# Technical Abstracts

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# Technical Abstracts



## Poster Presentation Abstracts





NOTE: Pages 1-41 constituted the program section of the original printed Program and Technical Abstracts booklet

*Abstracts are listed in the approximate presentation order as scheduled in the conference program.*

## Alphabetical Listing of All Authors with Submitted Abstracts





*Abstracts are listed in the approximate presentation order as scheduled in the conference program.*

## Viticulture—Climate Change Symposium

### Sunburn Damage Assessment Under Different Levels of Sun Exposure and Temperature in Sangiovese and Pignoletto Berries

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In the low-vigor vineyards of the North Italian hills, sunburn damage has drastically increased due to elevated summer temperatures and prolonged drought caused by climate change. With serious consequences on yield and berry composition, sunburn damage is now an emerging issue in these wine areas. In 2021, we conducted a study on the *Vitis vinifera* cultivars Sangiovese (red) and Pignoletto (white) to determine the role of cluster exposure and berry temperature on sunburn symptoms. Three levels of cluster exposure were imposed at veraison by leaf removal to differentiate the light incidence on the berries and their temperature. Afterward, the evolution of sunburn browning, sunburn necrosis, and berry shrivel was monitored weekly. Berry temperature was recorded continuously by thermocouples to identify the threshold level for the appearance of each symptom. A thermocamera was used to monitor changes in cluster temperature during the day. Damaged berries were sampled throughout ripening and high-performance liquid chromatography analysis was used to characterize sunburn browning and berry shrivel in terms of anthocyanin and flavonol content. Sunburn necrosis was observed on the most exposed berries of both varieties just after leaf removal and this damage worsened with maximum berry temperatures > 40°C. Berry shrivel appeared on Sangiovese only about three weeks after veraison and progressed until harvest, often leading to complete dehydration of the berries. Broadly, berry shrivel reduced concentrations of anthocyanins and flavonols (expressed as mg/berry) compared to healthy berries. Sunburn browning was evident only on Pignoletto, in berries receiving the most sunlight, and the concentration of flavonols increased with intensification of the brown color. In the next seasons, adaptation strategies will be tested on both varieties.

*Funding Support: This project is part of the ERA-NET Cofund ICT-AGRI-FOOD, with funding provided by national sources (Italian Ministry of University and Research) and co-funding by the European Union's Horizon 2020 research and innovation program, Grant Agreement number 862665.*

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### Heatwave Frequency Affects Gewürztraminer Leaf Physiology and Grape Cuticular Wax Profile

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Heat stress events (heatwaves) significantly impair grapevine leaf physiology and berry quality. The prevalence and frequency of heatwaves are predicted to increase in the coming decades, even in moderate climates. Despite this, the effects of heatwave frequency on grapevine physiology remains largely unstudied. We researched heatwave frequency by subjecting potted Gewürztraminer grapevines to a single heatwave event (SHW) at mid-ripening or a double heatwave event (DHW) at both veraison and mid-ripening, and compared them to untreated vines. Leaf gas exchange was measured before, during, and after the heatwave events, while chlorophyll fluorescence was also recorded afterward to evaluate stress recovery.

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## Viticulture—Climate Change Symposium—CONTINUED

Additionally, berry shriveling was analyzed in accordance with the berry cuticular wax profile and berry transpiration. Photosynthesis was reduced drastically during the heatwave events, but rebounded immediately post-heatwave in both SHW and DHW. In contrast, fluorescence was initially reduced by both SHW and DHW following the events. At harvest maturity, both photosynthesis and fluorescence were significantly reduced only by DHW, suggesting long-term damage to leaves. Berry shrivel was greater in heatwave treatments compared to their respective controls; however, shriveling was not greater in DHW than in SHW. This was attributed to a significant increase in total berry wax (11.8%) and total contents of triterpenes (11.7%) in DHW. As a result, berry cuticular transpiration was reduced by DHW, which correlated strongly with an increased ratio between the two most abundant wax and triterpene compounds, oleanolic acid and ursolic acid. We conclude that 1) grapevines are less resilient to a double than to a single heatwave event, and 2) the ratio of oleanolic to ursolic acid may be an important target for mitigation strategies to reduce berry shrivel. Future work will explore techniques to mitigate heat stress effects on grapevine physiology and quality.

*Funding Support: This work was financially supported by the NSERC Discovery program (AWD-000128 NSERC 2020).*

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### VitisGen2: Incorporating Marker-Assisted Selection to Produce More Disease-Resistant and Climate-Resilient Cultivars

Lance Cadle-Davidson, Bruce Reisch, Jason Londo, Anne Fennell, Matthew Clark, Craig Ledbetter, Gavin Sacks, Chin-Feng Hwang, Cheng Zou, Qi Sun, Ugochukwu Ikeogu, Dario Cantu, and **Timothy Martinson***
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In adapting to climate change, growers will need to cope with climate-induced changes in phenology, disease and pest complexes, and other stressors. While adapting cultural practices may mitigate climate-related challenges, breeding varieties that are more resilient to climate change will provide new solutions to long-standing weaknesses in current cultivars: notably, extreme susceptibility of *Vitis vinifera* cultivars to powdery mildew (PM) and downy mildew (DM). The VitisGen2 project is a nationwide collaboration (USDA-Geneva, UC Davis, USDA-Parlier, Cornell University, Missouri State University, University of Minnesota, South Dakota State University, Washington State University, and North Dakota State University) to identify DNA marker-trait associations and incorporate marker-assisted selection (MAS) into breeding programs. A novel genetic mapping platform (rhAmpSeq) that provides 2000 markers that are transferable across the Vitis genus has been used with 16 mapping populations in CA, NY, MO, and SD to identify >70 novel quantitative trait loci for PM and DM resistance, fruit quality traits (malate metabolism, anthocyanin acylation), and bloom phenology. Over the past eight years, the project has used MAS to screen over 60,000 grape seedlings from breeding programs in CA, MN, NY, ND, SD, AR, FL, and MO, and produced so-called "RenStack" breeding lines for researchers to access four to six PM resistance loci simultaneously for crossing. Abundant and affordable DNA sequence information is transforming grape breeding.

*Funding Support: NIFA Specialty Crop Research Initiative Competitive Grant #2017-51181-26829*

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## Viticulture—Climate Change Symposium—CONTINUED

### Adapting Stomatal Traits to the Climate Projected for Premium and High-Production California Wine Regions

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Stomatal traits determine grapevine water use, carbon supply, and water stress, which directly impact yield and berry chemistry. Breeding for stomatal traits has strong potential to improve grapevine performance under future, drier conditions, but the trait values that breeders should target are unknown. We used a functional-structural plant model developed for grapevine (HydroShoot) to determine how stomatal traits impact canopy gas exchange, water potential, and temperature under historic and future conditions in a premium and a high-production region (Napa and the Central Valley). Historic climate data (1990 to 2010) was collected from weather stations and future climate (2079 to 2099) was projected using four representative climate models for California, assuming medium- and high-emissions (RCP 4.5 and 8.5). Five trait parameters, representing mean and extreme values for maximum stomatal conductance (*g*max) and leaf water potential threshold for stomatal closure (Ysc), were defined from meta-analyses. Compared to mean values, the water-spending extremes (highest *g*max or most negative Ysc) had negligible benefits for carbon gain and canopy cooling, but exacerbated vine water use and stress for both sites and climate scenarios. These traits increased cumulative transpiration by 8 to 17%, changed cumulative carbon gain by -4 to 3%, and reduced minimum water potential by 10 to 18%. Conversely, the water-saving extremes (lowest *g*max or least negative Ysc) strongly reduced water use and stress, but potentially compromised the carbon supply for ripening. Under RCP 8.5 conditions, these traits reduced transpiration by 22 to 35% and carbon gain by 9 to 16%, and increased minimum water potential by 20 to 28%, compared to mean values. Overall, selecting for more water-saving stomatal traits could improve water-use efficiency and avoid the detrimental effects of highly negative canopy water potentials on yield and quality, but more work is needed to evaluate whether these benefits outweigh the consequences of minor declines in carbon gain for fruit production.

*Funding Support: UC Davis Department of Viticulture and Enology*



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## Viticulture—Climate Change Symposium—CONTINUED

### Fruit Zone Cooling in Winegrapes During Heatwaves

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Heatwaves impose excessive heat stress on grapevines and may compromise grape production. Knowing how vines respond to elevated temperature can inform management decisions. We acclimated potted Cabernet Sauvignon vines to warm (32°C/15°C day/night) or cool (27°C/10°C) seasons before exposing them to a spectrum (40 to 25°C) of maximum temperature regimes in environmentally controlled growth chambers. Leaf gas exchange was measured at noon and in the late afternoon, when air temperature reached its maximum. The results showed that the vines responded to elevated air temperature with a reduction in gas exchange. The sensitivity of leaves to temperature change was similar in vines acclimated to warm and cool seasons, suggesting that mitigating sudden raises in temperature might be the key to prevent heat stress. To mitigate heat stress in the vineyard, we developed a misting-type evaporative cooling system (MECS). The MECS detects leaf or fruit surface temperature and automatically activates misting nozzles at 35°C, but stops misting if the surface temperature is lower than 33°C. Following operation for canopy cooling of Cabernet Sauvignon in 2020, we modified the MECS in 2021 to mitigate heat accumulation in the fruit zone, using upward-facing nozzles placed on the drip-irrigation wire. Successive heatwaves in 2021 brought record high air temperatures of >44°C in late June, during the period of berry size determination. The MECS kept the air temperature in the fruit zone 7°C cooler than the peak ambient temperature. Cooling the fruit zone during heatwaves resulted in larger berries, heavier seeds, and more seeds per berry. Titratable acidity was higher in the juice from cooled vines. There was no significant effect of the cooling treatment on yield, disease incidence, berry splitting, sunburn, or shoot growth. These results show that the MECS can stabilize grape berry growth and acidity during extreme heatwaves.

*Funding Support: Northwest Center for Small Fruit Research Program, USDA Specialty Crop Block Grant Program, Washington State Grape and Wine Research Program*

## Enology—General Enology Session

### Rationale for the Evaluation of the Antioxidant Capacity Related to Inactivated Dry Yeast Nucleophilic Composition

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Inactivated dry yeast (IDY) are gaining interest due to their wide spectra of and enological applications. There is a great diversity of compounds released by specific glutathione-rich inactivated yeast (Bahut et al. 2020): notably, sulfur-containing compounds that act as sacrificial nucleophiles in the cascade of phenolic compound oxidation reactions. Nucleophiles released from IDY are thus related to their antioxidant activity. To develop a new method to measure this antioxidant activity, and to explore its correlation with the chemical diversity of IDY-released nucleophiles, we propose to measure the characteristic half-life time of a stable isotope-based nucleophile, during controlled oxidation of a standard polyphenol (4-methylcatechol) in model wine, by UHPLC-ESI-Q-ToF MS. We propose that the higher the native nucleophilic environment of IDY-released compounds, the greater the half-life time of the stable isotope nucleophile will be. Competition reactions in the presence of increasing concentrations of sulfites with the stable isotope-based nucleophile allowed us to build a model to express the characteristic half-life time of the latter in mg/L free sulfites equivalent. This characteristic half-life determined for IDYs is used to classify their nucleophilic composition released into a model solution. This method is a powerful tool to rationalize the antioxidant activity related to the nucleophilic composition of complex matrices and has great potential for development of biological antioxidants for winemaking.

