Grapes could suffocate under drought and high temperatures

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Background

Global temperatures and the frequencies of heatwaves and drought events are increasing due to climate change. This challenges the wine industry, since temperature and water are important factors affecting the growth and physiology of grapevines. Particularly, berry ripening under stressful conditions could result in substantial loss of mass due to cell death within the berry and shrivel, which may negatively affect grape quality and lead to higher alcohol wines. We hypothesised that high temperatures may lead to oxygen deficiency (hypoxia) within grape berries due to the greater demand for oxygen by respiration, and also reduced oxygen diffusion within the berry due to water stress.

Objectives

1. Measure berry internal oxygen concentrations ([O_2]) in different grape cultivars.
2. Investigate association of berry internal [O_2] with berry cell death.
3. Test whether stressful conditions (heat and water stress) are linked to berry internal [O_2].

Key findings

1. **Berry internal [O_2] of Chardonnay, Shiraz and Ruby Seedless, during berry ripening, was correlated with changes in berry cell death.**
2. **Close similarity between the pattern of cell death across the berry mesocarp and the [O_2] profile was observed (Fig. 1).**
3. **Lenticels are an important pathway for berry oxygen uptake (Fig. 2 & 3).**
4. **[O_2] increased towards the berry central axis (Fig. 1).**
5. **Water stress decreased Shiraz berry internal [O_2] (Fig. 5) and increased cell death.**

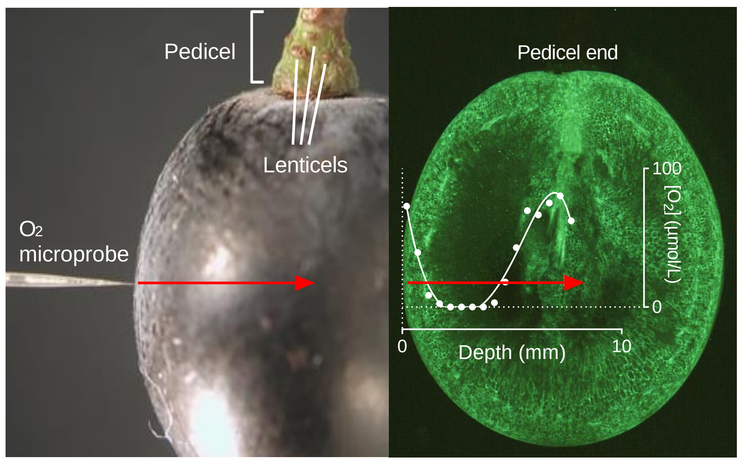

Figure 1 Probing a Shiraz berry to measure [O_2] profiles within the flesh. The berry pedicel can be seen with lenticels on the surface (left). Oxygen profile across a Chardonnay berry shows that [O_2] decreases from the surface towards the middle region of the flesh and increases towards the central vascular bundles (right).

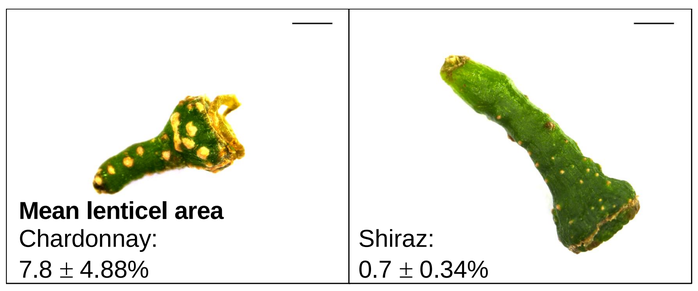

Figure 2 Differences in lenticel morphology and relative lenticel area between Chardonnay and Shiraz berry pedicels. Chardonnay showed higher mean lenticel area relative to pedicel surface area compared to that of Shiraz berries (t-test, $P < 0.05$). Scale bars = 1 mm. Data are means ± SE, n = 5.

Main methods

1. Berry internal [O_2] of seeded (Shiraz, Chardonnay) and seedless (Ruby Seedless) grapes was measured using oxygen micro-sensors.
2. Berry cell death was assessed using fluorescent diacetate (FDA) vital stain.
3. Micro CT was used to visualise the grape locule (Fig. 4).
4. A field trial was implemented to investigate the effect of heat and drought on Shiraz berry cell death and internal [O_2] in Nuriootpa (2014/2015 and 2015/2016).

