Berry desiccation: developing pre-emptive methods to adapt to heat spikes and dry conditions

Mount Langi Ghiran vineyard, in Western Victoria, in collaboration with The University of Melbourne, is researching compounds in vineyards to mitigate the impacts of extreme heat events. Research outcomes show treatments can reduce berry desiccation at statistically significant levels.

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Extreme heat events can be termed an abiotic stress factor, which may have direct and indirect impacts on vine physiology, fruit integrity and, ultimately, wine quality.

Climate change modelling has predicted increased frequency in extreme weather events such as heatwaves (Intergovernmental Panel on Climate Change, 2007). Webb *et al* (2009) documented the heatwave experiences of many winegrowing regions during January and February of 2009 and identified issues such as berry desiccation and arrested berry development in Pinot Noir.

Keller (2010) identified that consistent, uniform grape composition was positively associated with quality wine production. Therefore, if heat spikes increase ripening asynchronicity and damage to berry integrity, then the outcome of heat stress is reduced fruit (and wine) quality.

Anecdotal evidence supports the association between berry desiccation and detrimental sensory effects, with an understanding that raisining imparts a "dead fruit" character in wine and contributes to higher potential alcohol. Assuming predicted climatic scenarios are correct (Webb *et al*. 2007), the wine industry needs to plan for, and mitigate, such events.

Research identifies different types of berry shrivel syndromes (Krasnow *et al*. 2009; B. Bondada (pers.comm. 2 July 2010). Certain types of berry shrivel have their own idiosyncratic symptoms, for example late season dehydration in Shiraz occurred in the trial site about 95 days post-anthesis and the loss of berry weight is more closely related to anthesis than other determinants, such as temperature summation. (McCarthy, pers. comm, 17 Jan 2011; McCarthy 1999).

In our research, berry desiccation appears to be a suitable descriptor for the issue, being less associated with the various types of shrivels described by Bondada (pers.comm. 2 July 2010), but more associated with extreme heat events during the ripening period (Webb *et al*. 2009).

An ongoing vineyard trial at Mount Langi Ghiran (Grampians, Victoria, Australia), in conjunction with The University of Melbourne is investigating the impact of heat spikes and dry conditions, aiming to maintain fruit and wine integrity under these weather conditions.

On-vineyard research work identified that increased berry desiccation was correlated to basal leaf senescence (Scarlett, 2009), which suggests a physiological (stress) signalling component such as abscisic acid may be involved (Loveys *et al*. 2004). Trials have identified (and eliminated) a number of mitigation treatments. Research has also shown the limitations of irrigation in reducing desiccation under extreme heat events in Mount Langi Ghiran Shiraz and in Pinot Noir at Yering Station, Yarra Valley, Victoria, with foliar treatments reducing shrivel levels beyond irrigation affects (Scarlett 2009).

Positive outcomes have been shown with low-analysis, inorganic macro-nutrient fertiliser (NPK) with trace elements and organic seaweed extract. Apparent amplification of positive responses was identified when NPK and seaweed extract was combined with the osmoregulator, glycine betaine.

Recent vintages have seen below average rainfall resulting in low water storage in dams. This meant the most obvious tool of mitigating extreme heat events via strategic irrigation was not readily available; hence foliar treatments were used in the trials.

Glycine betaine (*N,N,N*-trimethyl glycine) is a non-toxic, water-soluble, organic compound known to have a role in plant adaptive response to abiotic stress at a cellular level (Sakamoto and Murata 2002) Under hot, cold, dry and salty conditions, glycine betaine can aid maintenance of cellular turgor pressure, the integrity of enzymes, protein complexes and cell membranes. Hackett (2009) discusses the potential of extreme heat events to inhibit photosynthesis via enzyme denaturation and destruction of photosystem complexes, which may be mitigated by glycine betaine due to its ability to stabilise the oxygen-producing photosystem II (Sakamoto & Murata 2002). Certain areas of glycine betaine modes of action remain unclear and are subject to further research. This trial was instigated to further investigate the role of glycine betaine to ameliorate grape berry desiccation in Victorian Shiraz.

