# Late season canopy management practices to reduce sugar loading and improve color profile of Cabernet-Sauvignon grapes and wines in the high irradiance and hot conditions of California Central Valley

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## Abstract

Global warming is accelerating grape ripening, leading to unbalanced wines from fruit with high sugar content but poor aroma and colour development. Reducing the size of the photosynthetic apparatus after veraison has been shown to delay technological ripeness in cool climates, but methods have not been tested in areas with high irradiance and temperature where fruit exposure could have disastrous effects on berry composition. In this Cabernet-Sauvignon trial, we compared the application of an antitranspirant (pinolene), to severe canopy topping and above bunch zone leaf removal, all performed at mid-ripening, with an untouched control. We monitored the vines weekly by measuring stem water potential, gas exchange, fruit zone light exposure. We sampled berries to measure berry weight, total soluble solids, pH, titratable acidity, and the anthocyanin profile. At harvest, we assessed yield components, measured carbon isotope discrimination, rated sunburn on clusters, and produced experimental wines. We submitted harvest samples to metabolomic profiling through PFP-Q Exactive MS/MS and wines to sensory analysis. Application of the antitranspirant significantly reduced stomatal conductance and assimilation rate but did not affect the stem water potential. Inversely, leaf removal and topping increased water potential but did not affect leaf gas exchange. The late topping was the only treatment able to decrease sugar content (up to 2Bx), increase titratable acidity and pH, and improve anthocyanin content because of lower degradation of di-hydroxylated forms. Late leaf removal above the bunch zone increased lightning conditions in the canopy and produced the most significant damage on fruits. Yield components were not affected. This work suggests that late-season canopy management can effectively control ripening speeds and improve grapes and wines. Still, the effect on grape exposure in a critical time must be well balanced to avoid problems with the appropriate technique.

## Introduction

Cabernet-Sauvignon is the leading red variety of California wines and the most important by value. It is also one of the most sensitive to the current change in the climate. With high temperatures, all varieties tend to have undesirable chemical profiles, resulting in increased sugar concentration and low acidity. In cabernet-sauvignon, the problem is exacerbated by a strong decoupling between sugar loading and phenolic maturity, consisting in an excessively fast sugar accumulation while anthocyanin and tannin development lags. As a consequence, the wines have poor color and harsh tannins. In the case of California, where high temperatures are coupled with high radiation intensity, ripening imbalance problems are exacerbated by a direct degradation of quality compounds caused by grape exposure to the sun, culminating in the loss of crop because of sunburns in the worst cases. In the hottest and driest wine-producing regions of California, the San Joaquin Valley, the effect of climate change on this variety is evident. Although for some production goals, the wine color could be fixed with the addition of small portions of other more colored musts, this is not an easy option for fine wines, and in the bulk wine market, the grape composition in secondary metabolites is increasing in importance and value. In the San Joaquin Valley, the latitude at which Cabernet-Sauvignon vineyards may be deemed profitable will continue moving North with negative effects on the whole supply-chain system.
In this context, it is essential to find solutions that could increase the resilience to the cultivation of this and similar varieties to climate change. Successful solutions will need to be cost-effective and applicable on large surfaces while being tailored to the peculiar conditions of California viticulture, given the weather and trellis systems. Previous trials have demonstrated the efficacy of shade nets in protecting grapes from extreme weather

(Martinez-Luscher et al., 2017, 2019). However, this is not a practice that could be pursued at a large scale, given the current availability and cost of the workforce. Late season irrigation has proven to be effective (Previtali et al., 2021), but an increase in irrigation rates cannot be a long-term solution with the recurring droughts we are experiencing. Cultural practices adapting California systems to climate change must be mechanizable and sustainable, and therefore they are limited to canopy management or sprayings. In other regions of the world, the effect of antitranspirants like pinolene (1-di-p-menthene), or sun reflectants like kaolin, have been tested with success (Brillante et al., 2016). However, they still lack a comprehensive evaluation in California conditions. The same goes for late-season source limitation practices. These practices reduce the photosynthetic leaf area in the second part of the season (after veraison) to slow down sugar accumulation and acid degradation. An increase in the time the fruit hang could have positive effects on phenolic compounds and no impact on yield.
This research aims to address these issues. In a complete factorial design, we compare to an untreated control the effects of antitranspirant (pinolene) to late leaf removal and late shoot trimming operated after veraison.

## Materials and methods

### *Field site, experimental design, treatments:*

The experiment was conducted at the Fresno State Vineyard in Fresno, CA. The experimental block is planted with Cabernet-Sauvignon (clone FPS07) grafted on 1103P rootstock. The vines are spaced at 11′x7′ (row x vine), spur pruned and trained in a bilateral cordon with 2 wires on a 24″ cross arm to catch the foliage with drip irrigation.