*Funding Support: Lallemand*

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### $H_2S$ Formation During Wine Storage in Aluminum Beverage Cans—Effects of Wine Composition and Liner Type

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The fastest-growing category of wine packaging, canned wines offer several advantages over glass-packaged wines in terms of recyclability, durability, and convenience. However, storing wines in cans can occasionally (and unpredictably) increase hydrogen sulfide ($H_2S$; "rotten egg" aroma) in certain wine can liner combinations after several weeks or months. We report the development and validation of an accelerated aging test to predict $H_2S$ formation and use its evaluating parameters that affect $H_2S$ production during canned wine storage. For the accelerated assay, coated Al coupons are incubated in 25 mL wine at 50°C in crimp-topped glass vials and $H_2S$ is measured after three and 14 days. Reliable control of oxygen during storage to <1 ppm was critical to achieve reproducible $H_2S$ results. Validation with commercial wines showed good correlation in $H_2S$ production between conventional aging up to 32 weeks and accelerated aging. Traditional BPA epoxy and newer BPA-NI epoxy liners had similar performance, but acrylic liners resulted in significantly more $H_2S$ formation in all wines. Among wine composition parameters, molecular $SO_2$ was most strongly correlated with $H_2S$ production during storage. Several other components, including Cu, did not correlate with $H_2S$ production.

*Funding Support: The Sherwin Williams Company, New York State Wine and Grape Foundation*

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## Enology—General Enology Session—CONTINUED

### Seeded Search Estimation Algorithm for On-line Prediction of Wine Fermentation

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Mathematical models for wine fermentations and parameter estimation algorithms have been used to analyze wine fermentations; however, such analysis is performed off-line, typically after fermentation is completed. Combined with automated Brix measurements, an on-line model estimation system would allow automated prediction of fermentation density and quantification of rates of energy and $CO_2$ evolution across all concurrent fermentations in a winery. The overlapping curves of many concurrent fermentations—with different starting times, temperatures, volumes, starting compositions, inoculations, etc. –yields highly non-uniform loads. The electricity charges for such loads are based on the maximum peak rate of use (kW), the energy used (kWh) and the time of use during each day. The measured and predicted rates of fermentation energy can be used to manage refrigeration loads and their energy requirements. Additionally, the rates of $CO_2$ evolution can be used to manage loads on future carbon capture and sequestration systems. Here, an on-line seeded search parameter estimation algorithm, in combination with the Boulton fermentation model, is proposed to predict fermentation trajectory and provide a confidence in the estimate. The method was evaluated on a set of red and white fermentations. From the rate of fermentation, the rates of energy and $CO_2$ production were also compared to the on-line model predictions. As more data becomes available, confidence in the on-line predictions increases and closely follows the automated measurements. Finally, the summation of overlapping energy and $CO_2$ loads are calculated from automated Brix measurements for all fermentations from the 2021 harvest at the UC Davis Teaching and Research Winery.

*Funding Support: T.J. Rodgers Fellowship in Electrical and Computer Engineering, Treasury Wine Estates, Stephen Sinclair Scott Endowment in Viticulture and Enology*

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### Chemical and Temporal Sensory Effects Post-Expectoration in Co-Fermented and Blended Merlot, Malbec, and Petite Sirah

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Wine sensory perception has a strong temporal component, especially with regard to the perception of retro-nasal flavor and astringency after expectoration. The purpose of this experiment was to evaluate the temporal impact post-expectoration on Merlot, Malbec, and Petite Sirah wines that had been co-fermented, in contrast to wines that were blended post-alcoholic fermentation and post-malolactic fermentation along with single-cultivar controls. Each of the three winemaking techniques used a combination of each cultivar: Merlot-Malbec, Merlot-Petite Sirah, Malbec-Petite Sirah, and Merlot-Malbec-Petite Sirah. Selected phenolic classes and color were followed up to 14 months postbottling. The 15 treatments were also evaluated four times using Temporal Dominance of Sensations by 11 trained panelists for five retro-nasal aroma attributes (fruit, floral, mineral, vegetal, and spicy), two taste attributes (bitter and acid), and one mouthfeel attribute (overall astringency). Anthocyanins were higher in Malbec and Petite Sirah monovarietal wines and

blending/co-fermenting with these tended to increase anthocyanin content. Tannins were higher in Merlot and Petite Sirah monovarietal wines and cofermentation, and post-alcoholic fermentation blending preserved more tannins than post-malolactic fermentation blending. The detailed chromatic composition of the wines was heavily determined by each monovarietal wine, with blending and cofermentation playing a much less relevant role on these parameters. The sensory data were analyzed with TDS curves and a trajectory principal component analysis. Preliminary sensory results found that while the different blending periods shared several attributes, the time of dominance differed. Co-fermentation and post-malolactic blending tended to show dominance earlier in evaluation than post-alcoholic fermentation blending. Additionally, each cultivar appeared to contribute to the dominance of certain attributes. Malbec was associated with the dominance of acidity, while Petite Sirah tended to influence the dominance of the spicy retro-nasal aroma and early perception of astringency.

*Funding Support: E&J Gallo Winery*

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### Investigation of Pre- and Post-Fermentation Alcohol Adjustments on Sauvignon blanc Wines Harvested at Three Maturities

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Harvest and alcohol concentration are known to have significant effects on wine aroma and taste attributes. In this experiment we added dealcoholization to a maturity trial to better understand the effects of alcohol on sensory attributes. Sauvignon blanc was harvested at three different maturities (19, 22, and 25 Brix). At each harvest, alcohol was controlled by either chaptalization or dilution for the pending/previous harvests. Dealcoholization was used to lower the alcohol of the medium- and high-alcohol treatments by ~2.0% (v/v) to match the lower treatments. Basic wine chemistry showed statistical differences by harvest for all analysis. The alcohol treatment showed significant differences for alcohol, RS, and pH. The dealcoholization treatment was significant for alcohol and TA. Descriptive analysis was carried out with 12 panelists (seven female, five male). All taste attributes were significant, while nine of 16 aroma attributes were significant. Principal component analysis showed that wines separated based on alcohol and harvest. Generally, higher-alcohol wines associated with hot, viscous, bitter, and alcohol, while lower-alcohol wines were associated with boxwood, sour, and sweaty attributes. Later-harvest wines were found to be more briny and herbal while earlier-harvest wines had more grapefruit, melon, and sour candy attributes with greater overall intensity. Analysis of variance showed that harvest was significant for most aroma attributes and three of the taste attributes (sweetness, bitter, and sour). The alcohol treatment was primarily significant for all five taste attributes. However, several aroma attributes appeared sensitive to the alcohol treatment (citrus, grapefruit, and honey). Overall, harvest and alcohol dominated the sensory profile of the wines. Dealcoholization results suggest this technology can be used to mimic wines made from less-mature or diluted juice. Gas chromatography-mass spectrometry will be used to evaluate chemical and sensorial effects.

*Funding Support: This research was funded by Washington State University, Auction of Washington Wines and all Washington State winegrape growers and wineries through the Washington State Wine Commission.*

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## Viticulture—Pest Management Session

### Illuminating Ultraviolet-C Light for Grapevine Powdery Mildew Management

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Germicidal Ultraviolet-C (UVC) is a promising management tool for grapevine powdery mildew (*Erysiphe necator*). We evaluated UVC disease management efficacy and impact on berry quality in 2020 and 2021 in a mature *Vitis vinifera* Chardonnay vineyard at WSU Prosser. UVC was applied at 200 J/m2 30 min post-sunset with an over-the-row light array. In 2020, we evaluated application intervals of once per week and every 14 days; in 2021, we evaluated application intervals of twice per week and once per week. Unsprayed and standard spray programs were included. Plot sizes included 30 vines replicated four times throughout the vineyard. Treatments began at 7 to 15 cm shoot growth and ended at approximately three weeks post-fruit set. These vintages were challenging for disease evaluation, as there was naturally low disease pressure. End-of-season disease severity in the untreated controls was 43% (2020) and 16% (2021) for foliar and 3% (2020) and <1% (2021) for clusters. Despite this low pressure, positive trends were seen with UVC treatment. Disease severity was converted to accumulated area under the disease progress curve (AUDPC) and the presented statistics represent this. In 2020, while UVC did not statistically reduce foliar disease severity, treatment once per week reduced foliar disease by 25% compared to the unsprayed control. In 2021, the twice per week application reduced disease by 79% and the once per week by 50% compared to the untreated control, though treatments were not statistically different ($p$ = 0.09). Berry weight, Brix, pH, and titratable acidity were not affected by UVC treatment, but there was an increase in total skin phenolics when treated with UVC once per week in 2020 ($p$ = 0.009); 2021 data is still being processed. The consistent disease reduction with UVC applications once or twice per week, even under very low disease pressure, and the lack of detrimental impact on berries, suggests that UVC could be a complementary powdery mildew disease management tool.

*Funding Support: Washington State Grape and Wine Research Program*

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### Examining Sulfur Use Patterns in Western United States Winegrape Vineyards

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Fungicide use, especially sulfur, is currently an indispensable part of powdery mildew management in United States winegrape production. Sulfur has a long history of effective use for disease control and there is very low risk of *Erysiphe necator* resistance development. This makes sulfur important for fungicide resistance management and product stewardship. Understanding how applicators are using sulfur can inform extension efforts and improve use recommendations. The Fungicide Resistance Assessment Mitigation and Extension (FRAME) network collected winegrape fungicide records from growers in California (CA, 51 vineyards), Oregon (OR, 43 vineyards), and Washington (WA, 15 vineyards) to take an in-depth look at sulfur use between 2016 and 2020. During this period, on average, sulfur comprised 35% of the total fungicides applied in-season, with a range of 25% (WA) to 39% (OR). On an annual basis, sulfur use increased from 27% (2016) to 41% (2020) of total fungicides applied in-season. The prevalence of sulfur use

and application method, alone or in a mix, was dependent on the time of season applications were made. For example, 62% of all first in-season applications were either solely sulfur (46% of total applications) or contained sulfur as a partner in a tank mix (16%). In contrast, only 8% of the last in-season sprays were either solely sulfur (2% of total applications) or contained sulfur as a partner in a tank mix (6%). This reduced sulfur use late-season is likely due to concerns related to daytime high temperatures or residue carryover into the winery. Preliminary analyses suggest that applicators are using sulfur in ways that align with extension fungicide stewardship recommendations: using it early season as a contact product application, and generally increasing its use between 2016 and 2020 as a tank mix option for fungicide stewardship.

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### Developing a Method for Making Transgene-Free Gene-Edited Grapevines

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Techniques to obtain transgene-free plants from genome-edited material, either through direct DNA-free genome editing or by eliminating transgenes following conventional transformation methods, are not established in many clonally propagated perennial crop models, including grapevine. We developed a research project in two phases to generate transgene-free, gene-edited grapevine material. In Phase 1, the objective was to create stable transformants in grapevine via *Agrobacterium*-mediated transformation using an "excisable" genetic cassette containing the gene-editing ingredients targeting gene(s) of interest along with other "foreign" DNA required to select transgenic plants. Phase 2 will deliver a RiboNucleoProtein editing complex (RNP) to the edited plant material from Phase 1 to "excise" the inserted genetic cassette, making the edited plant material GMO-free. To facilitate the entry of the RNP, we are testing a series of nanocarriers called Cell-Penetrating Peptide (CPP), widely used in medical sciences for drug, DNA, and protein delivery to human cells. To the best of our knowledge, no studies report the use of CPP's for gene editing in plant sciences. As a proof of concept, we have generated a series of edited mutants altering expression of four MLO susceptibility genes whose altered activities are known to confer resistance to mildew in a variety of crops. We will discuss the current progress of the project and the milestones achieved, which include but are not limited to generation of MLO-edited grapevine materials and a set of preliminary experiments showing the ability of CPP to facilitate entry of the RNP into grapevine regenerable tissue (somatic embryos). This will be the first report to demonstrate RNP delivery into intact grapevine cells, if successful. It will offer an alternative to conventional technology (protoplast and viral-mediated transient expression) to generate transgene-free edited grapevines.

