}$	relaxation half time (s)
TIP	tonoplast intrinsic protein

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