# The Effect of Canopy Area on Ripening and Wine Quality (2017)

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## Summary

This study examines the impact of canopy height and ripening on wine quality in Merlot. Three sets of five rows of Merlot were hedged to different heights in mid-June: 52 inches (High canopy), 44 Inches (Medium canopy, normal height), and 36 inches (Short canopy). All other vineyard treatments were identical. Not much additional shoot growth occurred after hedging. Grapes were harvested on August 25 and processed into separate T Bins. All other treatments were identical. Juice Brix was slightly higher for the short canopy compared to the higher canopy. This may have been due to a seeming resistance to rain dilution seen in the short canopy vine compared to the medium and higher canopy vines. The ethanol, TA, color, and tannin increased with decrease in canopy height, and pH decreased with canopy height. Overall, descriptive analysis had difficulty distinguishing the wines consistently. The short canopy treatment tended to have slightly more Bitterness and Overall Aromatic Intensity. The short canopy wine also exhibited some slight reduction relative to the other two wines, which may have influenced results. Fruit Intensity and Astringency tended to vary between wines between tastings. In general, the high canopy wine tended to be the most preferred. Future studies should examine how bud fruitfulness and yield are impacted by multiple vintages of heavy hedging, pick fruit at different times depending on which treatment is deemed "optimally" ripe, and hedging shoots when they reach their designated height to try to force lateral growth. More studies are needed to confirm the trends seen in this study, as well.

## Introduction

There should be a balance between leaf area and fruit yield (Koblet 1975; Smart et al. 1990). Generally, on a vine with 2 clusters per shoot it takes around 10-14 leaves to ripen it, or 0.8-1.2$m^2$ leaf area/kg fruit for single-canopy trellises (Koblet 1975; Kliewer and Dokoozlian 2005), and 0.5-0.8$m^2$/kg for divided canopy trellis systems (Kliewer and Dokoozlian 2005). However, different grape varieties can ripen at different leaf area to fruit yield ratios. Additionally, it is likely that the optimum leaf area to fruit yield ratio would need to be higher in cooler regions (Kliewer and Dokoozlian 2005). Furthermore, this ratio may change depending on the trellising system used, as different trellis types can have different amounts of leaf area required for equal ripening due to more efficient sun exposure of the canopy (Amberg and Shaulis 1966; Shaulis et al. 1966; Shaulis and May 1971; May et al. 1976; Smart 1982; Smart et al. 1982; Kliewer 1982; Shaulis 1982; Kliewer et al. 1988; Smart et al. 1991; Schultz 1995; Gladstone 1999; Kliewer and Dokoozlian 2005). For example, double curtain trellises have higher leaf exposure than single curtain and therefore require less leaf area per kg fruit (0.9-1.0$m^2$/kg vs 1.3-1.4$m^2$/kg) (Kliewer and Dokoozlian 2005).

In general, large canopy surface area which maximizes sun exposure (Smart 1973; Smart et al. 1990) should be developed quickly in the spring, as this allows for increased yield and can promote healthy ripening (Clingeleffer 1989; Smart et al. 1990). Large canopy surface area also reduces canopy density (Shaulis and Smart 1974). However, shoots continue to grow past the optimum balance length, and generally need to be hedged in humid climates (Smart et al. 1990).

An area of vine balance that is often not covered is the disparity between older and younger leaves. Younger leaves are more photosynthetically active than older leaves (Koblet 1969; Yang and Hori 1980; Koblet 1985; Vasconcelos and Castagnoli 2000). Grape leaves overall produce more carbohydrates than they use until they approach 50-80% of their full size (Koblet 1969; Yang and Hori 1980). The rate of photosynthesis in leaves increases until they reach full size, after which the rate declines (Kriedemann et al. 1970; Kurooka et al. 1990). Young leaves, then, may contribute more to ripening than older leaves. Therefore, hedging can be thought of as a way to manipulate the age of the canopy and can be strategically performed at particular growth stages of the vine (Vasconcelos and Castagnoli 2000).