*Funding Support: AVF, OWB, CDFA, Erath Family Foundation*

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*indicates corresponding author

## Viticulture—Pest Management Session—CONTINUED

### Efficacy of Minimal-, Moderate-, and High-Input Disease Management Systems for Pierce's Disease-Resistant Hybrids

**Shane Breeden*** and Phillip Brannen
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Pierce's disease- (PD-) tolerant hybrid winegrape cultivars are an important alternative to *Vitis vinifera* cultivars in the southeastern United States. While these hybrid cultivars lessen the concern from PD, there is little to no available information on their susceptibility to other grape diseases or tailored disease-management programs specific to these hybrids. Three different spray programs (treatment regimens) were used on five PD-resistant Vitis hybrid cultivars: 07370-84 and 'Camminare noir' from the UC Davis PD-resistance grape breeding program, 'Lomanto', 'Blanc du bois', and 'Crimson Cabernet'. Regimens tested were: (1) an untreated control; (2) low input (no fungicides with significant powdery mildew activity); (3) moderate input (addition of products with more efficacious downy mildew activity); and (4) high input (additional materials added for rots, powdery mildew, and downy mildew). All cultivars developed downy mildew, though the degree of mildew varied. Powdery mildew did not develop on Blanc du bois or Crimson Cabernet in these trials. Though distinctions in mildew development were observed, all of these PD-resistant hybrids will require a full program for commercially-acceptable rot management. Black rot (*Guignardia bidwellii*), bitter rot (*Greeneria uvicola*) and Macrophoma rot (*Botryosphaeria dothidea*) were prevalent. For all hybrids, fruit rot incidence, measured as area under the disease progress curve (AUDPC), was consistently and substantively lower for the high-maintenance fungicide regimen ($p \leq 0.05$). It had been hypothesized that some of these hybrids might provide some resistance to rots due to the inclusion of native grapes in their heritage. Unfortunately, though hybridization with native grape species conferred resistance to Pierce's disease, it does not allow for use of more economical spray programs as a whole.

*Funding Support: Southern Region Small Fruits Consortium*

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### Comparison of Insecticides to Control Vine Mealybugs (*Planococcus ficus* Signoret) in Organic Winegrape Production

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Vineyard mealybugs (Hemiptera:*Pseudococcidae*) are a matter of increasing concern for grapegrowers, as economic losses resulting from infestations continue to increase. Several species of mealybugs are present in California, but the vine mealybug (*Planococcus ficus* Signoret) is most problematic. It is an invasive species, introduced ~20 years ago and not yet under control. In a large vineyard trial, this project compared the efficacy against mealybugs of several products commercially available in organic production: pyrethrins, neem oil, diatomaceous earth, *Chromobacterium subtsugae*, stylet oil, and potassium salts of naturally derived fatty acids. The project also controlled for side effects on grapevine physiology and grape composition related to spraying dusts and oils on leaf and berry surfaces.

## Viticulture—Pest Management Session—CONTINUED

The experiment was set up as a randomized complete block design with four treatments plus control and four replicates. Each replicate was one acre, for a total of 20 acres, and repeated in two years with different products. The vineyard was planted with Pinot noir and moderately infested with mealybugs. None of the products significantly reduced the number of mealybugs on the trunk or leaves, and none had negative or positive effects on plant physiology or grape composition. This project provides new and unbiased information that will help organic growers make informed decisions on what products to apply for controlling mealybugs in organic vineyards.

*Funding Support: American Vineyard Foundation*

## Enology—Smoke Taint Session

### Profiling Volatile Phenols in Grapes as a Tool to Track the Impact of Wildfire Smoke during Berry Development

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Recent wildfires have significantly impacted the winegrape growing regions on the West Coast. Research has shown that wildfires release large quantities of phenols to the air that can absorb into grapes, impacting grape and wine quality. However, as the wildfire-released phenols also occur naturally at different levels in different grape varieties, it is essential to determine 'baseline' levels to determine elevated levels due to wildfire smoke exposure. Current known smoke marker compounds are guaiacol, 4-methylguiacol, o-, m-, and p-cresol, 4-methylsyringol, syringol, and their glycosylated precursors. The glycosides are naturally present in grapes and can also form enzymatically in grapes during smoke exposure as part of the plant defense mechanism. Currently, there is no baseline data available to the industry to facilitate interpretation of grape smoke marker compound levels. The current project seeks to develop robust baseline data for the seven main varieties (Cabernet Sauvignon, Merlot, Pinot noir, Zinfandel, Syrah, Chardonnay, and Sauvignon blanc) in several AVAs over multiple seasons. Total, free, and bound volatile phenols are determined using liquid/liquid extraction with GC-MS/MS and UPLC-QTOF-MS methods. Air quality data during the growing seasons were obtained from governmental sources and used to ascertain whether the volatile phenol profile was affected by ambient smoke. Initial results for Cabernet Sauvignon and Chardonnay in several California wine regions show good agreement with the literature, with syringol being the most-abundant volatile phenol. Data also indicate similar volatile concentrations for grape samples from close-proximity locations. This project is the first step in creating a robust database for the normal range of volatile phenols in different grape varieties. Because annual variations in growing conditions and climate can impact the natural levels of volatile phenols in grapes, data from several seasons will be needed.

*Funding Support: American Vineyard Foundation*



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## Enology—Smoke Taint Session—CONTINUED

### Using A Model System to Trace Glycosidically-Bound Smoke Taint Markers from Grape to Wine

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The increasing frequency of wildfires on the West Coast of the United States is a significant risk for the grape and wine industry. During wildfires, large quantities of volatile phenols (VPs) are released into the air due to thermal degradation of lignin. Besides the detectable free forms of these VPs, grapes can store a large portion of VPs as various nonvolatile glycosides, then release them during fermentation and wine aging. It is difficult to predict the smoke taint potential of a particular wine by simply measuring free VPs or their corresponding acid-labile forms, because the VP glycosylation mechanism is not clear, including the various glycosides formed from a particular volatile phenol compound. In this study, clusters of Cabernet Sauvignon grapes were exposed to isotopic VPs in a contained atmospheric system. After exposure, the glycosylation of absorbed isotopic VPs in grapes was traced and identified by UHPLC-qTOF-MS. In addition, both the free and acid-labile forms of isotopic VPs in the exposed grape were analyzed by gas chromatography-mass spectrometry (GC-MS). Exposed grapes were microfermented and the isotopic VPs' levels of juice/must were monitored every two days until fermentation was complete. Finally, the obtained wines were analyzed by GC-MS for free and acid-labile VPs, while the related glycosides were determined by UHPLC-qTOF-MS. Grape enzyme activity showed variable ability to form mono-, di-, and trisaccharide VPs when exposed to VPs in this in vitro study. By tracing the formation of isotopic VP-glycosides and the hydrolyzed levels of related isotopic VPs during microfermentations, this study expands the knowledge of the correlation between different forms of VPs and their related glycosides.

*Funding Support: USDA-ARS*

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### Olfactory Detection Thresholds for Smoke Taint in Red Wine

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This work determined the olfactory detection thresholds of a mixture of volatile phenols (VP) representative of wildfire smoke exposure in red wines, namely guaiacol, 4-methylguaiacol, 4-ethylguaiacol, 4-ethylphenol, m-cresol, p-cresol, and syringol. The concentrations of the individual VPs included in the mixture were obtained from a literature review of red wines made with grapes that had been exposed to wildfire smoke. Threshold testing was conducted following the ASTM-E679 method, using an unoaked Cabernet Sauvignon wine spiked with increasing levels of the VP mixture and a panel of 25 consumers. The Best Estimate Threshold (BET) values for the VP mixture were ~30% of the average concentration of VPs found in red wines produced with grapes exposed to wildfire smoke. For some compounds such as guaiacol, the BET values were ~16% of the threshold reported in the literature. Our results highlight how olfactory detection threshold concentrations are significantly decreased by the synergistic effect of multiple

volatile compounds in the wine matrix. For winegrowers and winemakers, our results suggest that consumers will be able to detect smoke-exposed wines at lower concentrations than currently reported in the literature.

*Funding Support: CSU-Agricultural Research Institute Grant 22-02-115; Oak Solutions Group, Inc.; E&J Gallo Winery*

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### Functionality of Different Inter-Stimulus Protocols for Sensory Analysis of Smoke-Tainted Wines

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Smoke is an aerosol that carries organic compounds over vast distances. As wildfire occurrence has increased around the world, the smoke produced from them has begun to pose unique issues to wine. These volatile organic compounds, when absorbed by grapes, impart an unpleasant smoky and burnt flavor, with a lingering ashy finish. This lasting ashy finish poses problems when tasting many samples in sequence, which may contain both smoke-tainted and untainted wines. In sensory analysis, carryover bias is introduced when residual sensations can cause increased intensity ratings of lasting attributes as you move from sample to sample. For accurate intensification and analysis of smoke-trained wines, this bias must be accounted for. Previous work indicated that a 1 g/L pectin rinse solution is effective in combatting this bias; however, this rinse requires a lengthy separation of two minutes between samples. This work sought an equally as effective, but more efficient, rinse that can mitigate carryover of smoke-related flavor attributes in the mouth. The progression of smoke characteristics and typical wine attributes were evaluated over time in smoke-tainted wines using a fixed-time point evaluation system. Four rinse systems were evaluated, which included the currently recommended pectin solution. Of the rinses studied, 4 g/L dextrose was effective in clearing smoke flavor perception and was more efficient than the pectin rinse, only requiring 90 seconds to clear these flavors. Along with rinse evaluation, this work additionally identified retronasal flavor references to better define the in-mouth sensations associated with wildfire smoke-affected wines. This study overall provided increased insights into the sensory flavor impact that wildfire smoke introduces into wine and the results can help guide future sensory analysis.

*Funding Support: USDA-ARS*

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### Evaluation of Kaolin and Bentonite Adsorptive Sprays to Reduce Uptake of Smoke-Related Compounds during Smoke Exposure Events

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Kaolin or bentonite-based adsorptive sprays were applied prior to deliberate smoke exposures in portable hoop-houses over four growing seasons (2018 to 2021) to evaluate their ability to reduce uptake of smoke-related compounds. Sprays (0.5 lb/gallon) were applied to clusters and surrounding leaves to the point of run-off using hand-held or backpack sprayers the day prior to exposure. The sprayed vines and unsprayed controls were exposed to fresh smoke from burning either rangeland plant material for 48 hrs (2018) or hardwood pellets for 36 hrs (2019



**indicates corresponding author*

## Enology—Smoke Taint Session—CONTINUED

to 2021). Sprayed and unsprayed controls were also prepared for the unsmoked control hoop-houses. At normal maturity, berry extracts were prepared from smoke-exposed and control fruit (2018 and 2019) or bucket-scale fermentations were done (2020 and 2021). In 2018, there was little difference in smoke marker content among treatments. In 2019, control and treated berries were wiped clean prior to preparing extracts. The resulting extracts from kaolin- or bentonite-sprayed berries had significantly less guaiacol and 4-methyl guaiacol than extracts from unsprayed smoked berries, suggesting that removal of the sprayed materials would be necessary prior to making wine from the sprayed fruit. In 2020, all treatments were exposed to smoke from actual wildfires in addition to the smoke from the deliberate exposures, confounding the results for that year. In 2021, the number of treated vines per hoop-house was increased and half of the vines were sprayed with water seven days post-exposure to remove the kaolin or bentonite spray materials. The wines made from the rinsed fruit contained significantly lower concentrations of smoke-related marker compounds than wines made from fruit that had not been rinsed after exposure, confirming the expectation that using kaolin- or bentonite-based barrier adsorptive sprays will require their removal prior to fermentation to avoid release of the adsorbed smoke compounds into the fermentation.