Materials and methods

The aim of this field trial was to investigate the role of glycine betaine in combination with other foliar treatments to reduce shrivel in Shiraz grapes. The grapes from each treatment were made into wine and assessed for common quality parameters.

Vineyard foliar treatment

Previous research outcomes directed us to select a range of heat mitigation compounds which we could apply to the canopy by spraying (foliar). There were four

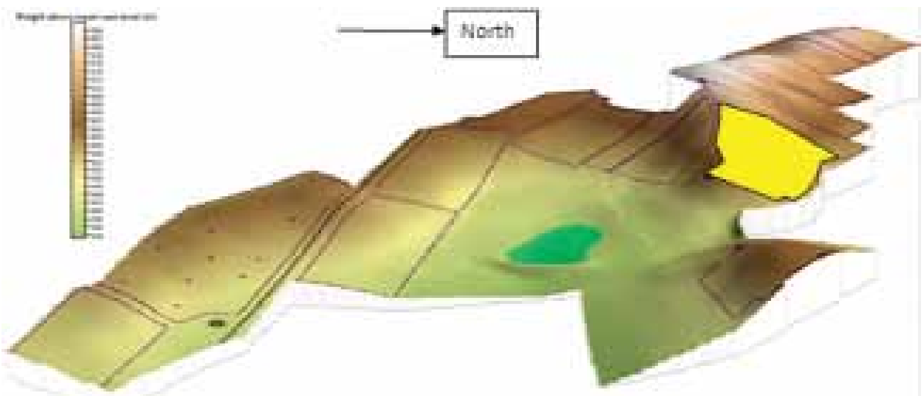


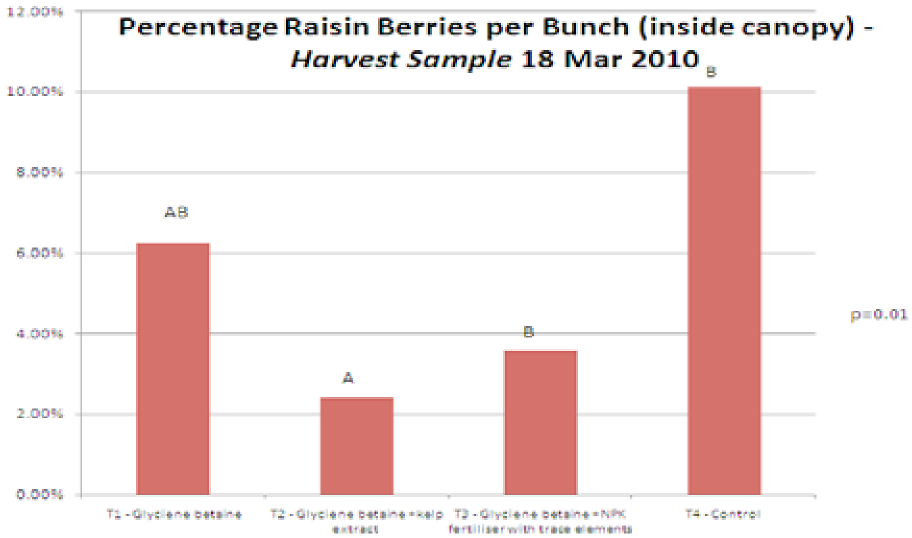
Figure 1: The Mount Langi Ghiran vineyard block where the trial occurred (trial area coloured in yellow).

treatments; Treatment 1: Glycine betaine, Treatment 2: Glycine betaine + Certified Organic Kelp Extract, Treatment 3: Glycine betaine + inorganic fertiliser NPK +trace and Treatment 4: Control Treatments were applied at three dates, 8 Jan 2010, 22 Jan 2010 and 12 Feb 2010.

The foliar treatments were applied with a standard vineyard fungicide unit prior to heat spikes beginning after Christmas (pre-veraison, Scarlett 2009). Timing of treatments was strategic, aiming to reduce abiotic stress on the vines at a key reproductive stage and/or when maximum environmental stress was likely. Treatments were applied to a north facing 2.5 hectare Shiraz block, 352-370m above sea level (37º 18S, 143º09E) with north-south rows on Mount Langi Ghiran (Estate vineyard) identified in yellow in Figure 1. The vineyard design is 2469 vines per hectare (2.7x1.5), own-rooted, cane pruned, VSP canopy with no shoot-thinning and one wire lift. This block was chosen due to its sufficient size and for consistency of soil type, aspect (north), vine age and vine vigour. Treatments (replicated twice) were applied in three rows, with three buffer rows separating each treatment.