### *Assessment of leaf area removed*

The leaf area removed will be collected from 10 shoots individually and sampled shoots flagged to be measured again at the end of the experiment. Collected leaves will be measured through scanning on a Licor LI-3100C to obtain the total leaf area removed per shoot. At the end of the experiment all leaves on these same shoots will be collected and measured in the same way. The ratio of leaf area removed per shoot will then be obtained by dividing the removed leaf area by the total leaf area.

### *Assessment of sun exposure in the fruit zone*

Before and after treatment applications, and one more time before the end of the experiment, we will collect the amount of light in the fruit zone by inserting a ceptometer Licor LI-191R right in the center of the fruit zone and parallel to it. Data will be obtained every 2h in all experimental units in each measurement day.

### *Plant and berry temperatures*

In two days during the experiment, we will collect thermal imaging of canopies and berries with a thermal camera Flir Duo-Pro 640R. Images will be obtained every 2h in all experimental units and later elaborated to obtain the average temperature of fruits and leaves.

### *Solar noon stem water potentials*

Plant water status will be assessed by taking stem water potential measurements at solar noon, after covering the leaves with a zip-top plastic bag and aluminum foil for 2h. Four leaves, sampled from the middle section of the main shoot axis, from four different plants will be measured in each one of the experimental units. Sampled plants and leaves will randomly vary between dates. Plants will be measured weekly starting the week prior to the first treatment application (before veraison).

### *Stomatal conductance*

Stomatal conductance ($g_s$, mmol $H_2O$ $m^{-2}$ $s^{-1}$) will be measured with SC-1 leaf poromoter (Meter Group) in the morning hours (10:00-12:00). In each experimental unit, four sun-exposed leaves from four grapevines will be sampled from the middle section of the main shoot. Two readings per leaf will be obtained and averaged.

### *Yield components*

On four plants per experimental unit, we will measure yield components: yield per plant, # of clusters per plant, berry weight, and derived variables (e.g., yield per meter of row, etc.). Yield components will be measured at harvest.

### *Grape must composition*

The berry total soluble solids (TSS, measured as °Brix), juice pH, and titratable acidity (TA) will be analyzed from one hundred random berry samples collected weekly from each treatment replicate from veraison to harvest. TSS will be measured using a digital refractometer (Atago PR-32). The juice pH and titratable acidity (TA) will be determined by titrating up to pH 8.2 with NaOH, and TA will be expressed as g $L^{-1}$ of tartaric acid.

### *Grape anthocyanins profile*

We will collect 20 berries in each experimental unit, six times during the experiment. The berries will be freshly weighted, then the skins will be separated, freeze-dried, powdered, and extracted for 24h with methanol, water, hydrochloric acid (70:29:1) then measured through reverse phase HPLC with a gradient of acetonitrile and formic acid as described in Martínez-Lüscher et al., 2019.

### *Winemaking*

Grapes from each treatment were manually harvested into picking bins with max. 8 kg. Bins were stored in a cold room at 10°C for 3 days. Each treatment was crushed separately, and must lots of 10 gallons were created (3 replicates per treatment, total of 12 independent fermentations). Potassium metabisulfite was added at 30 ppm to every wine lot at crush. Musts were cold-soaked in a cold room at 50 °F for 24 hours to allow must analysis (Bx, titrable acidity, pH, and yeast assimilable nitrogen, YAN). Adjustment of YAN will be made using DAP prior to yeast inoculation as needed. All wines will be inoculated with the same commercial yeast (*Saccharomyces cerevisiae*) according to standard dosage recommendation (2lb/1000 gal). Manual punch-downs once a day will occur every morning, and must sample will be collected for monitoring °Brix and temperature. Wines will be pressed at the end of alcoholic fermentation using a benchtop vertical press and racked into 1-gallon glass jugs for settling in the cold room at 50°F for two weeks. During racking, free sulfur dioxide will be adjusted in all finished wines to 30 ppm. Samples will be filtered using a benchtop pad filter. Wines will be bottled in 750 mL bottles with screw caps and kept in storage at 50F.

### *Wine Analysis*

Must analysis include TA, pH, YAN, and °Brix. Fermentation Brix and temperature were monitored with a hydrometer and digital thermometer. YAN in must was measured with an Oenofoss™ (FOSS, Denmark). TA and pH were determined according to standard potentiometric methods. Residual sugars (glucose and fructose), free and total sulfites, and volatile acidity were measured with a Foss-Winescan™ (Foss, Denmark). Color intensity (absorbance at 420, 520, and 620 nm) were measured with a Perkin Elmer Lambda 25 Spectrophotometer. Anthocyanins were measured using HPLC-DAD according to Martínez-Lüscher et al., 2019.