*Funding for this project: Washington State Wine and Grape Research Program and the M.J. Murdock Charitable Trust Partners in Science*

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### Evaluation of Smoke Compounds in Wine Derived from $^{13}$C-Labelled Smoke

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A major concern for many winegrape growers and winemakers currently is the effect of wildfire smoke on the final wine quality. Wildfire smoke has impacted many wine regions around the world, including the west coast of the United States, Australia, and even parts of France. The compounds associated with smoke in wine, such as guaiacol and syringol, have long been used to describe the presence of smoke in the vineyard and smoke-impacted grapes. However, the current marker compounds are not as successful in predicting smoke taint in wines. To identify and track the compounds from wildfire smoke found in smoke-exposed grapes and smoke-tainted wines, $^{13}$C-labelled smoke was used. $^{13}$C-labelled barley was grown in an elevated $^{13}$CO2 atmosphere and used to create $^{13}$C-labelled smoke upon ignition, achieving a $^{13}$C/$^{12}$C composition in dry barley as high as 4.47 3 0.74%, evaluated using IRMS. The $^{13}$C compounds were then tracked in smoke-exposed grapes and wine. GC-MS, LC-MS, and $^{13}$C-NMR were used to evaluate potentially novel compounds due to smoke exposure and tracked by the presence of elevated $^{13}$C. By better understanding the chemical influences smoke has on wine, amelioration to remove smoke-related compounds could be more targeted, without impacting other, desirable wine qualities.

*Funding Support: American Vineyard Foundation, USDA-Northwest Center for Small Fruits Research USDA-ARS*

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## Viticulture—Vineyard Management Research Session

### Comparison of Planting Stock on the Early Growth and Productivity of Chardonnay Grapevines

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Plant material used can be a critical factor influencing early vine development and productivity. The objective of this study was to evaluate nursery stock for their potential to advance vine development and yield. In 2016, a trial was established in a Chardonnay vineyard in the Salinas Valley of California to compare standard, 30 cm-long dormant bench grafts to 90 cm-tall bench grafts. Vine growth and yield parameters were measured from 2016 to 2021. The treatments were: 1) field-grown dormant, 30 cm; 2) tall green-growing potted, 90 cm; 3) tall dormant-potted, 90 cm; 4) tall dormant field-grown, 90 cm; and 5) tall dormant field-grown, 90 cm, untrimmed roots. Standard vines were trained to a single trunk in the first year. Cordon training started in the first year for all treatments where growth was adequate. The dormant tall field-grown bench grafts produced vines with larger-diameter trunks at the end of the first year, tall potted vines were intermediate, and the standard bench grafts were the smallest. The length of cordon development in the first year was greatest for tall dormant potted vines, intermediate for tall field-grown vines and not possible for most of the standard or tall green-growing vines. Yield in the second year was greatest for dormant tall vines, intermediate for standard vines, and not possible for tall green-growing vines due to the lack of cordon development. In the third and fourth years, yield was greater for tall dormant bench grafts, intermediate for standard vines, and lowest for green-growing vines. By the fifth year, all plant material had similar yields. Higher yield of dormant tall vines was possible due to the greater development of the permanent structures of the vines, which increased the capacity to produce crop in the early production years.

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### Vineyard Nutrition: Reevaluation of Sampling Protocols

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Vineyard nutrient management is crucial to reach production-specific quality standards, yet timely nutrient status evaluation remains challenging. The existing sampling protocol of collecting vine tissue (leaves and/or petioles) at bloom or veraison is time-consuming and does not provide spatial resolution for vineyards. Moreover, fertilizers are often applied based on historic nutrient data. The main goals of this project are to 1) optimize existing tissue-sampling protocols; and 2) determine the amount of nutrients removed at the end of the growing season. Updated protocols will support development of non-destructive tools for real-time monitoring of vineyard nutrient status. Soil and tissue sampling started in 2020, and field trials were established in 2021, in commercial vineyard blocks in Washington, with three rates of K applied in Chardonnay, three rates of N applied in Syrah and Sauvignon blanc, and two rates of N applied in Concord. Dormant canes and trunks; whole shoots at the five-to-six leaf stage; leaves (blades and petioles) at bloom and veraison; berries at lag phase and harvest; whole clusters at harvest; and whole leaves at leaf fall were collected from each block. Results showed no significant differences in yield components of harvest fruit and in nutrient levels of shoots, or in leaf blades collected at bloom or veraison (samples are still being processed).

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## Viticulture—Vineyard Management Research Session—CONTINUED

Blade and petiole nutrient concentrations were not well correlated with higher N concentrations and lower K concentrations in blades than petioles. There were positive correlations between N, P, and K concentrations in cane internodes and trunks in Chardonnay, and between P and K concentrations in dormant tissues and leaf blades. Fruit harvest and leaf fall removed significant amounts of nutrients per hectare, depending on variety and crop yield. Lost nutrients must be replaced through fertilizer addition to sustain vineyard productivity.

*Funding Support: USDA-NIFA-SCRI, WA State Grape and Wine Research Program, WA State Concord Grape Research Council*

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### Effect of Irrigation on Dry-Farmed *Vitis vinifera* L. cv. Zinfandel as a Function of Vine Age

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Natural rainfall in viticulture is often supplemented with irrigation during the dormant and active seasons. Unfortunately, rainfall events are becoming scarce and prolonged drought has dwindled water reserves. Additional information is needed on the influence of vine age on dry-farmed vine performance. This study evaluated the effect of dry farming and growing season irrigation on vine performance and fruit composition as a function of vine age in Zinfandel. The vineyard was historically dry-farmed during the growing season and received winter irrigation. Age treatments included Young vines (five to 12-years-old), Control vines (2:1 ratio of old to young, representative of the block), and Old vines (40 to 60-years-old). Within each age designate, there were irrigated and non-irrigated vines. Irrigation based on age-specific ETc was applied manually to the Irrigated treatment vines at veraison and veraison + four weeks. Irrigation did not influence vine development, except during some growth stages. Leaf abscission and chlorosis variations were significant among age and non-irrigation treatments. Shoot length varied significantly as a function of age, but not irrigation status. Stomatal conductance, photosynthetic rate, and leaf water potential showed no significant effects. Vine age influenced fresh and dry berry skin weight. Irrigated treatments had higher Brix than non-irrigated vines. Additionally, Old vines produced more fruit in both irrigation treatments (49.6 kg more irrigated; 6.8 kg in non-irrigated). This suggests irrigation added to traditionally dry-farmed vines during the growing season has minimal influence on performance. Additionally, dormant season irrigation applications are potentially enough to overshadow any notable difference imparted by irrigation events during the active season as a function of vine age.

*Funding Support: CSU Agricultural Research Institute Award 21-03-101; Historical Vineyard Society; Dusi Vineyards*

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## Viticulture—Vineyard Management Research Session—CONTINUED

### Predawn Leaf Water Potential is a Good Proxy for Dry, But Not Wet, Soil Water Potential

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Accurate and representative measurements of soil moisture are challenging because of the high spatial variability in soil under field conditions. Leaf water potential ($\Psi_{leaf}$) is a function of the soil water potential ($\Psi_{soil}$) and the vapor pressure deficit (VPD) and is controlled by the stomata. Predawn leaf water potential ($\Psi_{pd}$) is often used as a proxy for $\Psi_{soil}$, assuming that there is no transpiration at night and that enough time has passed for a hydrostatic equilibrium to be established. Despite numerous publications that indicate there is a disequilibrium between $\Psi_{pd}$ and $\Psi_{soil}$ and potential causes for this, models that are based on the equilibrium assumption continue to be published, including models for irrigation scheduling and several functions that divide plants, including grape varieties, into different levels of isohydricity. A field trial was conducted to test the assumption that $\Psi_{pd} = \Psi_{soil}$. Thirty different winegrape varieties were grown in a single experimental vineyard in southeastern Washington, where the $\Psi_{pd}$ and the soil water content under each sampled plant were measured multiple times during two dry-down cycles. The $\Psi_{soil}$ was calculated from the soil water content by means of retention curve data. At high soil water content, $\Psi_{soil}$ was consistently greater than $\Psi_{pd}$ for 24 out of 30 varieties, but the difference decreased as the soil dried. These results suggest that the $\Psi_{pd} = \Psi_{soil}$ assumption is only met for dry soils, while correction factors are required for wet soils. The difference between $\Psi_{soil}$ and $\Psi_{pd}$ may reflect the water potential gradient from the bulk soil to the leaves due to nighttime transpiration.

*Funding Support: Washington State Department of Agriculture Specialty Crop Block Grant Program and Washington State Grape and Wine Research Program*

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### Convective Mass Transfer: A New Model for Estimating Evapotranspiration Using Proximal Sensing Data

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As California becomes increasingly affected by drought and water use regulations become more restrictive, the demand for increased water use efficiency grows in importance. Currently, the viticulture industry relies on bulk irrigation, which assumes all vines in a given area have the same water demands. This assumption ignores individual plant health, the heterogeneity of soil, canopies, topography, and many other factors which affect plant water use, leading to over- and underwatering. To increase water use efficiency, irrigation practices must take spatial variation into account. Existing methods for estimating single-vine ET, such as sap flow or aerial imaging, are too expensive and/or technically advanced for use in most commercial settings. The purpose of this project is to provide proof-of-concept that ET sensors, combined with appropriate, physically-based models, allow precise control of irrigation down to single-vine resolution. Four mature Zinfandel vines were potted and placed on load cells in a vineyard setting, as simple weighing lysimeters to accurately measure ET. In 2020, we introduced three ET models and discussed their



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## Viticulture—Vineyard Management Research Session—CONTINUED

strong correlation with real ET. This presentation explores one of these models, the Convective Mass Transfer model, more closely, discussing the first principles concepts underlying the model and the meaning of each term in the model. Results from the 2021 season comparing CMT-model predicted water use rate and real ET provide further evidence that it could be possible to inform irrigation decisions at the previously unthinkable scale of single vines.

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### Subsurface Irrigation to Reduce Weed Management Costs and Chemical Use, and Improve Irrigation Efficiency

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A two-year trial was established in two regions of New Zealand where dripline was buried 30 cm off the vine trunk and 30 cm below the surface. Lines were specifically designed for subsurface use, with vacuum breakers to prevent soil being sucked into the line and root intrusion protection built into the drippers. In Hawkes Bay, the trial was carried out in Syrah vineyards and in Marlborough, the trial was carried out in Sauvignon blanc vineyards. The trials were set up as a split plot design in a single irrigation zone. All vines received the same irrigation amounts, fertilization, and cultural practices. Applying irrigation below the surface and off the vine row did not consistently affect vine canopy development, yield, berry weight, or fruit composition. Effects on vine water potential were mixed. There was a clear and significant reduction in weed growth in the vine row when water was applied below ground and off the vine row. Weeds could still access applied water, but grew where they could be mowed with a normal midrow mowing pass, rather than necessitating a slow, undervine weeding pass with specialized equipment. Other trials have shown a 30% water reduction with no negative effect on yield, though that was not part of the present study. Subsurface irrigation offers several benefits, including moving weeds to an easier-to-control area, reducing damage to irrigation lines and infrastructure by machinery and grazing animals, and offering the potential of increased water efficiency, especially if lines are buried deeper than the 30 cm in the present study, so weeds could not access the applied water.