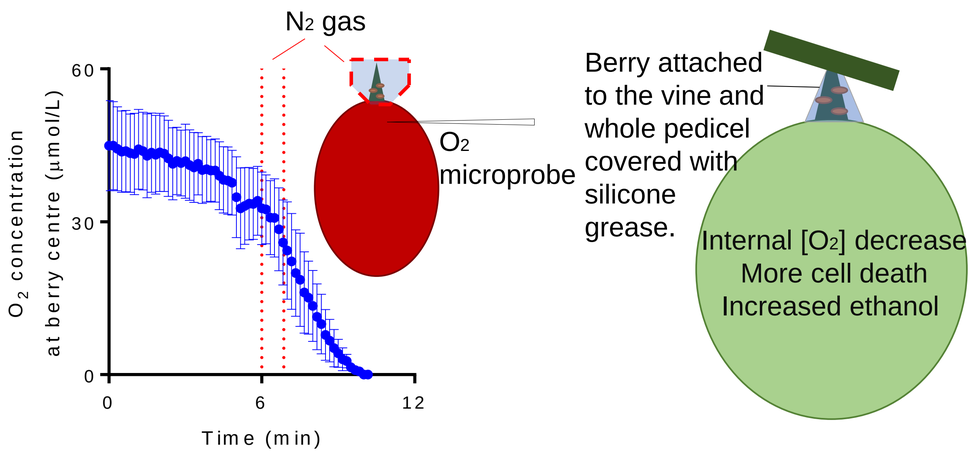

Figure 3 Flushing nitrogen (N_2) gas around the pedicel caused an immediate drop in [O_2] in the central axis of the berry which approached to near zero after 4 minutes (left). Blocking lenticels on berry pedicels, still attached to the vine, decreased berry internal oxygen concentration, increased ethanol within the berries and resulted in increased berry cell death (right).

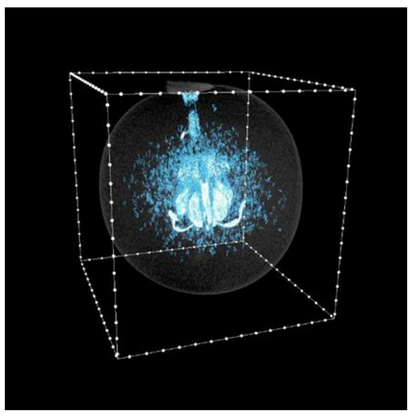

Figure 4 Air spaces in a Chardonnay berry (around 100 days after anthesis) as determined by X-ray micro-CT. Image has been manipulated to indicate the berry outline. White dots on the box outline are at 1 mm intervals.

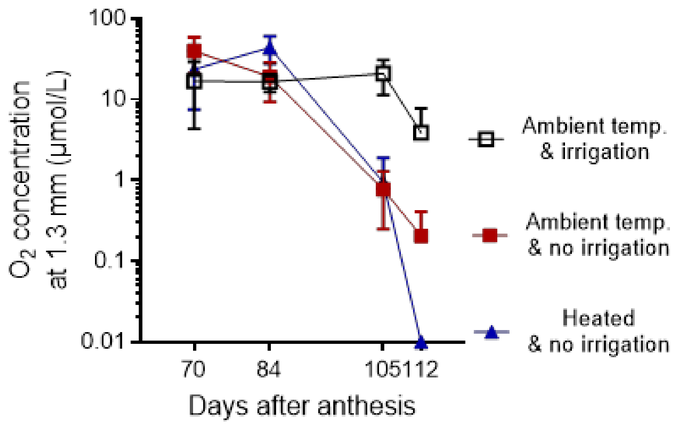

Figure 5 [O_2] at 1.3 mm beneath the skin of Shiraz berries at different stages of development under the field treatments. Data are means ± SE, n = 3.

Conclusion

The reduced berry internal oxygen concentration is related to the reduction in air space and percentage of living tissue. Cell death, and by implication berry shrivel, are strongly linked to oxygen supply and demand. This new knowledge on how grapes uptake oxygen provides the basis for further research into berry quality and cultivar selection for adapting viticulture to a warming climate.

Publications

Xiao Z, Liao S, Rogiers S.Y., Sadras V.O., Tyerman S.D. (2018) Effect of water stress and elevated temperature on hypoxia and cell death in the mesocarp of Shiraz berries. Australian Journal of Grape and Wine Research Vol. 24, 487-497.

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FOR MORE INFORMATION

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