Hedging at the 14th internode over summer enhanced ripening in Switzerland, resulting in higher sugar accumulation and less acidity (Koblet 1985). Others hedged Sangiovese in Italy at the 12th internode 25 days after bloom. Although the leaf area was less in hedged vines than in unhedged vines, hedging increased berry growth, TA, and malate, and reduced pH (Solari et al. 1988). Gewürztraminer ripened more effectively with 10-12 nodes per shoot than with longer shoots (Smart 1985b). In another study, hedging at bloom increased fruit set and cluster weight but decreased total yield, juice pH and leaf area. Longer lateral shoots resulted in higher juice soluble solids, pH, and anthocyanin (Vasconcelos and Castagnoli 2000). Therefore, hedging can benefit certain ripening characteristics, but with seemingly mixed effects on acidity.

This effect on ripening may be because hedging the shoots encourages lateral growth at the hedged tip, which produces younger, more photosynthetically active leaves which can therefore help ripen fruit faster than if only older leaves had stayed on the vine (Hale and Weaver 1962; Koblet and Perret 1971b; Koblet 1985; Hughlin1986; Wolf et al. 1986; Solari et al. 1988; Reynolds and Wardle 1989a; Vasconcelos and Castagnoli 2000). Indeed, the most efficient leaves in the canopy are at the shoot tips and those on laterals (Candolfi-Vasconcelos et al. 1994; Vasconcelos and Castagnoli 2000). Additionally, defoliation increases photosynthetic activity of the remaining leaves (Hunter and Visser 1988). Therefore, some authors recommend not removing lateral shoots near the clusters (Koblet and Perret 1971a), since these shoots are likely to be contributing more photosynthate to the clusters than leaves further up the shoot. However, this is dependent on site (Vasconcelos and Castagnoli 2000). In vigorous sites, lateral shoots result in shading and increased disease incidence (Smart 1985a; Gubler et al. 1987; English et al. 1989; Smart 1994; Vasconcelos and Castagnoli 2000) whereas in less vigorous, cool sites laterals may enhance ripening and vine health (Candolfi-Vasconcelos and Koblet 1990; Vasconcelos and Castagnolie 2000). Other authors have not noticed any effect on lateral shoot growth on ripening. In one study, all lateral shoots were removed from fruit set onwards, with no grape differences except for a slight reduction in TA (Schneider 1985).

Some have found the opposite effect with hedging, reducing Brix, anthocyanins, and increasing pH (even though more light could diffuse through the hedged canopy) (Kliewer and Bledsoe 1986). Furthermore, shoots that are too short may not ripen fruit (Peterson and Smart 1975; Koblet 1987). In vines hedged either at the 6th node or the 10th node (2 leaves past the fruiting zone vs 6 leaves past the fruiting zone), with shoots allowed to regrow after veraison, hedging to the 10th node increased yield, cluster weight, and Brix whereas hedging down to the 6th node decreased these attributes and resulted in poor coloration (Peterson and Smart 1975). Others found that vines with 5 leaves per shoot performed worse than 10 or 15 leaves per shoot, and that hedging at veraison resulted in less ripening than hedging at pre-bloom or at full canopy. This may have been due to increased lateral shoot growth acting as a carbohydrate sink from the 5-leaf treatment (Reynolds and Wardle 1989b). This suggests that a critical leaf density is required in the early stages of grape development to properly ripen. In general, early trimming seems to encourage fruit ripening (Solari et al. 1988; Koblet 1987; Koblet 1988; Smart et al. 1990), and later hedging may discourage ripening (Reynolds and Wardle 1989b). However, severe hedging does not necessarily have to have a very strong impact, or not as strong as would be expected (Reynolds and Wardle 1989b).

