Viticulture Trial
Impact of Freeze-killed Leaf Material in Cabernet Sauvignon

An industry and university joint effort to profile the sensory and chemical impacts of freeze- killed grape leaves in Cabernet Sauvignon from Washington state.

Bryan Avila

Bryan Avila is a formally trained enologist, seasoned commercial winemaker, ACUE-Credentialed Educator and co-founder of the Vintners Institute. The Vintners Institute is a grassroots, next-gen effort to bring wine industry producers and allies together, online and in-person, to innovate with nature, educate the workforce and inspire good leaders. A freelance writer for *WBM*'s Winemaker Trials, Bryan would love to hear what you are doing in your vineyard and winery to overcome challenges, grow better grapes and make better wine. Contact: *bryan@vintnersinstitute.com*.

Trial Lead: Jim Harbertson, Ph.D., corresponding author and associate professor of enology at Washington State University, Prosser Washington

Dr. Harbertson's research interests are based in wine chemistry focused on the phenolic compounds found in grapes and wine and their biochemical and chemical changes during grape ripening, winemaking and aging. Example projects include understanding the variability of tannin found in red wine cultivars and the ultimate relationship between tannin, polymeric pigments and astringency. Harbertson works with wineries to solve simple and difficult problems. Jim's forte is wine chemistry and production, with special emphasis on phenolic compounds found in grapes and wine. In addition to teaching, Jim spends most of his time between research and extension.

Research Program Director: Melissa Hansen, Washington State Wine Commission

Melissa Hansen is the Washington wine industry's point person on grape and wine research. She leads the industry's own research grant program, as well as the statewide research program at Washington State University, ensuring they are industry-driven and -guided, with results accessible to all Washington grape growers and wineries. Before serving the Washington wine industry, she wrote grape and tree fruit articles for the Yakima, Wash.-based Good Fruit Grower magazine for 20 years and spent 15 years involved in California's table grape and tree fruit industries as research director for the California Table Grape Commission and government affairs for what is now the California Fresh Fruit Association.

Grape leaves killed by frost become brittle and break down rapidly into "confetti"-sized bits. This means that mechanical sorting methods are often not sensitive enough to cleanly pick the leaves from the grapes or sort them on the crush pad. Manual methods of sorting are possible but often not practical, except for ultra- premium or luxury brands. This means that much of these leaves will make it into the winemaking process. For whites, the pre-fermentation pressing operation will provide one more level of separation when the skins and seeds are pressed off the juice and gross solids are settled and racked. Red, macerated styles do not have this luxury, so the frozen leaf "tea" has more time to steep into the wine.

While the frozen leaf flavors in a wine may tell a story of terroir in a cold vintage for some vineyard blocks, frozen tea leaf-infused wine flavors are confusing to the customer. The frozen grape leaves infuse a flavor profile of their own that mask important markers of wine quality, such as color, aromatic complexity and astringency, creating wines with a lower perceived quality despite quality farming practices or region.

This article presents a summary of the findings presented in the scientific journal titled, "Frozen Leaf Material Causes 'Frost Taint' in Cabernet Sauvignon" authored by Scott C. Frost, Danielle J. Fox, Markus Keller, Thomas S. Collins and James F. Harbertson, published by the American Journal of Enology and Viticulture. Dr. James Harbertson is the corresponding author for this work. Melissa Hansen directs wine research efforts for the Washington State Wine Commission and helped to garner industry support and funding for this trial.