Assessment

A destructive randomised sampling regime was undertaken to assess the impacts of treatments on fruit composition. We collected 100 berry samples and six bunch samples were taken for each of the replicate treatments about two weeks apart. Both exposed and shaded bunches were randomly sampled. Leaf samples were taken (fifth leaf above the basal node) from each of the replicates. Wine was also made from each of the treatments, consolidated in 2 tonne open fermenters, inoculated with the same *Saccharomyces cerevisiae* yeast culture and acid/sulfur adjusted as occurs in the winery.



Graph 1: Percentage desiccated Berries per Bunch (at harvest 18 March 2010) with letters representing treatment statistical differences.

A number of analyses were carried out on the berry, bunch and leaf samples as well as the wine, including total soluble solids (TSS), acid, colour, raisined berries per bunch, berry weight, yeast assimilable nitrogen (YAN), yield, petiole tissue composition, alcohol, volatile acidity, malic acid and residual sugar. Standard procedures were followed for all of the above winery analyses. Obvious longitudinal berry skin striations were used as a determinant of desiccation, to accurately decipher turgid and raisined fruit.

Results and discussion

Bunch-zone data loggers (TinyTag™) observed seven days over 35 degree during the 32 days of logging. Bureau of Meteorology data (Ararat Prison) shows average number of days over 35 degree for the entire months of February and March as 2.7 days and 0.7 days, respectively. Observations from the data loggers show maximum daily temperatures fall into the Bureau of Meterology's Decile 1 maximum (10th percentile of maximum temperatures). Therefore, it is reasonable to suggest the hot conditions experienced during the trial can be described as being an 'extreme heat event'.

Treatments varied in their ability to reduce desiccation, however, treated vines had lower desiccated berries per bunch than control vines, confirming work from a previous trial (Scarlett 2009). Vines from all treatments had no obvious differences in leaf colour/health. During vineyard sampling differences in berry raisin levels were not immediately obvious but, on further analysis, statistically significant effects of treatments was identified.

The grapes sampled on 3 March showed minimal berry desiccation levels, however by 18 March, desiccated fruit was present in the bunches, equating to 123 days after anthesis. Results for the harvest sampled fruit (sampled on 18 March 2010) were statistically analysed via GenStat™ software. Within experiment significant differences based on ANOVA least significant differences (lsd) shows statistically different results for treatments identified in Graph 1.

Nutrition data from petioles was collected to determine if there was an obvious macro/micro nutrient anomaly. There are no guidelines that indicate the standard nutrition values for a grapevine at harvest as exists for nutrition at flowering. There are some variations in elemental composition of the petioles (see, for example, manganese in Table 1), which may be investigated in future research.

Analysis of berry weights shows no treatment effect on turgid berries, with all berry weight the effectively the same (c.1g/berry). Changes in berry weight are obvious on desiccated fruit with the average of weight loss of shriveled fruit being 56% fresh berry weight.

Analysis shows control vines having 10% berry raisin per bunch, thus the raisin effect could be approximately a 5% loss of yield. When desiccation levels are high, significant late season yield losses and an additional complexity for crop forecast accuracy could be expected.

Harvest must analysis showed few differences in key areas of sugar content (Baume – Be'), pH or yeast assimible nitrogen (YAN), however, some differences between control and treatments in final wine alcohol content and pH were identified. The lack of correlation between harvest must Be and wine could be contributed to difficulty getting an homogenous must sample, yeast efficiency or could relate to a possible glucose/fructose ratio effect, which may be investigated in the future (M.McCarthy, pers.comm 17 Jan 2011).

Conclusions and recommendations.

The 2010 vintage data shows foliar treatments can reduce berry desiccation after extreme heat events. This research highlights an opportunity for viticulturists to maintain berry integrity when extreme heat events present.

Further, associated benefits of potentially reducing alcohol in finished wine are viewed as a desirable outcome of strategic importance to the Australian wine industry.