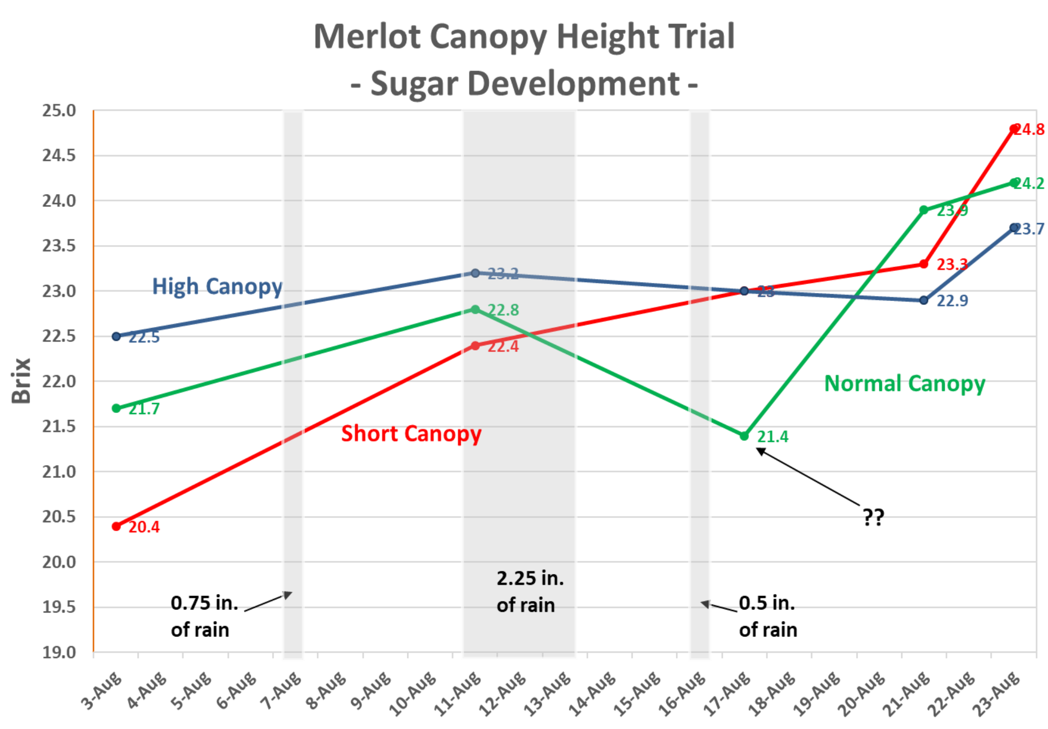
It is difficult to draw conclusions on hedging due to the conflicting nature of the results of studies. Differences in these studies may be due to climate (Jackson and Lombard 1993), vintage, and grape variety, and more studies should be performed to evaluate these effects further. However, it appears that in general hedging results in better ripening when compared to just letting the canopy grow incessantly, but at the same time too much hedging can prevent ripening. It is unclear what the result of sustained, severe hedging would be over multiple vintages. Hedging seems to work best when performed around bloom in order to encourage lateral growth. Hedging the vines at veraison, after shoot growth has slowed and laterals have already pushed, may cut away many of the younger, photosynthetically active leaves, slowing down ripening. Sustained continuous hedging throughout the growing season, especially severe hedging, would likely negatively impact fruit ripening, especially if performed over multiple seasons. More studies are needed, however, to gain a better understanding of these trends.

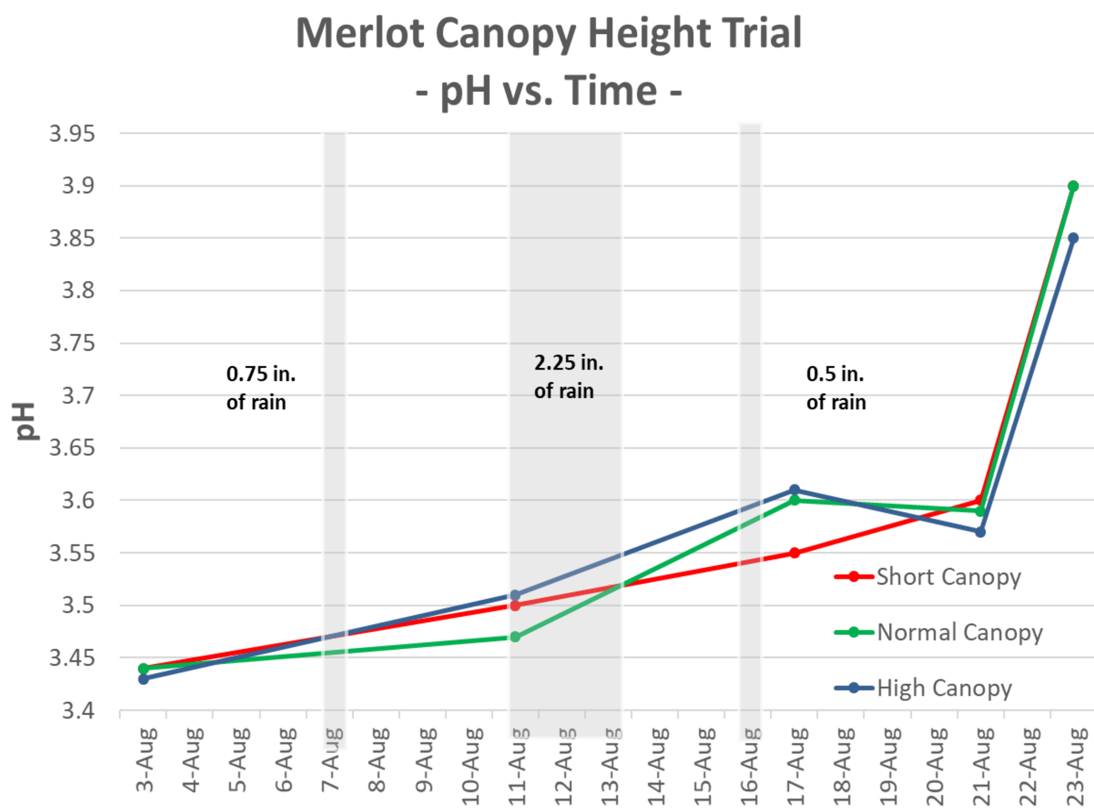
This study examines the impact of hedging a Merlot canopy at different heights on fruit chemistry and on wine quality.