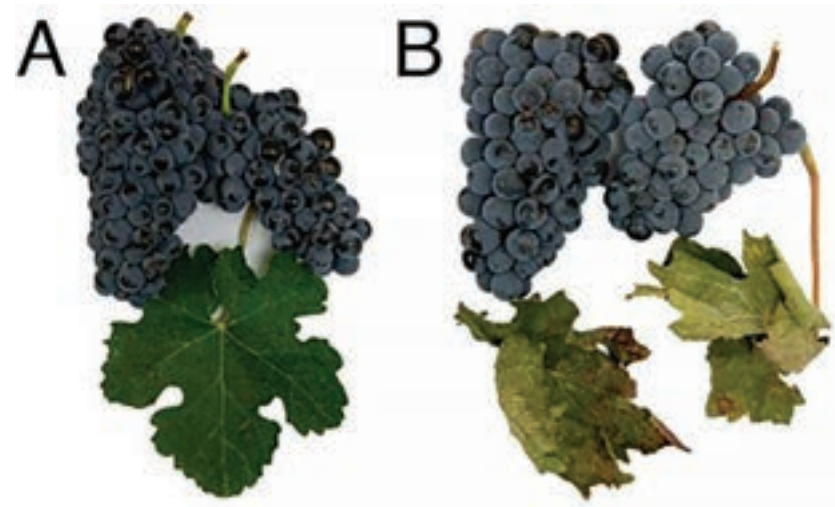

FIGURE 1: Cabernet Sauvignon clusters and leaves harvested from the same vineyard pre- (A) and post-frost (B), showing healthy and freeze-killed leaves.

Trial Objective

According to the Journal's abstract, "Washington state Cabernet Sauvignon wines made from fruit harvested after an autumn freeze have been shown to present potpourri, floral, and rose-like aromas. These aromas are described as atypical by Washington state winemakers, and the affected wines are termed to be 'rose tainted' or 'frost tainted.' Anecdotal evidence suggests that the inclusion of freeze killed leaf material (FKLM) into the fermentation is the source of the taint."

This trial set out to determine how much freeze-killed leaf material was required before a sensory panel noticed a difference in the aroma profile versus a control. The research also sought to characterize the types of aromas that were imparted by freeze-killed leaves in wine through sensory and chemical analyses.

Trial Description

This trial was carried out at the Ste. Michelle Wine Estates' Washington State University Wine Science Center. Freeze-killed Cabernet Sauvignon leaves were gathered from vines in the Horse Heaven Hills on October 21, 2019. Seven days later, Cabernet Sauvignon grapes, which had never been frozen, were harvested to kick off the experiment.

This experiment included controls that did not receive any leaf additions versus three levels of freeze- killed leaf material additions at low, medium and high add rates, each rate increased by four-fold. This experimental design spanned a range that would yield insights into thresholds of detection at the lower levels and clear sensory impacts at the higher levels. Each of these temperature-controlled, 140-liter ferments was triplicated for a total of 12 ferments, and freeze-killed leaf add rates were measured in grams of leaves per kilogram of must.

TREATMENTS:

CONTROL: 0 g/kg
LOW: 0.5 g/kg
MEDIUM: 2.0 g/kg
HIGH: 8.0 g/kg

Prior to leaf additions, all tanks were prepared and inoculated per standard red wine protocol with supplies purchased entirely from Scott Laboratories. This included inoculation for malolactic fermentation 48 hours after yeast inoculation. Temperature and cap management were tightly controlled, and each ferment went through 10 days of maceration prior to pressing and racking off gross solids.

Once these wines were dry by enzymatic analysis, they were sulfured and aged in 50-liter stainless steel kegs for another 71 days to allow for further settling prior to bottling. Once bottled, the standard chemistries of the resulting wines were as follows:

Conclusions

According to Harbertson et al., "Using a replicated pilot scale experiment, the current study successfully modeled the impact of freezing temperatures prior to harvest on Cabernet Sauvignon wine." The following bullet points indicate the key findings of this study, along with a visual representation of its data.

* Figure 3 demonstrates the results of responses from a sensory panel that show an increase in sensory traits not commonly associated with quality red wines. These results show a decrease in dark fruit character, lower astringency, increased floral and artificial fruit aromas not typical of red wine, and increased herbaceous characters, which are a common marker for poor quality and/or high levels of materials other than grape (MOG).

* Figure 4 shows the results of phenolic measurements and reduction in the compounds that are major quality markers for red wines, especially astringency from tannin and color intensity at the highest level.

Dose g/kg	pH	TA (g/L)	Malic (g/L)	Lactic (g/L)	VA (g/L)	RS (g/L)	Ethanol % (v/v)
0	3.7	6.23	0.04	1.13	0.14	0.13	14.01
0.5	3.6	7.19	0.04	1.11	0.13	0.13	13.77
2	3.6	6.95	0.05	1.02	0.14	0.13	14.11
8	3.6	7.07	0.04	1.02	0.16	0.13	14.21

FIGURE 2: Basic wine chemistry measures for Cabernet Sauvignon wines made with different dosages of freez- killed leaf material (g/kg of must).