*Funding Support: New Zealand Winegrowers*

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## Enology—Aroma Compounds Session

### Influence of Liqueur de Dosage Sugar Type on the Development of Maillard Reaction-Associated Products in Sparkling Wine

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The Maillard Reaction (MR) is a non-enzymatic, multi-step reaction involving reducing sugars and amino acids, which produces a variety of volatile and flavor-active compounds. In aged sparkling wine, MR-associated products (MRPs), including furans, heterocycles, pyrazines, and thiazoles, have been identified and contribute distinct nutty, caramel, and roasted aromas. Liqueur de dosage (composed of sugar, wine, and $SO_2$) is an addition made post-disgorgement. Sugars in dosage may degrade or interact with amino acids, thereby influencing the formation of MRPs. The aim of this study was to evaluate the influence of six dosage sugar-types: glucose, fructose, sucrose (cane-derived), sucrose (beet-derived), maltose, and rectified concentrated grape must, on the formation of MRPs in traditional method sparkling wine (2015 vintage; three years on lees; 59% Chardonnay, 41% Pinot noir) compared to zero-dosage wines (without sugar addition) over 18 months. Three bottles of each treatment were collected at 0, nine, and 18 months and analyzed in triplicate. MRPs were quantified by HS-SPME-GC-MS. Sugars and amino acids were quantified by enzymatic assay and NMR techniques, respectively, and sugar purity was measured by high-performance liquid chromatography. After 18 months of aging post-disgorging, four MRPs showed concentration differences between dosage sugar treatments at the 95% confidence interval (ethyl 3-mercaptopropionate, furfuryl ethyl ether, 2-ethylthiazole, and 2-furyl methyl ketone, with sensory descriptors of pleasant/fresh grape aroma, fruity, meaty/savory, and balsamic, respectively). Final analysis of the 0-month sparkling wine samples is currently underway and we anticipate that formation of MRPs will increase with extended aging, due to slow rates of MR activity under low pH (~3.2), high acid (7-12 g/L titratable acidity), and low temperature (12 to 14°C) sparkling wine conditions. This study establishs the effect of sugar type on formation of volatile MRPs in traditional-method sparkling wines during aging after dosage addition.

*Funding Support: Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery*

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### Achieving Tropical Fruit Aromas in White Wine through Innovative Winemaking Processes

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While tropical fruit aroma is often attributed exclusively to volatile thiols, contributions of other compounds and their interactions that cause this desired aroma are yet unexplored. In a previous study, the highly fruity sensory profile of esters transmitted tropical fruit aromas in a model wine spiked with acetate and ethyl esters. Moreover, samples that contained only thiols resulted in grassy and earthy aromas, not tropical fruit aromas as expected. Thus, this study hypothesized that, while the presence of thiols is critical to green aroma perception, tropical fruit aromas are caused by esters. This work investigated specific winemaking procedures that could increase both aroma families, esters and thiols, in white wines. Chardonnay grapes were harvested at the Oregon State University (OSU)

**indicates corresponding author*

## Enology—Aroma Compounds Session—CONTINUED

experimental vineyard and processed at the OSU research winery during the 2020 vintage. The control (standard winemaking) and four treatments were evaluated: skin contact (10°C for 18 hrs), enzyme addition (β-lyase, 40 µl/L), and two fermentation gradient temperature procedures (FGT 1: start at 20°C and after 100 hrs change to 13°C; FGT 2: start at 20°C and at ~12 Brix, change to 13°C). A full factorial design with all possible treatment combinations was proposed. An ester method (HS-SPME GC-MS) was developed to measure ethyl and acetate esters. The volatile thiols 3-MH, 3-MHA, and 4-MMP were quantified using a method by Capone et al. (2015). Results showed that skin contact, fermentation gradient temperature, and their interaction played a significant role in the concentrations of thiols. Significant differences were observed in skin contact and both FGT treatments for esters, but their interaction was not significant. Finally, the interaction of skin contact and FGT 1 resulted in the highest concentrations of both esters and thiols.

*Funding Support: American Vineyard Foundation*

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### Influence of Rose Oxide Enantiomers, Linalool, and α-Terpineol on Gewürztraminer Wine Aroma

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Monoterpenes are important aroma compounds in white wines. Many monoterpenes are chiral and the chiral forms have different aroma qualities. Rose oxide is an important chiral compound found in Gewürztraminer wines. The enantiomers of the chiral rose oxide vary in wines. The differences in the enantiomeric ratios have the potential to alter wine aroma and to change aroma quality in combination with other monoterpenes. The aim of this study was to evaluate rose oxide enantiomers at different ratios and the interaction of rose oxide with linalool and alpha-terpineol. Twelve compound combinations were tested in a dearomatized wine with different ratios of rose oxide and combinations with linalool and alpha-terpineol. Triangle tests, check-all-that-apply (CATA) and descriptive analysis were used to evaluate the aroma of the wine treatments. Results show that the ratio of rose oxide enantiomers did alter aroma. Additionally, descriptive analysis showed that the rose oxide enantiomer ratios altered aroma when linalool and alpha-terpineol were at low or medium concentrations, influencing grapefruit, lychee, and stone fruit aromas. At high concentrations, linalool and alpha-terpineol mask rose oxide, resulting in wines described as tropical fruit, ginger, rose, and honeysuckle. Understanding how different combinations and concentrations of monoterpenes alter aroma perception of white wines is important to achieve desired wine qualities and helps interpret flavor chemistry information.

*Funding Support: Fulbright Foreign Student Program*

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## Viticulture—Cover Crops Session

### Impacts of Native and Introduced Cover Crops on Soil Health in a Table Grape Vineyard of the San Joaquin Valley

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Cover crops are a component of sustainable agriculture, but their adoption in California is fairly low compared to other parts of the United States, primarily due to concerns over water use by the cover crops and diverse cropping systems. This study was conducted to determine how cover crops could be managed efficiently in a newly established Autumn King table grape vineyard in the semi-arid climate of the Eastern San Joaquin valley. The impacts of native species cover crops (*Phacelia tanacetifolia*) and introduced species cover crops (*Secale cereale* L. 'Merced') on soil health, crop water dynamics, and grapevine development were studied at the USDA-ARS at Parlier, CA. These cover crops were planted in vineyard inter-rows and the cover species were chosen for characteristics deemed beneficial to vineyards, such as ease in establishment, ability to attract beneficial insects, and low or non-competitiveness for soil water. In 2020, soil moisture in the native cover treatment averaged 15% more than in the introduced treatment and 41% more than the bare treatment, a trend that was retained even after irrigation run times were decreased in the native cover treatments. Vine vigor, a common assessment of vine health, was measured in December 2020. The average shoot mass, trunk diameter, and shoot mass per vine length were greatest in the native treatment. Soil aggregates assessed in 2021 showed that the percent soil mass of native treatment plots in the 2 mm fraction was 7.3% more than in the introduced and 7.9% more than the bare treatment. The vine vigor, soil aggregation, and soil moisture benefits in plots with native cover crops were not expected to be seen so definitively in first years of establishment. With more time and investigation, other trends may become apparent, potentially making cover crop adoption more feasible and appealing to California farmers.

*Funding Support: USDA-ARS*

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### Cover Crop Alternatives for Nematode Management in Washington Vineyards

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The northern root-knot nematode (*Meloidogyne hapla*) is the main plant-parasitic nematode affecting Washington State *Vitis vinifera* vineyards. This nematode induces small galls on roots, restricting water and nutrient uptake. This can impede vineyard establishment or exacerbate decline in chronically-stressed vines. While preplant fumigation is a common strategy for *M. hapla* management, its efficacy is temporary. Preplant and post-plant cover crops are a potentially viable addition to an integrated management approach for nematodes. Two trials were established to evaluate cover crops to reduce *M. hapla* densities in vineyards. Litchi tomato (*Solanum sisymbriifolium*) was used as a preplant fumigation alternative. We found that after one growing season, litchi tomato reduced *M. hapla* densities by 75% (fall 2020; $p < 0.0002$). This effect continued in the following spring with a 65% reduction (spring 2021; $p < 0.0002$). Fall 2021 sampling showed that *M. hapla* populations densities were reduced by 84% (fall 2021; $p = 0.014$) in plots that were planted to litchi tomato for two years. We are also evaluating Dracula oilseed radish

**indicates corresponding author*

## Viticulture—Cover Crops Session—CONTINUED

(*Raphanus sativus* var. *oleiformis*), White Dutch clover (*Trifolium repens*) and Pacific Gold mustard (*Brassica juncea*) for post-plant nematode suppression. After one year, plots planted with Dracula oilseed radish reduced *M. hapla* densities by 81% relative to the bare ground control (fall 2021; $p = 0.048$). *M. hapla* population densities trended lower in plots planted with White Dutch clover and Pacific Gold mustard compared to control plots; however, this difference was not statistically supported ($p = 0.078$). Soil samples will be taken again in spring 2022. Combined, our results demonstrate that pre- and post-plant cover crops may play an important role in *M. hapla* suppression in Washington winegrape vineyards.

*Funding Support: Washington State Grape and Wine Research Program; USDA National Institute of Food and Agriculture, Hatch project 1016563.*

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### No-till Systems and Perennial Cover Crops Show Minimal Effects on Vineyard Soil Microbiome Composition

**Maria Zumkeller**, Nazareth Torres, Runze Yu, and Kaan Kurtural*
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Soil erosion is a major source of agricultural soil degradation and it is estimated that 1% of topsoil is lost every year. This value is predicted to increase due to climate change, as precipitation events will become more unpredictable and extreme. The increase in recognition of soils as a non-renewable resource has encouraged a major shift in attention toward conserving and improving soils to mitigate the negative effects of climate change. Practices such as cover cropping and reduced tillage have become common in vineyard systems. However, their influence on soil physical and chemical properties and belowground microbial diversity and community is not entirely understood. We conducted a study in a Fresno County Ruby Cabernet (*Vitis* spp.) vineyard with a perennial grass (*Poa bulbosa* hybrid), annual grass (*Hordeum* spp.), and resident vegetation winter cover crop under till and no-till systems. Neither tillage nor cover crops significantly shifted the structure of the soil microbial community (16S species richness). However, soil macro- and micronutrients responded to the different tillage systems and no-till soils exhibited a decrease in carbon fixation, an increase in aerobic respiration, and a decrease in fermentation than soils under tillage. Similarly, potassium levels were also lower in no-till systems, which was supported by decreased titratable acidity values in no-till treatment berries at harvest. Furthermore, the annual grass and perennial grass cover crops responded quite differently from each other in characterization of microbial phytohormone pathways (auxin, cytokinin, and gibberellin production) and stress adaptation pathways (exopolysaccharide production). Overall, our results provided evidence that in the initial years of adoption of a permanent cover crop and no-till system, there is minimal influence on the microbial community structure, although no-till systems may experience a reduction in carbon and nitrogen cycling despite increased phytohormone production and micronutrient content.

*Funding Support: none*

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## Enology—Microbiology: Non-Saccharomyces Session

### Optimization of Temperature and Sulfur Dioxide Levels for Non-*Saccharomyces* Yeast Survivability and Metabolism

**Heather Carbon**,* Jonathan Brumley, and Charles Edwards
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Changes in viticultural practices involving extended ripening periods to achieve phenolic maturity have resulted in increased sugar concentrations in grape musts, with subsequent higher ethanol yields in wines. Non-*Saccharomyces* yeasts, which are found on grapes or in wineries, have been studied as a means to reduce ethanol yields in wines when sequentially inoculated with *Saccharomyces cerevisiae*. These yeasts consume glucose and fructose prior to inoculation of *S. cerevisiae* to reduce final ethanol content without negatively affecting wine quality. However, little work has been performed to optimize fermentation conditions, including temperature and sulfur dioxide tolerance, for non-*Saccharomyces* yeasts. Therefore, the objective of this research was to determine maximum $SO_2$ tolerance and optimal temperature levels for previously-isolated *Metchnikowia pulcherrima* and *Meyerozyma guilliermondii* strains from Washington vineyards. In this study, bottles containing 300 mL of sterile synthetic grape juice medium (pH 3.70, 300 mg/L YAN, 240 g/L fermentable sugars) were inoculated with either *Mt. pulcherrima* P01A016, *My. guilliermondii* P40D002, or *S. cerevisiae* D254 (control) at 106 CFU/mL. The bottles were subjected to 0.0, 0.2, 0.4, 0.6, or 0.8 mg/L molecular $SO_2$. Additionally, each bottle was held at 10, 15, 20, 25, or 28°C for 10 days, in triplicate, and sampled daily for population and sugar use. All ferments with >0.4 mg/L molecular $SO_2$ had inhibited growth of the non-*Saccharomyces* yeasts regardless of temperature. However, non-*Saccharomyces* culturability and sugar use at 0.0, 0.2, or 0.4 mg/L molecular $SO_2$ were temperature-influenced. Overall, *Mt. pulcherrima* and *My. guilliermondii* showed greater sugar use in ferments containing 0.4 mg/L molecular $SO_2$ at temperatures between 20 and 25°C. Continued work regarding the application of optimal conditions to pilot-scale grape fermentations using sequential inoculations of non-*Saccharomyces* yeasts prior to *S. cerevisiae* will be conducted.