## Results and Discussion

The short canopy had an ESCV:CW index of 1, medium canopy had an index of 1, and the high canopy had an index of 1.6. Optimal range is generally considered between 1 and 2, with above 1.5 considered to enhance structure and volume for red wines (IVF 2018). Juice Brix was slightly higher for the short canopy compared to the higher canopy. The short canopy vine appeared to have less berry dilution due to a rain event in August, which may have resulted in its higher Brix. Grapes were harvested on August 25. pH was not affected by canopy height in grapes.

| Month | Rain (in) | Deviation (in) | Degree-Days | Deviation (%) |
|---|---|---|---|---|
| April | 3.6 | 0 | 394 | +30 % |
| May | 5 | +3 | 470 | -10 % |
| June | 5 | +2 | 670 | -13 % |
| July | 1.2 | -2 | 890 | 0% |
| August | 3.5 | 0 | 755 | -12% |
| **Overall** | **18.3** | **+3 (20%)** | **3179** | **-5%** |






| Juice Chemistry | | | | | |
|---|---|---|---|---|---|
| | Harvest Yield (tons/acre) | Brix | pH | TA (g/L) | YAN (mg N/L) |
| High Canopy | 5.6 | 23.7 | 3.85 | 4.90 | 160.7 |
| Medium Canopy | 5.8 | 24.2 | 3.85 | 4.75 | 158.4 |
| Short Canopy | 5.2 | 24.8 | 3.85 | 4.80 | 160.3 |
| % Change Medium Canopy | 4% | 2% | 0% | -3% | -1% |
| % Change Short Canopy | -7% | 5% | 0% | -2% | 0% |

In House Data

The ethanol, TA, color, and tannin increased with decrease in canopy height, and pH decreased with canopy height. Previous studies have shown similar results (Vasconcelos and Castagnoli 2000), but these results were explained by hedging forcing lateral growth, thus instigating young leaves near the fruiting zone to enhance ripening. But lateral growth was not seen much after hedging in this study. Blind in-house tasting on September 6 and September 9 (after fermentation) suggested the short canopy had best balance and aroma, the medium canopy had better balance and aroma than the high canopy, and the high canopy was least balanced with coarse tannin.

| Wine Chemistry | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ethanol (%vol/vol) | Residual Sugar (g/L) | pH | TA (g/L) | Volatile Acidity (g/L) | Tartaric Acid (g/L) | Malic Acid (g/L) | Lactic Acid (g/L) | Potassium (mg/L) | IBMP (ng/L) | Total SO2 (ppm) | Free SO2 (ppm) | Molecular SO2 (ppm) |
| High Canopy | 14.53 | <1 | 3.64 | 5.68 | 0.4 | 1.8 | <0.15 | 1.26 | 1100 | 3.5 | 48 | 25 | 0.57 |
| Medium Canopy | 14.87 | <1 | 3.60 | 5.77 | 0.4 | 1.7 | <0.15 | 1.26 | 1150 | 3.9 | 54 | 27 | 0.68 |
| Short Canopy | 15.36 | <1 | 3.56 | 6.02 | 0.5 | 1.8 | <0.15 | 1.09 | 1100 | 3.9 | 56 | 25 | 0.71 |
| % Change Medium Canopy | 2% | | -1% | 2% | 0% | -6% | | 0% | 5% | 11% | 13% | 8% | 19% |
| % Change Short Canopy | 6% | | -2% | 6% | 25% | 0% | | -13% | 0% | 11% | 17% | 0% | 25% |