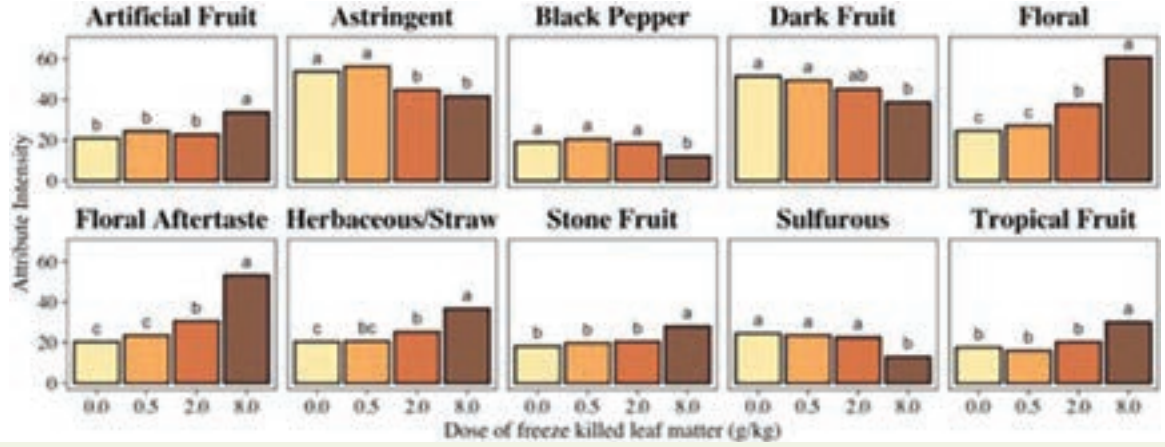

FIGURE 3: Average intensity for each sensory attribute, showing an effect of freeze-killed leaf material dosage (0, 0.5, 2.0, 8.0 g/kg must) on Cabernet Sauvignon wines. Each is grouped with a letter that shows similar traits between the fermentation groups.

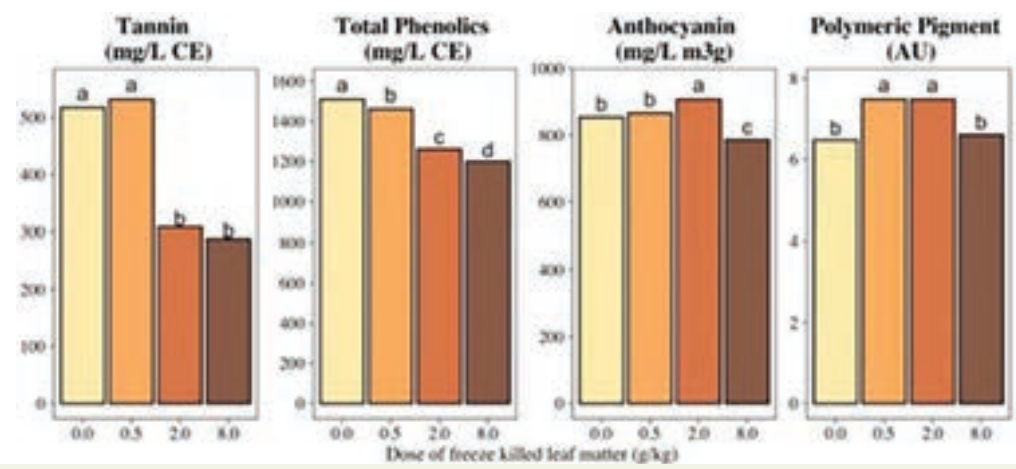

FIGURE 4: Mean concentration of four phenolic measures of Cabernet Sauvignon wines made with four different dosages of freeze-killed leaf material (0, 0.5, 2.0, 8.0 g/kg must). Each is grouped with a letter that shows the similar traits between the fermentation groups.

