Technical Note

ARC TRAINING CENTRE FOR INNOVATIVE WINE PRODUCTION

Delayed ripening enhances the aroma composition of Cabernet Sauvignon grapes

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Background and Aims

Warmer and drier conditions associated with climate change affect grapes in a variety of ways. Among these, concerning trends have been observed for sugar accumulation, which has been reported to be increasing faster in many wine regions[1]. In previous studies it was shown that faster sugar accumulation is not necessarily paired with more rapid accumulation of organic acids or colour compounds (i.e., anthocyanins), thus researchers have coined the term "decoupling" between sugar and specialised metabolites[2,3]. In practical terms, grape growers either need to harvest grapes at the targeted Total Soluble Solid (TSS) and be satisfied with lower concentrations of specialised metabolites, or wait until grapes have fully developed secondary metabolites at the cost of sugar levels being higher than originally desired. This phenomenon has led to the search for mitigation strategies to delay sugar accumulation, which can be beneficial to restore the balance between sugars and anthocyanins[4].

Grape aroma compounds represent an important source for the final bouquet of wine. It is still unclear to what extent the decoupling described here applies to specific aroma compounds, and whether delaying sugar accumulation enhances the aromatic composition of grapes. In our study, we attempted to clarify the relationship between the rate of sugar accumulation and the aroma profile of Cabernet Sauvignon grapes grown in the Lodi American Viticultural Area of California.

Experimental treatments, namely a combination of crop load manipulation through cluster-thinning and irrigation strategies were implemented to manipulate the rate of sugar accumulation and grapes were chemically analysed for the concentration of aroma compounds significant for winemaking. Cluster thinning and late season irrigation were selected as treatments to advance and delay ripening, respectively (**Figure 1**). Cluster thinning was applied 1 week pre-veraison, when clusters were removed to leave 1 basal cluster per shoot only. As for irrigation, the standard irrigation (85 % evapotranspiration) was compared to a late season irrigation, the latter scheduled as a 50 % increase in irrigation, starting when grapes reached 20 °Brix until harvest.

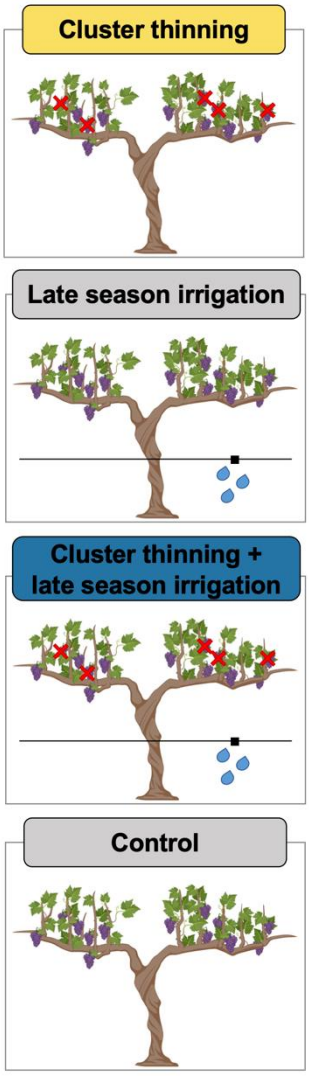

Figure 1. Illustration of the experimental treatments applied in this study.

Key outcomes

The full results of our research study have been reported in two publications: Previtali et al (2021)[5] describes the effect of ripening rates on ripening kinetics and grape composition, while Previtali et al (2022)[6] reports the impact of ripening rates on the chemistry of wines. The main outcomes of the experimental trial are summarised below.

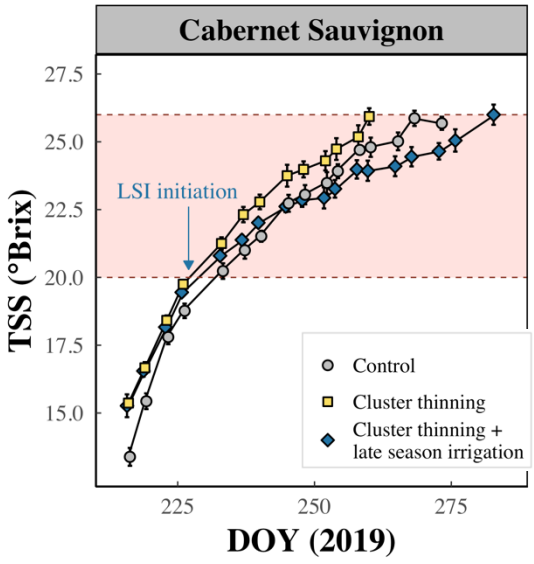

Figure 2. Sugar accumulation kinetics by treatment. Points and error bars represent means ± SE (n = 6). DOY: day of the year.