Results from ICV in Mid February 2018, Except IBMP from ETS

| Color Profile | | | | | |
|---|---|---|---|---|---|
| | A420 | A520 | A620 | Hue (420/520) | Intensity (420 + 520 + 620) |
| High Canopy | 0.419 | 0.624 | 0.141 | 0.671 | 1.184 |
| Medium Canopy | 0.441 | 0.673 | 0.150 | 0.655 | 1.264 |
| Short Canopy | 0.478 | 0.739 | 0.163 | 0.647 | 1.380 |
| % Change Medium Canopy | 5% | 8% | 6% | -2% | 7% |
| % Change Short Canopy | 14% | 18% | 16% | -4% | 17% |

Results from ICV in Mid February 2018

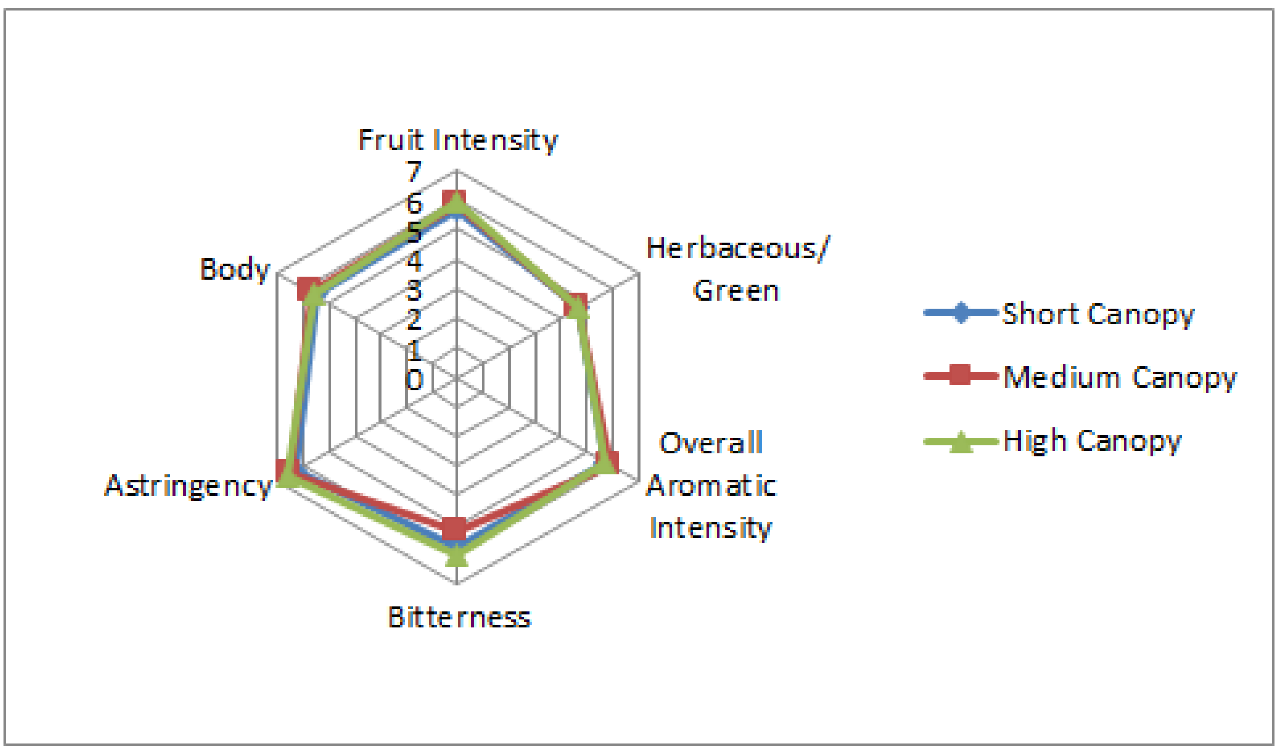
| Phenolic Profile | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Caffeic Acid (mg/L) | Caftaric Acid (mg/L) | Catechin (mg/L) | Epicatechin (mg/L) | Catechin:Epicatechin Ratio | Catechin:Tannin Ratio | Gallic Acid (mg/L) |
| High Canopy | 5 | 24 | 33 | 17 | 1.94 | 0.04 | 31 |
| Medium Canopy | 6 | 23 | 38 | 21 | 1.81 | 0.04 | 34 |
| Short Canopy | 5 | 23 | 40 | 20 | 2.00 | 0.04 | 36 |
| % Change Medium Canopy | 20% | -4% | 15% | 24% | -7% | 0% | 10% |
| % Change Short Canopy | 0% | -4% | 21% | 18% | 3% | 0% | 16% |