### *Sensory evaluation*

The intensity of astringency was measured using line scaling. Eighteen tasters were presented with a flight of four wines corresponding to each of the treatments. Samples were presented monadically according to a Williams Design. Sample presentation, randomization, and data collection was done with Compusense20 software (Okta, USA) in sensory evaluation boots at the Jordan Agricultural Research Center at Fresno State.

### *Statistical analysis*

Treatment impacts will be compared using analysis of variance (ANOVA) and means separated using Tukey's HSD test. As measured by the rating scale, treatment influences on cluster damage will be compared in a two by two contingency table with treatments separated using Pearson's chi-square.

## Results and discussion

Treatments are shown in figure 1. Late season canopy manipulation practices reduced shoot leaf area by 40-70%. As expected, the antitranspirant and control had the same leaf area per shoot. Late topping and late leaf removal where not significantly different, although in average late topping was a more severe limitation than leaf removal with 30% lower leaf area per shoot. Considering the percentage of light in the fruit zone, the late topping was the only treatment that significantly enhanced (up to 2.5 folds with respect to the control) the amount of light in the fruit zone measured at solar noon, when the sun is perpendicular to the canopy. We monitored plant water status through stem water potentials weekly and observed significant differences across the treatments in all dates. The antitranspirant always had the lower stem water potential, while late-season canopy manipulations tended to reduce water stress. This was also confirmed on stomatal conductance in the case of late topping, but not in the case of leaf removal. Stomatal conductance was generally higher than the control in the late topping treatment, although significantly different in only one date. In the late topping treatment, we also observed a general increase in net assimilation, although again significant in only one date. This is primarily due to an improvement in the gas exchange as stomata were more open, more than to an enhancement in the photosynthetic apparatus because of compensation following severe source limitation.

We did not observe significant differences between the yield per plant at harvest, but we did observe a difference in the damage from the sun to clusters. Leaf removal had a significantly larger number of damaged fruits, with over 50% belonging to classes C and D showing many to most berries dehydrated or discolored. Leaf removal was operated above the fruit zone and only exposed the occasional cluster that was higher in the canopy. The late topping did not show a similar trend, and cluster conditions were the same as in control and in the antitranspirant treatments. It is important to remember that in the late topping, the number of leaves removed and the amount of solar radiation in the fruit zone at solar noon was the highest. We did not measure the amount of light in the fruit zone in the afternoon and in the morning, but it is likely that at this time of the day, the clusters were in the shade in the late topping and not in the leaf removal treatment. Considering the effect on grape composition, figure 2 shows the result on °Brix and pH. The late topping was the most effective treatment in delaying ripening, and °Brix accumulation only increased by 1.5 °Bx during a two-month hang-time. In comparison, the control raised by 3.5 °Bx. Sugar accumulation in late topping was two times slower than in the control. Antitranspirants had an intermediate effect, and leaf removal was not different from the control, most likely because of berry dehydration. Grape pH had a similar trend; it was generally lower in the late topping and higher in the control, although in the last month of hang-time, the leaf removal treatment had the highest pH of all. Antitranspirant had a more moderate effect again. After winemaking and stabilization, we measured the wine color with a spectrophotometer. Late leaf removal was the only treatment that enhanced color in the wine, as expressed by optical density at 420nm, 520nm, and 620nm. The perception astringency in the wines was

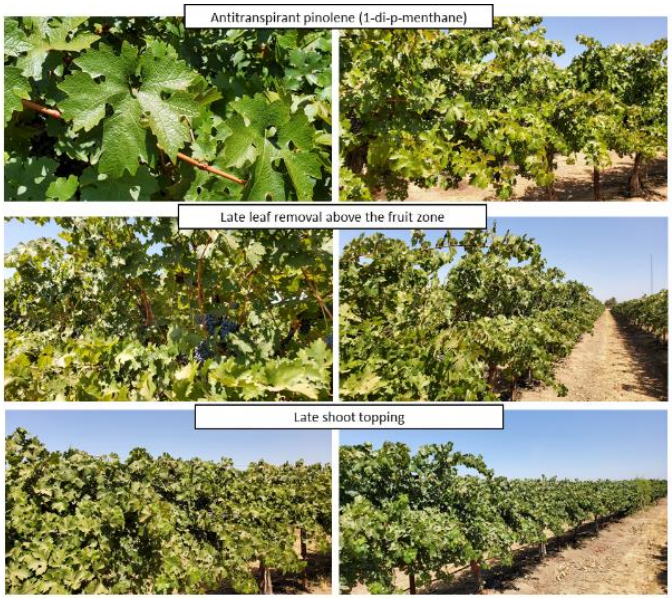


**Figure 1.** Treatments evaluated in this study

evaluated by a panel of 18 tasters (students) on a line scale.