These outcomes show there is opportunity for viticulturists to actively cope with unfavourable weather conditions such as heat spikes and drought associated with climate change and justifies further research into such programs.

We believe a matrix of mitigation techniques including, but not limited to, strategic nutrition/anti-stress agents and irrigation is essential if we are able to combat the impacts of heat stress on the Australian wine industry.

Table 1: Petiole tissue analysis data

Element	T1- Glyciene betaine	T2- Glyciene betaine +organic kelp extract	T3- Glyciene betaine +inorganic NPK fertiliser with trace elements	T4 - Control
Boron	29.7	30.1	27.4	26.7
Calcium	1.5	1.44	1.53	1.44
Chloride	1.49	1.58	1.4	1.51
Copper	16.71	16.5	19.55	21.59
Iron	40.9	29.1	27.8	25
Magnesium	1.92	1.83	2.25	2.08
Manganese	55.5	21.1	20.7	20
Nitrate	1557	789	1009	758
Phosphorous	0.07	0.05	0.07	0.05
Potassium	3.51	3.08	1.7	2.08
Sodium	0.17	0.27	0.2	0.24
Sulfur	0.16	0.13	0.14	0.15
Total Nitrogen	0.96	0.78	0.93	0.77
Zinc	80.16	62.08	62.57	56.82

Table 2: Berry weight at harvest.

	Berry weights (grams)		
	Desiccated	Turgid	% Loss in Berry Weight
T1 - Glyciene betaine	0.54	1.00	54.16%
T2 - Glyciene betaine +organic kelp extract	0.54	1.00	54.27%
T3 - Glyciene betaine +inorganic NPK fertiliser with trace elements	0.57	1.00	57.35%
T4 - Control	0.59	1.01	58.43%
Average	0.56g	1.00g	56.06%

Table 4: Harvest must and Wine analysis data.

	Harvest Analysis			Wine Analysis				
	Harvest Baume (Be')	Must pH	YAN (mg/L)	Alcohol (% v/v)	pH	Volatile Acidity (g/L)	Malic Acid (g/L)	Residual Sugar (g/L)
T1 - Glyciene betaine	14.5	3.82	110	14.10	3.49	0.57	0.06	0.16
T2 - Glyciene betaine +organic kelp extract	14.3	3.74	120	14.20	3.49	0.66	0.01	0.18
T3 - Glyciene betaine +inorganic NPK fertiliser with trace elements 3	14.2	3.83	110	14.30	3.44	0.59	0.05	0.11
T4 - Control	14.2	3.75	97	14.70	3.6	0.59	0.05	0.11

Additional research is needed to understand how the anti-stress treatments are affecting vine physiology and their biochemical processes. A process of elimination is required to determine what components are creating the positive effects and the mechanisms by which this occurs. Importantly, accurate taxonomy should be applied to such studies as different forms of shrivel exist and desiccation could be misinterpreted.

Acknowledgements

Sincere thanks to the Mount Langi Ghiran viticultural and winemaking team for their enthusiastic support and commitment to the project. Thanks also to Dr Michael McCarthy (principal scientist, SARDI) and Dr Bhaskar Bondada (Assoc. Prof Viticulture and Enology, Washington State University) for their commentary.

Appendices: Details of trial products

NPK (+trace elements): 15% Nitrogen, 2.5% Phosphorus, 25% Potassium, 2.4% Sulphur, 1.5% Magnesium, 0.04% Iron, 0.02% Manganese, 0.02% Zinc, 0.011% Copper, 0.01% Boron, 0.0012% Molybdenum\

Kelp Extract (Organic Product) with plant growth regulators - Cytokinens, Auxins, 0.02% Nitrogen, (P^{2O5}) <1%: Phosphorous, 4.3% Potassium plus trace levels of Na, Cl, Ca, Mg, S, Zn, Mo, Al, B, Co Cu, Fl, Fe, I, Mn, Hg, Ni, Se, Ag, V.

GB: 97% Glycine betaine

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Personal communication

Assoc. Professor B. Bondada (pers.comm. 2 July 2010) Conference Poster titled: Not all shrivels are created equal

McCarthy, M. Pers.Comm 17Jan2011, Principal Scientist - SARDI