Results from ETS in Mid February 2018

| Phenolic Profile | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Malvidin glucoside (mg/L) | Monomeric Anthocyanins (mg/L) | Polymeric Anthocyanins (mg/L) | Quercetin (mg/L) | Quercetin Glycosides (mg/L) | Tannin (mg/L) | Total Anthocyanins (mg/L) | Resveratrol (cis and trans) (mg/L) |
| High Canopy | 175 | 305 | 51 | 8 | 30 | 775 | 356 | 3.0 |
| Medium Canopy | 173 | 302 | 58 | 10 | 28 | 859 | 360 | 3.2 |
| Short Canopy | 167 | 307 | 62 | 12 | 24 | 899 | 369 | 3.3 |
| % Change Medium Canopy | -1% | -1% | 14% | 25% | -7% | 11% | 1% | 7% |
| % Change Short Canopy | -5% | 1% | 22% | 50% | -20% | 16% | 4% | 10% |

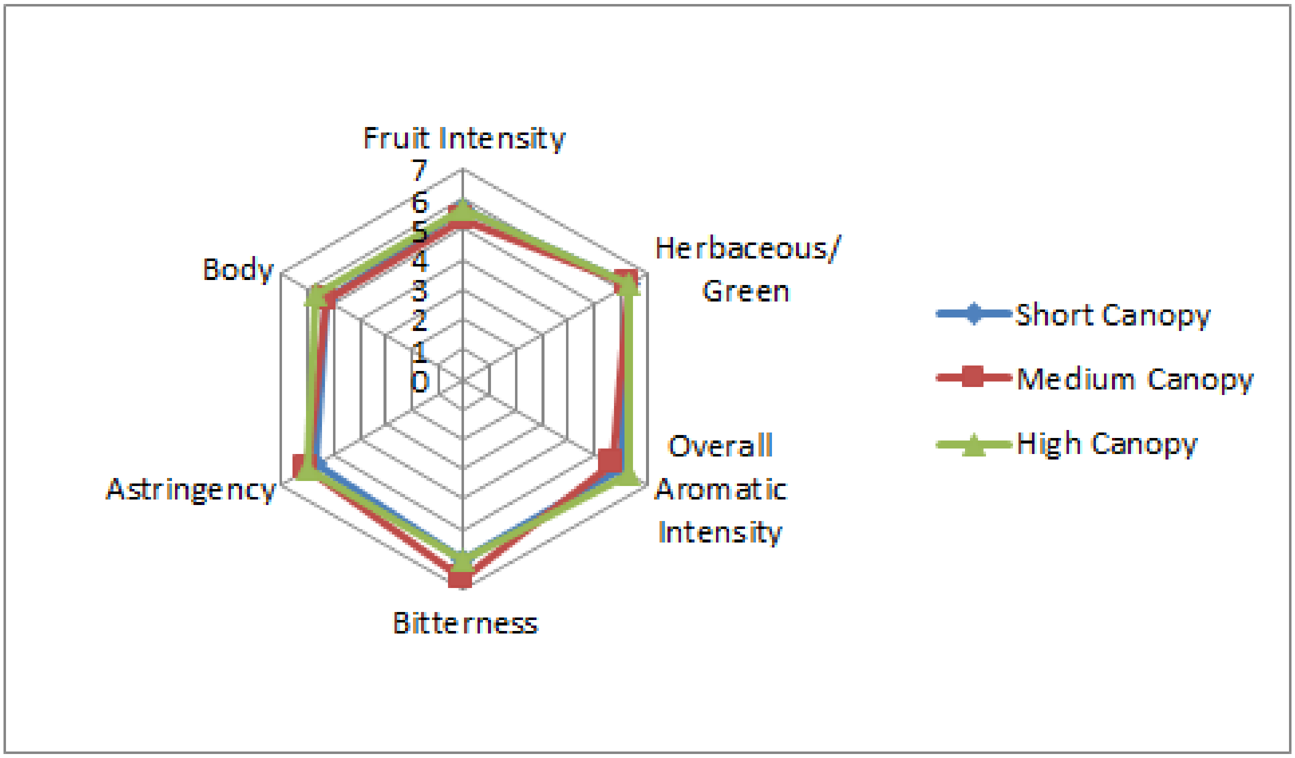
Results from ETS in Mid February 2018

For the descriptive analysis on February 28, there were no strong trends for the descriptors used in this study. Astringency and Fruit Intensity were slightly higher in higher canopy heights. There was a slight preference for the high canopy treatment.