Despite the absence of significant differences, differences in mean values potentially suggest that a trained tasting panel is likely to differentiate between the treatments and provide conclusive evidence of changes in astringency and mouthfeel.

## Conclusion

This trial has demonstrated that late topping is effective in delaying ripening and alleviating water stress during the hang time while still protecting grapes from sunburn. Leaf removal has been able to improve color in wines but has not been able to protect grapes from sunburn therefore. It is also clear that combining late topping with di-1-p-menthene may slow down ripening even further. The validity of a combined approach also needs a deeper investigation of the source-sink modifications caused by these practices. We need to understand better what happens at the berry level to better tailor the timing and severity of the application, considering that the goal is not to reduce sugar content but improve color and wine profile. Future research will address these issues and increase the work on secondary metabolites to provide growers with crucial information to enhance the resilience of winegrowing in California with this climate change.

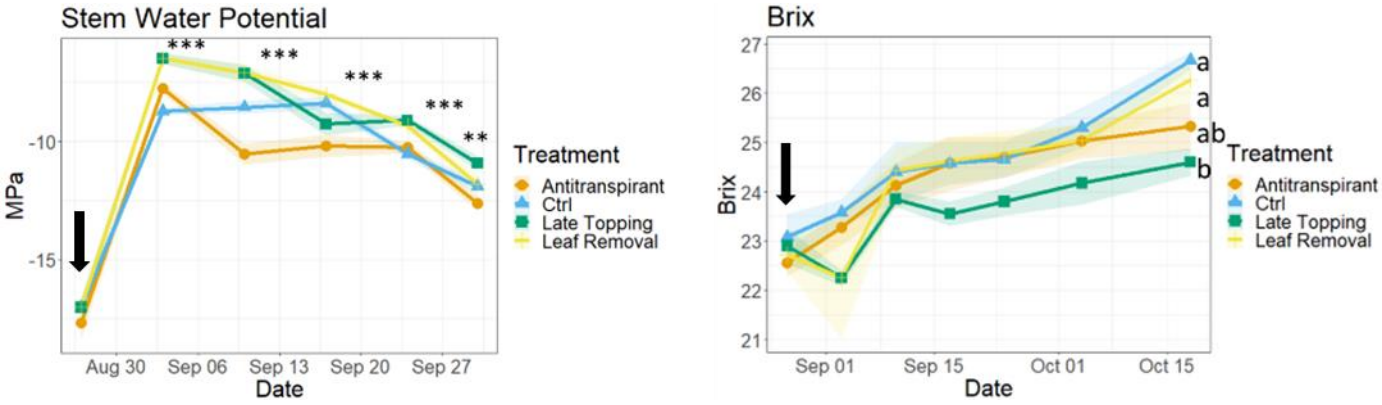


**Figure 2.** Stem water potentials (left panel) and grape total soluble solids (right panel). Treatments were applied as indicated by the black arrow. Different letters indicate statistically significant differences among treatments, and *** indicates p-value < 0.001, ** p-value < 0.01

## References

Brillante, L., Belfiore, N., Gaiotti, F., Lovat, L., Sansone, L., Poni, S., Tomasi, D. (2016). Comparing kaolin and pinolene to improve sustainable grapevine production during drought. PLoS One 11, 1–19. https://doi.org/10.1371/journal.pone.0156631

Martínez-Lüscher, J., Brillante, L., Kurtural, S.K. (2019). Flavonol profile is a reliable indicator to assess canopy architecture and the exposure of red wine grapes to solar radiation. Front. Plant Sci. 10, 1–15. https://doi.org/10.3389/fpls.2019.00010

Martínez-Lüscher, J., Chen, C.C.L., Brillante, L., Kurtural, S.K. (2020). Mitigating heat wave and exposure damage to "Cabernet Sauvignon" wine grape with partial shading under two irrigation amounts. Front. Plant Sci. 11, 1–15. https://doi.org/10.3389/fpls.2020.579192

Previtali, P., Dokoozlian, N.K., Pan, B.S., Wilkinson, K.L., Ford, C.M., (2021). Crop load and plant water status influence the ripening rate and aroma development in berries of grapevine (*Vitis vinifera* L.) cv. Cabernet Sauvignon. J. Agric. Food Chem. 69, 7709–7724. https://doi.org/10.1021/acs.jafc.1c01229.