*Funding Support: Washington State Grape and Wine Research Program; American Society of Enology and Viticulture Scholarship Program*

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### Use of Sulfur Dioxide and Non-*Saccharomyces* Yeast to Reduce Ethyl Acetate Production during Pre-Fermentation Maceration

**James Osborne**,* Michael Qian, and Melanie Nichols
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Growth of *Hanseniaspora uvarum* during prefermentation maceration (cold soaking) can result in excessive production of ethyl acetate, resulting in wines with a noticeable nail polish remover aroma. Typically, an addition of $SO_2$ is made at the start of cold soaking to inhibit *H. uvarum* growth. However, renewed emphasis on lowering the amount of $SO_2$ used during winemaking has led to exploration of alternative methods, such as the use of non-*Saccharomyces* yeast as bio-protectants to prevent microbial spoilage. This study investigated the effectiveness of non-Saccharomyces yeast in combination with $SO_2$ to reduce *H. uvarum* growth and ethyl acetate production during prefermentation cold soaking. Six-day cold soaks of Pinot noir grapes were conducted at 10°C with the addition of 0, 25, 50, or 75

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mg/L $SO_2$ and/or *Metschnikowia fructicola* or *Torulaspora delbrueckii* at ~105 CFU/mL. The addition of 0 or 25 mg/L $SO_2$ had little impact on *H. uvarum* growth whether *M. fructicola* or *T. delbrueckii* had been added or not. Reduced growth of *H. uvarum* was observed when 50 mg/L $SO_2$ was added, but lower *H. uvarum* populations were observed if *M. fructicola* was also added. Increasing the amount of $SO_2$ added significantly reduced production of ethyl acetate, as did the addition of *M. fructicola.* The addition of *M. fructicola* alone was as effective at reducing ethyl acetate as an addition of 50 mg/L $SO_2$. Significant interactions between $SO_2$ concentration and addition of *M. fructicola* were also noted. In contrast to *M. fructicola*, the addition of *T. delbrueckii* did significantly impact the production of ethyl acetate. These results suggest that *M. fructicola* could be used to lower the amount of $SO_2$ needed to be added during cold soaking to prevent spoilage by *H. uvarum.*

*Funding Support: Northwest Center for Small Fruits Research*

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### Wine Bioprotection with a Specific *Metschnikowia pulcherrima*: Alternative to $SO_2$ Combining Anti-Spoilage and Antioxidant Properties

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Modern consumers are more frequently seeking natural products. Non-*Saccharomyces* yeasts are a good alternative to chemical inputs such as $SO_2$. Among them, *Metschnikowia pulcherrima* present interesting characteristics for bioprotection during pre-fermentative stages, allowing lower $SO_2$ addition. Indeed, *M. pulcherrima* ensures biocontrol against spoilage microorganisms during pre-fermentation by (i) producing pulcherriminic acid, leading to iron depletion, and (ii) colonizing the niche without media alteration thanks to low fermentative metabolism. However, $SO_2$ is not only an antimicrobial agent, but also an antioxidant. Therefore, to combine both antioxidant and antimicrobial properties, a study of *M. pulcherrima* biodiversity was conducted, and a specific *M. pulcherrima* was selected among 100 other yeasts for its ability to consume oxygen. This specific non-*Saccharomyces* yeast, isolated in Burgundy, France, has been deeply characterized since its selection. We confirmed its low fermentative capacity, good growth and survival under enological conditions (even at low temperature), low nitrogen requirement, pulcherriminic acid production, and high oxygen consumption rate. Moreover, we also demonstrated its huge ability to remove copper, an oxidation catalyzer, from the must. These antioxidant actions lead to visible color improvement when compared to no protection. Moreover, consequences on wine organoleptic quality have been confirmed, with significantly more thiols produced with this specific *M. pulcherrima* in comparison to a classical bioprotection tool during winery-scale trials in Sauvignon blanc.

*Funding Support: Institut Français de la Vigne et du Vin (IFV); Lallemand*

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## Viticulture—Rootstocks Session

### Testing Nematode-Resistant Rootstocks for San Joaquin Valley Viticulture

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Plant parasitic nematodes can damage grapevine roots that are not resistant to them extensively, especially in vineyards with sandy soils, as is common in the San Joaquin Valley of California (CA). Fumigation is an effective control measure; however, regulations have restricted the use of fumigants in CA, heightening the importance of nematode-resistant rootstocks. The development of better nematode-resistant rootstocks is an ongoing effort. Documenting the viticultural performance of scions grafted to rootstock selections is critically important for proper selection and commercial acceptance of rootstocks and should be part of the process of selecting new material for potential release. Therefore, the performance of newer nematode resistant rootstocks (RS-3, RS-9, GRN1, GRN2, GRN3, GRN4, and GRN5), along with 1103P and Freedom as controls, were planted in a replicated trial in Madera, CA. Data collected over the past three years show differences in canopy size and water stress. GRN2, GRN4, and GRN5 maintain the largest canopies throughout the season. GRN3 and RS-3 are intermediate and GRN1 and RS-9 have smaller canopies. Larger canopies are linked to greater water need. However, larger canopies also show less water-stress, measured as midday leaf water potential. GRN2 stays the least stressed throughout the season, while RS-3 and RS-9 are the most stressed. Interestingly, GRN3 normally maintains a midrange water stress, except when the vineyard adds in water stress postveraison. During this dry-down, GRN3 becomes one of the most water-stressed rootstocks. This may indicate that this rootstock is more susceptible to drought stress.

*Funding Support: American Vineyard Foundation California Grape Rootstock Improvement Commission*

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### Field Response of Rootstocks to Northern Root-Knot Nematode

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Management of plant parasitic nematodes in Washington State vineyards undergoing replanting has been dominated by preplant soil fumigation. Our past work showed this approach does not result in long-term suppression. In 2015, we established a trial evaluating rootstocks in a commercial vineyard undergoing replanting after 20+ years of production. The rootstocks were planted in replicated plots of fumigated (metam sodium), nonfumigated, and nonfumigated inoculated with *Meloidogyne hapla* (northern root knot nematode). By fall 2021, all evaluated non-*vinifera* "resistant" rootstocks (101-14 MGT, 1103P, Harmony, Teleki 5C) supported *M. hapla* development; however, Teleki 5C and 1103P supported fewer *M. hapla* than the own-rooted *Vitis vinifera* control vines (eightfold fewer nematodes; $p = 0.02$). While not statistically different than own-rooted *V. vinifera*, Harmony and 101-14 MGT supported threefold fewer nematodes. When considering the multi-year chronic exposure to *M. hapla* (nematode dosage), all evaluated rootstocks had reduced *M. hapla* dosage than own-rooted *V. vinifera.* This *M. hapla* dosage comparison also provides a means to visualize nematode "tolerance": 1103P and

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Teleki 5C supported the fewest *M. hapla* over time, followed by Harmony and 101-14 MGT, with own-rooted *V. vinifera* supporting significantly more *M. hapla* over time ($p < 0.0001$). The rootstocks evaluated in this study had heavier pruning weights than own-rooted *V. vinifera* after three growing seasons ($p < 0.0001$). Among the non-*vinifera* rootstocks, some supported more nematodes than others, but after seven growing seasons, there was not a statistical difference between rootstock choice and influence on dormant pruning weights ($p < 0.05$). This enforces the concept of tolerance: though a rootstock might support *M. hapla* development, there is not a discernable phenotype difference. The use of non-vinifera rootstocks, while still supporting some *M. hapla* development, are still a sustainable long-term solution for *M. hapla* management.

*Funding Support: 80% Washington State Grape and Wine Research Program, 10% USDA National Institute of Food and Agriculture, Hatch project #1016563, 10% USDA-ARS Current Research Information System 2072-22000-043-00D*

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### Evaluating the Effects of Rootstocks on Mature, Dry-Farmed Pinot noir Vines

**Jeremy Schuster** and Patricia Skinkis*
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Rootstocks are used in vineyards worldwide; however, there is renewed interest in rootstock suitability given the need for grapevine adaptation to changing environmental conditions, including increased drought frequency. Rootstock performance has long been studied. However, studies indicate variable rootstock performance based on regional climate and soil type. As Oregon experiences warmer seasons and changing precipitation patterns, growers are interested in exploring rootstocks that provide more drought tolerance than the commonly planted rootstocks (3309C, Riparia Gloire, and 101-14). A long-term rootstock trial (planted in 1997) has been in place in Oregon's Willamette Valley, where many vineyards are dry-farmed. The trial includes Pinot noir grafted onto 19 rootstocks and own-rooted vines, and the vineyard has been dry-farmed for more than a decade. During 2019 to 2021, vines were evaluated for vegetative growth, productivity, and fruit composition. The most consistent rootstock effects were found in vegetative growth. Rootstocks 1616 and 420A had larger dormant pruning weights than drought-sensitive Riparia Gloire and 44-53. 420A had larger three-year average yields than Riparia Gloire and 44-53. Fruit chemistry was also impacted, with drought-sensitive rootstocks having higher total soluble solids at harvest than drought-tolerant rootstocks, which also had larger canopy sizes and overall vegetative vigor. The impact of rootstock on vine growth is likely related to both drought tolerance and nitrogen status, as the more vigorous rootstocks (1103 Paulsen and 1616) had higher season-long stem water potential and leaf stomatal conductance than lower-vigor rootstocks (Riparia Gloire and 101-14) which had the lowest. Yeast assimilable nitrogen was greater in the most drought-tolerant rootstock (1616) than in the most drought-sensitive (Riparia Gloire). This research indicates the impact of rootstock on long-term vine stress response and is providing regional growers with important plant material information for future vineyard developments.

*Funding Support: Oregon Wine Board, Erath Family Foundation, and Oregon Wine Research Institute*

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## Enology—Tannin Management Session

### Chemical and Chromatic Effects of Fermentation Temperature and Cap Management on Pinot noir Clone 667

**Paul Gannett**, Christian Hepburn, Marina Tacconi, Emily Stoffel, Isabelle LoMonaco, and Federico Casassa*
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Pinot noir (clone 667) from a coastal vineyard located in Pismo Beach (25.7 Brix, pH 3.63, titratable acidity 6.4 g/L) was made into wine with triplicate fermentations of a factorial combination of selected fermentation temperatures, ranging from Hot (25 to 32°C), to cold (8 to 16°C) and an alternation of them (cold/hot) with contrasting punch-down regimes (no punch-downs, NO PD; two punch-downs/day 12 hrs apart, PD). Anthocyanins (60% increase) and tannins (264% increase) were extracted more rapidly under Hot conditions than Cold treatment, regardless of the cap management regime. The progression of small polymeric pigments (which cannot precipitate protein) progressed steadily in all the combined treatments (albeit with faster relative formation rates in the Hot and Cold/Hot treatments than in the Cold treatments). The evolution of large polymeric pigments (LPP), which precipitate proteins, was largely impaired under the conditions of the Cold treatment, highlighting the crucial effect of alcoholic fermentation temperature on mouthfeel-active polymeric pigments. After completion of malolactic fermentation (MLF), chroma values in the Hot PD treatment (27 CIELab units), and Hot NO PD treatment (30 CIELab units) largely surpassed those of the Cold PD treatment (17 CIELab units) and Cold NO PD treatment (18 CIELab units), which concomitantly correlated with higher hue values in the Cold treatments. A two-way analysis of variance separating the effect of temperature and cap management regime on 12 chromatic and phenolic parameters pooled together after completion of MLF showed a significant effect of the temperature regime. Contrastingly, the punch-down regime affected primarily anthocyanins, LPP, and a* (red color component). Sensory analysis of the wines is underway and will be reported.