Ripening kinetics. The kinetics of sugar accumulation were affected by the treatment applied (**Figure 2**), with the exception of grapes submitted to late-season irrigation without cluster thinning. Ripening was advanced (7 days) and delayed (14 days) compared to the control when vines were submitted to cluster thinning only and to the combination of cluster thinning and late season irrigation, respectively. In low crop load vines, the application of late-season irrigation readily caused a decrease of TSS/day.

Yield components and crop load. The effect of cluster thinning and late-season irrigation on yield components is shown in **Table 1**. Yield components were affected by cluster thinning, which resulted in a reduction of about 35% in vine yield and clusters/vine. Berry weight was not affected by cluster thinning or late season irrigation, importantly indicating that differences in grape composition were not driven by dilution or concentration. Pruning weight and shoots/vine were not affected by crop load manipulation nor irrigation regime. In light of values described for yield and pruning weight, crop load, calculated as the yield-to-pruning weight ratio, was decreased by 40% on average by pre-veraison cluster-thinning.

Table 1. Yield components and vine balance of Cabernet Sauvignon grapes submitted to cluster thinning and late season irrigation.

	Yield components			Vine balance		
	Yield (kg/vine)	Clusters/vine	Berry weight (g)	Pruning weight (kg)	Shoots/vine	Crop load (kg fruit/kg pruning)
Crop load						
Low	7.12 a	77 a	1.10	2.62	69	2.81 a
High	11.39 b	120 b	1.17	2.49	65	4.67 b
Irrigation						
Standard	10.21	103	1.17	2.67	67	3.59
Late season	8.29	95	1.10	2.44	67	3.89

Note: low and high crop load correspond to cluster-thinned and unmanipulated vines, respectively. Different letters denote significant differences at $p < 0.05$ for crop load or irrigation separately.

Effect of delayed ripening on grape aroma profile. Grapes for the three experimental treatments reported above were harvested at the same targeted maturity of 26 °Brix to investigate the link between ripening rates and grape aromatic composition. The aroma profile of Cabernet Sauvignon grapes was improved when a significantly slower ripening rate was achieved (**Figure 3**, next page). Delayed ripening resulted in lower abundance of C6 compounds and IBMP, compounds responsible for capsicum-, green- and grass-like odours that are negatively associated with quality of red wines in the majority of cases. Free terpenes and norisoprenoids, which have fruity to floral aromas, were decreased due to their volatile nature. However, the aroma precursors of norisoprenoids were highest in grapes which ripened at a slower rate, and are expected to improve the fruitiness or floral bouquet of wine upon their release during fermentation. The concentration of anthocyanins (ie, the main drivers of red colour) was also increased, which was another important beneficial effect of delayed ripening.

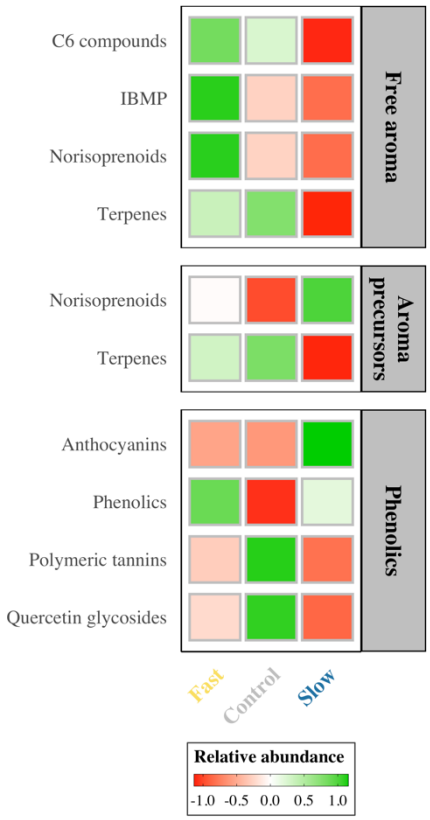

Figure 3. Effect of ripening rates on the aromatic and phenolic profile of grapes. Colours show differences in the relative abundance of each compounds from low (red) to high (green).

Recommendations

The findings of our study highlighted the importance of achieving an appropriate rate of sugar accumulation to counteract the increasingly frequently heat-driven ripening advancement. It is recommended that growers carefully monitor TSS accumulation through periodical testing and adopt mitigation strategies to delay ripening when sugar accumulation is excessively fast. Another technical note is available that reports the findings of our study on the suitability of different vineyard practices to delay ripening.

Acknowledgements

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