| | Short Canopy | Medium Canopy | High Canopy | Total Votes |
|---|---|---|---|---|
| Most Preferred | 30% | 30% | 41% | 27 |
| Second Most Preferred | 25% | 38% | 38% | 24 |
| Least Preferred | 44% | 32% | 24% | 25 |

For the March 14 tasting, Bitterness seemed to be slightly higher in the short and medium canopies. The short and high canopy treatments seemed slightly higher in Overall Aromatic Intensity. There was a very slight preference for these two treatments.




For the descriptive analysis on May 9, there were no strong trends for the descriptors used in this study. There was a slight tendency for the short canopy wine to have higher Overall Aromatic Intensity, Bitterness, and Astringency. The high canopy wine had a slight tendency to have lower Fruit Intensity and Bitterness. In general, judges preferred the high canopy the most, and the short canopy the least.

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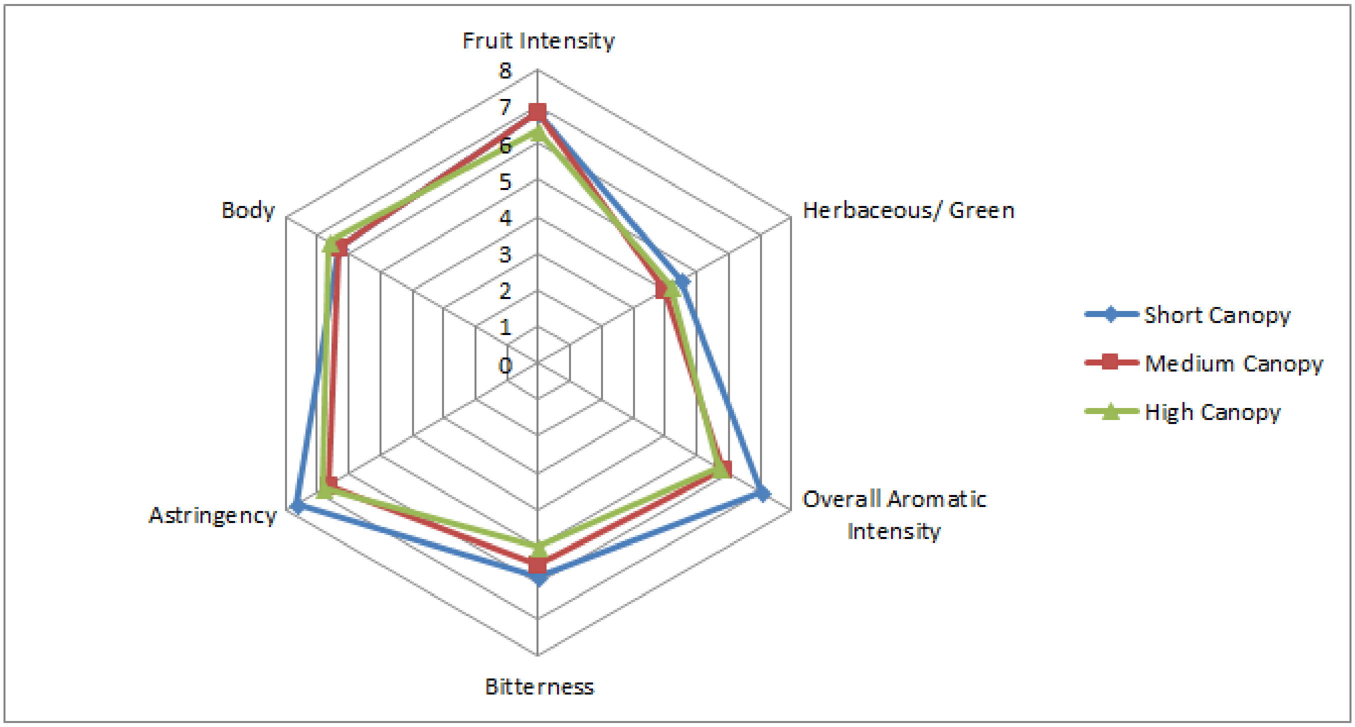