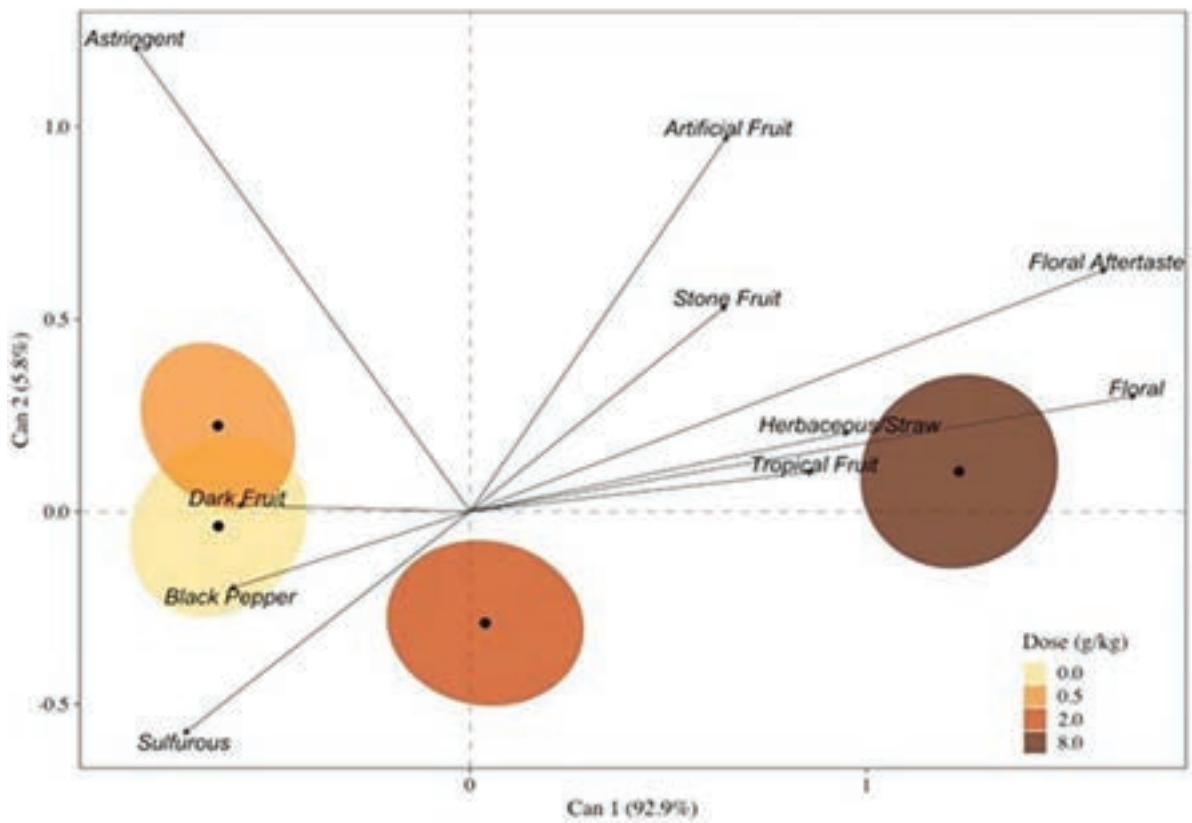

FIGURE 5: Canonical variate analysis of Cabernet Sauvignon wines made from four different dosages of freeze-killed leaf material (0, 0.5, 2.0, 8.0 g/kg must) show the relationship between freeze-killed leaves and their corresponding resulting flavor profile.

* Figure 5 shows how each addition rate of freeze-killed leaves impacts the overall flavor profile as compared to the no-leaf control relevant to the wine descriptor obtained from descriptive analysis. While the 0.5 addition rate is slightly different from the control, four-fold increases in freeze-killed leaf material dramatically shift the aromatic profile away from normal red wine aromas to what appear to be white wine aromas.

Post-Mort Q&A

Why are you studying the impact of freeze-killed leaf material on wine quality?

Harbertson: We are studying the impact of freeze-killed leaves on wine because it's a problem in this industry this far north and its effects on wine have not been researched well here. At first, I wasn't entirely convinced that it was real, until the 2019 vintage, because some have said that the freeze-killed leaf character is part of the regional terroir. Once we added the freeze-killed leaves to some ferments in our own research winery, we became believers and knew that a full study was necessary.

Freeze-killed Leaf Material (FKLM) is sometimes referred to as Freeze Taint or Rosey Taint. Why is this an inaccurate description?

Harbertson: It's not that it's an inaccurate description so much as the freeze-killed leaf material just causes atypical aromas in wine. These aromas are still from the grapevine as opposed to other taints we have become familiar with. I call it grape leaf tea because it is essentially frozen grape leaves infused into wine. It just doesn't taste that good because it adds a layer of confusing complexity to wines that people are not used to.

What variety/varieties are you working with for this experiment? Why?

Harbertson: We are focusing on late-ripening varieties that are in the most danger of having their leaves frozen. This means mostly Cabernet Sauvignon although we are working on some Riesling as we speak.