*Funding Support: World of Pinot noir Support research funds*

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### Chemical and Sensory Effects of Whole-Cluster and Dried-Stem Additions in Syrah and Tannat Wines from California

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Syrah (23.5 Brix, pH 3.39, titrable acidity 6.5 g/L and stems comprising 5% of fruit fresh weight) and Tannat grapes (23.3 Brix, pH 3.46, titratable acidity 4.2 g/L and stems comprising 9% of fruit fresh weight) were made into wine by applying three winemaking treatments, in addition to a Control wine, in triplicate fermentations (n = 3): whole-cluster (WC, consisting of 100% whole-cluster fermentation, foot-stomped); green-stem additions (GS, consisting of adding 100% of stems back to the fermentors); and dried-stem additions (DS, consisting of adding 100% of the stems back to the fermentors after treating the stems with heat via a convection oven). Wines were analyzed at the end of alcoholic fermentation and submitted to sensory descriptive analysis after three (Tannat) or six (Syrah) months of bottle aging. A two-way analysis of variance combining both cvs. showed that all treatments increased in pH from 3.71 (Control wines) up to 3.84 (WC wines). In Syrah, WC and



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## Enology—Tannin Management Session—CONTINUED

GS reduced wine color significantly, while in Tannat, only GS caused significant color reduction. Whereas none of the techniques affected anthocyanins and polymeric pigment formation at pressing, we observed tannin increments relative to Control wines of 67% in DS Tannat wines and of 216% in DS Syrah wines. In Syrah, WC wines enhanced the typicity of this cv. by increasing the perception of smoky, black olives and black pepper aromas, while DS wines were characterized by greater perceived astringency, with a suede-like textural subquality. In Tannat, GS wines showed enhanced vegetal and mint/eucalyptus aromas, while WC wines had an intense chocolate aroma. DS wines were again greater in perceived astringency, with complementary notes of cooked blue fruit aromas and bitterness.

*Funding Support: The E&J Gallo winery is thanked for donation of the fruit for this project, as well as logistic support during the harvest and transport of the grapes*

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### Role of the Tannin to Anthocyanin Ratio in the Formation of Polymeric Pigments and its Influence on Red Wine Mouthfeel

**Ingrid Weilack**,* Sandra Feifel, Pascal Wegmann-Herr, Dominik Durner, and Fabian Weber
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Tannins are arguably the most important group of polyphenols for red wine quality, as they are responsible for mouthfeel and color stability. During red wine aging, tannins incorporate anthocyanins and form protein-precipitable polymeric pigments, ensuring the longevity of wine color. The formation of polymeric pigments is determined by the concentrations of tannins and anthocyanins, which in turn are influenced by their extractability, grape maturity, and their ability to interact with each other. In this study, wines were made from Pinot noir and Cabernet Sauvignon grapes of three consecutive maturity stages, using different winemaking techniques including varying numbers of punch-downs and the increase of the potential alcohol content. Red wine polyphenols were characterized by their polarity using normal-phase chromatography, protein precipitation assay, and color. Additionally, wine sensory analysis was conducted. Anthocyanin concentrations in the wines increased according to grape ripeness and were minimally affected by changes in the winemaking protocol. While tannin concentration was increased significantly in the early-harvest variants with higher alcohol levels, the proportion of pigmented tannins remained unchanged. However, the fraction of polar polymeric pigments increased, along with a harder mouthfeel and a coarse astringency of the wines. This shows that the formation of protein-precipitable polymeric pigments in red wines depends on the ratio of tannin and anthocyanin concentrations and that an excess of extracted tannins leads to an imbalanced tannin profile. Due to the altered physicochemical properties of the pigmented tannins, their interactions with proteins and polysaccharides change. This results in a change in perceived astringency, showing their importance not only for color stability but also for red wine astringency.

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## Enology—Tannin Management Session—CONTINUED

### Interaction Between Alcohol Concentration, Maturity, and Extended Maceration Treatment on Wine Phenolic Compounds

**Juliana Pazos**, Danielle Fox, Thomas Collins, and James Harbertson*
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The goal of this study was to evaluate the effect of alcohol concentration and harvest time on extended-maceration wines with their respective controls. Cabernet Sauvignon was harvested at three different times in 2019 from the Columbia Valley (at 22, 25, and 28 Brix) and soluble solids were adjusted to 20, 24, and 28 Brix for each harvest through chaptalization or saignée and water addition. An extended maceration (240 days of skin contact) was carried out for each harvest-soluble solids combination with their respective controls (10 days of skins contact). The 18 treatments were done in triplicate, resulting in the production of 54 wines. The Adams-Harbertson assay was used to measure anthocyanins, total phenolics, tannins, and polymeric pigments over 24 months. Anthocyanins significantly decreased between months eight (after pressing) and 12, while tannins and total phenolics significantly increased by month 24 ($p < 0.05$). By month 24, extended maceration significantly decreased anthocyanins and small polymeric pigments and increased tannins, total phenolics, and large polymeric pigments. Higher alcohol concentration significantly increased large polymeric pigment formation and late harvest increased anthocyanins ($p < 0.05$). Numerous interactions between harvest time, maceration length, and alcohol concentration were found, suggesting that these parameters have a significant influence on the phenolic composition of the wines. Significant interaction was found between harvest time and extended maceration for anthocyanins, total phenolics, and tannins, while an interaction between the maceration and alcohol treatments was significant for tannins and small polymeric pigments. Harvest time and alcohol concentration presented a significant interaction for large polymeric pigments. Focusing on the extended maceration wines, tannin concentrations were significantly greater for those wines with high alcohol, particularly when harvesting at 22 and 28 Brix.

*Funding Support: Northwest Center Small Fruits Research*

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## Viticulture—Red Blotch: Virus and Vector Evaluation Session

### Overcoming the Challenges to Insect-Vectored Disease Management: A Case Study of Leafroll and Red Blotch Diseases

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Leafroll and red blotch are the most consequential viral diseases of grapevine in North America. Disease management integrates prevention, avoidance, monitoring, and selective suppression tactics. Because disease management is knowledge- and resource-intensive, an improved understanding of these factors could improve adoption of management tactics. Towards that end, we conducted a survey (n = 154) and interviews (n = 42) with industry professionals involved in the decision-making process of virus management in California and Washington vineyards. Nine economic, technical, and social-behavioral factors, along with 24 sub-factors, were

**indicates corresponding author*

## Viticulture—Red Blotch: Virus and Vector Evaluation Session—CONTINUED

identified as influencing adoption. Economic factors were impact of disease on yield, ability to sell infected product, and the costs of management. Technical factors were availability and acquisition of disease knowledge and the efficacy of extension and outreach activities. Social-behavioral factors included internal organizational processes, government subsidies, regulatory practices, and regional collaboration. Context determined how each factor affected adoption and there was an interplay between factors that underscores the complexity of decision-making and management. These studies provide context for the agricultural industry, research scientists, extension educators, and other supporting partners of the financial, interpersonal, and technical issues that must be overcome to successfully manage grapevine viral diseasess.

*Funding Support: California Department of Food and Agriculture, Pierce's Disease and Glassy-Winged Sharpshooter Program, CDFA Agreement Number 19-0271-000-SA*

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### Characterizing the Spread of Grapevine Red Blotch Virus in the Russell Ranch Foundation Vineyard

Vicki Klaassen, **Maher Al Rwahnih**,* Neil McRoberts, Brianna McGuire, Kent Daane, and Alexis Billings
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Understanding grapevine red blotch virus (GRBV) spread rates and patterns in infected vineyards can provide important disease management information. However, this information has been documented and analyzed in only two California vineyards. The availability of limited information on GRBV spread is largely due to the expense of testing many individual vines in infected vineyards. Therefore, when GRBV was identified in 2017 in the Russell Ranch Foundation Vineyard (RRV) and reached a positive incidence of 18% by 2019, we decided to continue to document GRBV incidence and do a detailed analysis of spread patterns over time. RRV offered a unique opportunity for this study because GRBV was not introduced in infected planting material and yearly test data for more than 4000 vines was available. The specific objectives of this study were to document GRBV incidence in 2020 and 2021, use spatiotemporal analysis to analyze spread patterns from 2017 to 2021, plant and test 400 sentinel vines to characterize GRBV detection in newly-infected vines, and to survey insect populations. We conclude that GRBV was introduced into RRV from outside sources and then spread rapidly within the vineyard by an unknown vector that has a longer mean dispersal distance than mealybugs, the vector of grapevine leafroll associated virus-3. While all candidate insect vectors were present at RRV, none were associated with GRBV-infected vines. Test data from sentinel vines indicated that new GRBV infections could be detected by qPCR within a year, but low titer and/or uneven within-vine distribution would result in some unknown fraction of false negative test results. Combined, these factors indicate that in some vineyards, GRBV spread cannot be controlled by removing infected vines and insect management programs. For a foundation vineyard such as RRV, a greenhouse collection is the most feasible alternative.

*Funding Support: Pierce's Disease/Glassy-Winged Sharpshooter Board*

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## Viticulture—Red Blotch: Virus and Vector Evaluation Session—CONTINUED

### Advances in Protecting the Premier United States Grape Foundation Collection

**Maher Al Rwahnih**,* Teresa Erickson, Kristen Farrar, Minsook Hwang, and Vicki Klaassen
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Foundation Plant Services (FPS) is the primary source for certified, virus-tested, and true-to-variety grapevine plant material distributed to nurseries under the California Department of Agriculture's Grapevine Registration and Certification (R&C) Program, which provides most grapevines planted in the United States. FPS has successfully maintained collections of grapes in open foundation vineyards on the UC Davis campus for >70 years. However, the Russell Ranch Foundation Vineyard (RRV) recently became infected with grapevine red blotch virus (GRBV), an economically significant insect-vectored grapevine virus that was introduced into RRV from outside sources. Due to the importance of this grape collection and the potential threat of insect-vectored viruses, FPS and the grape industry have determined the best course of action is to protect the core collection of grapevine selections in a foundation greenhouse to exclude both known and unknown vectors. With the tremendous support of the California grape industry, FPS has secured funding to initiate construction of the first of two greenhouses on-site at FPS in 2022. FPS plans to construct a second greenhouse adjacent to Greenhouse 1 in the future. The core grapevine collection will be re-registered and elevated to the RRV standards (Protocol 2010). All selections will be tested by high throughput sequencing (HTS)/polymerase chain reaction (PCR) using our rigorous, recently revised testing protocol, confirmed for trueness-to-type and, if needed, treated with microshoot tip therapy for virus elimination. The revised USDA-APHIS-PPQ- and CDFA-approved diagnostic testing protocol replaces biological indexing with a combination of HTS and PCR testing for release of plant material. These methods used in combination result in more accurate test results than biological indexing, which will ensure that grapevine selections maintained in the FPS Foundation Greenhouse are the highest-quality source of virus-tested grapevine stock for nurseries in CDFA's Grapevine R&C Program.