| | Short Canopy | Medium Canopy | High Canopy | Total Votes |
|---|---|---|---|---|
| Most Preferred | 0% | 29% | 71% | 7 |
| Second Most Preferred | 29% | 43% | 29% | 7 |
| Least Preferred | 71% | 29% | 0% | 7 |

Overall, descriptive analysis had difficulty distinguishing the wines consistently. The short canopy treatment tended to have slightly more Bitterness and Overall Aromatic Intensity. The short canopy wine also exhibited some slight reduction relative to the other two wines, which may have influenced results. Fruit Intensity and Astringency tended to vary between wines between tastings. In general, the high canopy wine tended to be the most preferred. Future studies should examine how bud fruitfulness and yield are impacted by multiple vintages of heavy hedging, pick fruit at different times depending on which treatment is deemed “optimally” ripe, and hedging shoots when they reach their designated height to try to force lateral growth. More studies are needed to confirm the trends seen in this study, as well.

## Methods

Three sets of five rows of Merlot 343 (13 years old) on RG rootstock on cane pruned VSP, 6x4 spacing were used for this trial. Canopy depth was approximately 8 inches. These rows are planted on a slight slope which is perpendicular to the direction of the rows. All 15 rows were treated the same throughout the growing year except that after fruit set each set of rows were hedged at different heights until harvest as follows below:

| Canopy | Height (in) | Area Dev. | Lbs. Grapes |
|---|---|---|---|
| Short | 36 | -18% | 5.59 |
| Medium | 44 | 0.0 | 6.02 |
| High | 52 | +18% | 5.79 |

Bud break was on April 2, flowering on May 2, the vines were hedged Mid-June, veraison occurred on July 14, and the fruiting zone was netted on August 4. Vines were not hedged anymore after the initial hedging, and not much additional lateral growth was observed, possibly due to low rainfall in July and August.

Grapes were harvested on August 25 (42 days of ripening, 145 days from bud break to harvest). They were then refrigerated overnight and processed on August 26 into three separate T Bins. Each T Bin received 50ppm sulfur dioxide, 30g/hL Tannin VR Supra, and 40 g/ton HE Grand Cru Enzyme. Must was cold soaked for 5 days at 50°F.

All T Bins were inoculated on August 31 with X-Pure yeast at 25g/hL, with 30g/hL Dynastart. During fermentation, each treatment received 30g/L Thiozote, 30g/hL Nutristart Org, 15g/L VR Color, and 1g/L tartaric acid. Each fermentation received 2-3 punchdowns per day until September 7, and then one punch down per day until pressing. Only free run wine was used. Malolactic bacteria were added on September 4. Wines were pressed on September 13.

These wines were tasted on February 28, March 14, and May 9. In order to balance the data set to perform statistical analysis for descriptive analysis on the February 28 tasting, any judge who had not fully completed the descriptive analysis ratings were removed. In order to then make the number of judges between groups equivalent, two judges from group 2 were transferred to group 1. This resulted in a final data set of 3 groups, each with 8 judges (considered as replications within groups, and groups were considered as assessors). Data was analyzed using Panel Check V1.4.2. Because this is not a truly statistical set-up, any results which are found to be statistically significant ($p<0.05$) will be denoted as a “strong trend” or a “strong tendency,” as opposed to general trends or tendencies. The statistical significance here will ignore any other significant effects or interactions which may confound the results (such as a statistically significant interaction of Judge x Wine confounding a significant result from Wine alone). The descriptors used in this study were Fruit Intensity, Herbaceous/Green, Overall Aromatic Intensity, Bitterness, Astringency, and Body.

Due to the very small number of judges (3) at the March 14 tasting, only slight trends will be discussed for the sensory information.

The same procedures for data analysis were used on the May 9 tasting as were used on the February 28 tasting. For the descriptive analysis in this tasting, one judge was eliminated from group one so that each group had two judges, for a total of 6 judges.

44 Inch Canopy (typical)

Short Canopy

Medium Canopy (Typical)

High Canopy

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