How did you design your trial to prove the impact of frozen leaves on wine quality? How did you decide the range of how much leaves to add to the ferments?

Harbertson: We used a range of progressive amounts of leaf material, from 0.5 to 8 grams of leaf material per kilogram of grapes in ferments. This allowed us to determine the lowest amount added to wine to determine sensory thresholds, as well as high amounts to get good descriptive analysis data. We added freeze-killed leaves to fruit that was never frozen so that we can see and measure the impact of the leaf aroma characters in the wines versus a control wine made without leaves. This means that we took grape material from two sites. We collected leaves from a vineyard that froze then grapes from a vineyard that did not freeze about a week later. We analyzed the samples using GCMS to identify sensory compounds, as well as descriptive sensory analysis to characterize the flavor changes between treatments.

Did you encounter any complications or difficulties?

Harbertson: It was very difficult to get my team to believe that the frost-affected wines were real. The industry sort of knew about the impact of frozen leaves in wine, but there was no serious work reported on it yet, with just a little research done previously in Canada. My grant must have felt like a prophecy or a curse to the granting agency as the year it was funded much of Washington suffered through two early hard freezes separated by a week in early October. It was a bit of a scramble to get the wines produced, but with the help of our industry we made it happen.

Who else worked with you on this trial?

Harbertson: The Washington Winegrape Commission funded the research. Melissa Hansen from the wine commission and winemakers, Bob Berteau and Leah Adint, from Chateau Saint Michelle helped make the experiment possible. Julie Tarara helped us with leaf collection. Of course, all the authors contributed: Scott Frost was a post-doc who helped do a lot of the project work, Markus Keller made sure everything was done right in the vineyard, and Dani Fox ensured that all the wine analyses got done properly in the lab. Tom Collins helped Scott with the GC analyses to help us identify the aroma chemistry involved with leaf effects. We are also thankful to Andrew Reynolds of Brock University who shared his insights with us.

Did you or your colleagues have any predictions about the conclusions?

Harbertson: I try to go into all my research with a blank slate. It prevents me from having bias in the outcome. None of us was convinced that freeze-killed leaves had an impact on wine until we smelled it, firsthand, in our own research winery.

What are the conclusions for this trial that a grower or winemaker can use?

Harbertson: We learned that it takes about three leaves per vine to trigger sensory detection of freeze-killed leaves. We were very careful to point out that there are a lot of compounds that contribute to freeze-killed leaf material. We found that freeze-killed leaves in a ferment do three major things:

- They change wine aromas into herbal tea-like characters by adding floral/herbaceous aroma to red wines.
- They reduce phenolic content, including color and astringency.
- Markers for high quality fruit aromas, such as dark fruits, are masked, cheapening the perception of the wine.

With this information, growers can choose to hand-pick grapes, instead of machine-harvesting, or take a crop loss. Growers may even take out insurance policies on vineyards that have been identified for early frost risk. They can pick earlier, assuming that their grapes are reasonably ripe. Unripe grapes don't make great wine either. Sadly, aged samples of the rosey wines were significantly worse, so further complications may arise. The aroma change is complex. This is just the beginning of this research.

Are there any process technologies that remove these freeze-killed leaves from grape clusters or berries?

Harbertson: Once frozen, these leaves turn into confetti. They shatter and turn into very small particles that get through most sorters. Hand-picking is really the best way to avoid this, but it's cost-prohibitive for most wine programs.

Do you think that this knowledge will lead to advancements in process technologies, such as RO or nanofiltration and downstream permeate treatment? Will Washington State University lead any of these trials?

Harbertson: Yes, we are looking to figure out how to treat the wine since even small amounts can cause freeze kill issues. Similar technologies used for smoke taint treatment can be used for this. We are currently working on a new project since fining agents don't work well for applications like this. They just strip too much flavor.

Will you continue to study the impact of freeze-killed leaf material on wine quality? What would you do differently?

Harbertson: We will add a white wine experimental angle to cover all the bases. We have heard that white wines can show effects of freeze-killed leaves but haven't seen too many examples because most ripen earlier than reds and they generally don't spend much time on solids due to the early pressing.

We are also looking to recreate freeze-killed leaves in the lab under the same arid conditions we have here in Washington so we don't have to wait for the actual frost to happen. This will speed up our rate of learning.

Once we identify specific marker compounds, then we can share the knowledge with commercial labs, like ETS, so that the technology can be scaled for use by the industry. WBM