*Funding Support: California grape industry sources and Foundation Plant Services*



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## Viticulture—Red Blotch: Virus and Vector Evaluation Session—CONTINUED

### Using a Model to Disrupt Three-Cornered Alfalfa Hopper Life Cycles in Grapevine Red Blotch Disease-Affected Areas

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The three-cornered alfalfa hopper (TCAH) was shown to transmit Grapevine red blotch virus (GRBV), the causative agent for Grapevine red blotch disease, in a greenhouse study on grapes. GRBV is a major concern of winegrape growers due to its economic impact on wine quality. Plants in the family Fabaceae are preferred hosts of TCAH and are commonly planted as cover crops or present in a vineyard's native vegetation. In late winter, during grapevine dormancy, TCAH migrate into vineyards to feed and reproduce on these cover crop and weed hosts. Tilling vineyard floor vegetation provides growers an opportunity to disrupt the life cycle of early immature stages that are relatively immobile, reducing TCAHs first-generation population. Nymphal presence is difficult to detect in the field due to their small size and light coloration. First through third immature stages were not detected by sweep net in a two-year weekly sampling study, while fourth and fifth immature stages were first found on the same sample date as emerging first-generation adults. Once TCAH emerge as an adult, they can disperse and thereby circumvent control measures. A degree-day model was developed that predicted the ideal time frame for tillage at between 1310 and 1565°C accumulated degree days, when ~25 to 80% of early immature stages are present. Vineyards were sampled to further validate the model in six wine regions of Napa County (Oakville, Calistoga, Mt. Veeder) and Sonoma County (Healdsburg, Geyserville, Glen Ellen). Growers and viticulturists can access the UCIPM website and use a free degree day calculator that uses weather station data closest to their vineyard to calculate degree days accumulated. Using this model to exploit the time frame at which TCAH is most susceptible to cultural control measures can benefit vineyards that already include tilling in their seasonal operations.

*Funding Support: CDFA Specialty Crops Block Grant Program, CDFA PD/GWSS Grant, the California Grapevine Rootstock Improvement Commission, American Scandinavian Foundation Fellowship*

## Viticulture—Red Blotch: From Macro to Micro Effect Session

### Ultrastructural and Compositional Analyses of Grapevines Infected with Red Blotch Virus

**Bhaskar Bondada**,* Bailey Hallwachs, Marc Fuchs, Sadanand Dhekney, Benham Khatabi, Alexander Levin, and Patricia Skinkis
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Red Blotch disease caused by Grapevine red blotch-associated virus (GRBaV) is a severe concern to grapegrowers and winemakers in the Pacific Northwest, including California. One key aspect of all viruses, including Red Blotch, is their intimate association with cell components and anomalous structures following infection. Therefore, the objective of this study was to analyze the fruit quality and ultrastructure of various tissues and document the relationship of ultrastructural cytopathology with the GRBaV infection in Pinot noir employing various microscopy techniques. The infected vines exhibited typical red blotches in leaves, with pinkish red-colored veins, without rolling off the margins at the onset of ripening. The infected vines developed clusters of hens and chickens and altered seed morphology. Conversely, the healthy seeds were pyriform with a distinct beak. The infection significantly altered the primary and secondary metabolites desired for making wine. Since postveraison berry development and ripening relies on phloem influx, the altered metabolism was indicative of a disruption of the phloem pathway, either in the source leaf or in the berries. While the infected vines maintained primary leaf anatomical organization, the chloroplasts underwent significant ultrastructural changes, ranging from complete dismantling to massive accumulation of starch, plastoglobuli development, and tannins in the cytoplasm. The study demonstrated that structural integrity is key to maintaining the normal metabolism of the grapevine.

*Funding Support: NCSFR*

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### Sink Adjustments had Minimal Effects on Carbohydrate Translocation in GRBV Infected Grapevine

**Justin Tanner**, Dimitrios Mainos, Runze Yu, Nazareth Torres, Anita Oberholster, and S. Kaan Kurtural*
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Grapevine red blotch virus (GRBV) impacts winegrape (*Vitis vinifera* L.) composition and results in economic loss to North American vineyards. GRBV was suspected of impeding carbon translocation within the plant, affecting ripening speed, berry sugar, and flavonoid accumulation. A two-year trial was conducted to investigate the impact and utility of source-sink manipulation on GRBV-infected grapevines to assess whether non-structural carbohydrates would be preferentially translocated to fruit during ripening to mitigate the effects of GRBV. The source:sink ratio was altered by changing the number clusters retained without altering leaf area in a factorial arrangement of uninfected (GRBV [-]) and infected (GRBV [+]) grapevines. Effects of crop level and virus status on leaf and shoot non-structural carbohydrates, plant water status, leaf gas exchange, berry primary and secondary metabolites, and yield components were measured. Total non-structural carbohydrates in leaves began to accumulate around veraison. Conversely, GRBV(-) vines had more total non-structural carbohydrates in shoot sap than GRBV(+) vines. The presence of disease improved plant water status and berry mass. However, must total soluble solids were consistently lower in GRBV(+) vines despite altering the source:sink

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## Viticulture—Red Blotch: From Macro to Micro Effect Session—CONTINUED

threefold with cluster removal. Likewise, GRBV(+) plants produced berries with lower anthocyanin content at harvest regardless of crop level in both years. Our results provide fundamental evidence that impeded carbohydrate translocation in GRBV(+) vines is too great to overcome by reducing sink size and will result in inadequate fruit composition regardless of crop level.

*Funding Support: USDA-NIFA*

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### Foliar Potassium Application Increases Fruit Total Soluble Solids in Grapevine Red Blotch Virus-infected Grapevines

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Delayed ripening is one of the most-reported fruit symptoms in grapevine red blotch virus-infected (GRBV+) grapevines. Potassium (K) is closely linked with berry ripening and early studies on K in GRBV+ grapevines indicated low K status in GRBV+ leaves. Thus, it was hypothesized that foliar K application would improve berry ripening through improved leaf K status and sugar translocation. A split-plot field experiment was conducted in 2020 and 2021 to test two formulations of foliar K fertilizers (0-0-24) against a water control on previously identified healthy and infected grapevines. Treatments were applied weekly for four weeks beginning at veraison. At each application, the equivalent of 2.0 kg/ha of K was applied with a backpack sprayer to eight single-vine replicates. Leaf blades and petioles were sampled for nutrient analyses both before and after treatment application in 2020 and after treatment only in 2021. In both years, there was little to no effect of K application on K status in leaf blades, with all values in the normal range. In vines sprayed with K, berry fresh weight was reduced by 10% and 23% in 2020 and 2021, respectively ($p < 0.0001$ in both years), independent of GRBV status. Collaterally, berry total soluble solids (TSS) at harvest were increased by 1.6 and 4.1 Brix in 2020 and 2021, respectively ($p < 0.0001$ in both years) by both K fertilizers independent of GRBV status. However, there were no significant effects of K application on berry phenolic composition in either year. The lack of treatment effects on berry phenolic composition suggests that while foliar K application has limited effects on fruit quality in GRBV+ grapevines, the increased TSS may help reach an otherwise unachievable TSS target or advance the harvest date in heavily-infected blocks.

*Funding Support: USDA-NIFA-SCRI grant number 2019-51181-30020*

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## Viticulture—Red Blotch: From Macro to Micro Effect Session—CONTINUED

### Identifying Red Blotch and Leafroll Viruses in VIS/NIR Hyperspectral Images Acquired on the Ground in the Field

**Eve Laroche-Pinel**, Benjamin Corrales, Khushwinder Singh, Erica Sawyer, Monica Cooper, Marc Fuchs, and Luca Brillante*
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North American vineyards are highly affected by two groups of viruses that cause major economic losses: grapevine leafroll-associated viruses (GLRaVs) and red blotch virus (GRBV). Unfortunately, no curative solution has been found to eradicate these viruses in diseased vineyards. Therefore, the only way to limit their spread is to quickly identify and remove infected vines (i.e., roguing). For this purpose, remote sensing, especially hyperspectral imagery, is an encouraging tool to identify infected vines autonomously and on a large scale. We used >2000 canopy images acquired in the vineyard with a stationary VIS-NIR hyperspectral camera (from 510 nm to 900 nm). Images were obtained at six times per season, from the onset of veraison to harvest, in two consecutive growing seasons. Pre-trained machine-learning models were used to extract the canopy signal from the images and predict plant infection status previously assessed by molecular analyses. Binary (healthy, infected) and four classification categories (healthy, infected by GLRaVs, infected by GRBV, or infected by both viruses) were tested. Prediction accuracy across phenological stages was determined and compared. Additional analysis was conducted to highlight the most relevant wavelengths among the 234 acquired by the camera to identify these viral diseases. This work showed that VIS/NIR imagery combined with machine learning is a promising tool to identify infected vines in the vineyard from static images acquired on the ground.

*Funding Support: CDFA-SCBGP, CSU-ARI System Grants*



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## Enology and Viticulture Research Report Posters

### Microbiological Impact of Different Inoculation Timings of a Dry Yeast during Winemaking; E2U Direct Pitching

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Modern industrial winemaking is based on the use of wine specialized Saccharomyces cerevisiae starter cultures. Commercial wine strains guarantee stability and reproducibility. In this work, two modes of yeast inoculation were studied: bioprotection mode on grapes or during prefermentation operations and conventional modes, including direct pitching after settling. Regarding the times of pitching, four times were tested: (i) directly on the grapes in the reception buckets, (ii) in the juice after crushing, (iii) pressing, or (iv) into the juice after crushing and settling. For the conventional modes, four timings were studied: (v) direct inoculation into the juice just after settling and temperature rise, and (vi) rehydrated in room temperature water and with gradual acclimatization after settling and temperature rise. In bioprotection modes, HD A54 could be inoculated onto grapes and during prefermentation phases only if the temperature was cool controlled (<10°C) to slow down the onset of alcoholic fermentation and avoid settling issues. HD A54 yeast also inhibited development of non-*Saccharomyces* and *S. cerevisiae* yeasts when inoculated at 20 g/hL before pressing. It then develops best and starts alcoholic fermentation faster when inoculated after pressing. In conventional modes and highly indigenous microflora-loaded must, we showed that E2U-processed HD A54 yeast could be inoculated immediately after cold settling into the must or after temperature rise-up without any implantation and fermentation issues. It also fully showed its particular aromatic and organoleptic profile (especially extreme amylic notes). When inoculated with prior rehydration or acclimatization, implantation issues have been encountered, leading to deviant profiles. This study showed that for certain yeast strains, E2U technology combined with early inoculation timing could guarantee the achievement of the targeted wine type.

*Funding Support: Fermentis, division of SI Lesaffre*

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### An Old Player, a New Concept, and a Highly Resistant *Lactiplantibacillus plantarum* Strain to Control Malolactic Fermentation

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Four genera of lactic acid bacteria (LAB) were identified as the principal organisms involved in malolactic fermentation (MLF): *Lactobacillus*, *Leuconostoc*, *Oenococcus*, and *Pediococcus*. Wine pH is most selective, and at a pH <3.5, *O. oeni* is probably the best-adapted to overcome the harsh environmental conditions, so most commercial cultures consist of strains from this species. Under more favorable conditions above pH 3.5, species of *Lactobacillus* and *Pediococcus* may conduct the MLF. Among the LAB species, *Lactiplantibacillus plantarum* (formerly *Lactobacillus plantarum*) strains have shown interesting results under hot climate conditions, not only for their capacity to induce MLF, but also for their homo-fermentative properties toward hexose sugars, which makes them suitable for induction of MLF in high-pH and high-alcohol wines, when inoculated at the beginning of alcoholic fermentation. Recently, a highly concentrated *L. plantarum*, produced with an optimized process, not only induced and finished a MLF before the end of alcoholic fermentation, when applied in co-inoculation in high-pH red wines, but also worked for acidic white

wines, characterized by a low pH (2.95) and high malic acid concentrations. Due to its good alcohol tolerance (≤15% vol) it can be applied in co-inoculation or in sequential inoculation. An inoculation ratio could be used to control the amount of malic acid to be degraded to achieve either partial or a complete degradation of malic acid. Since this strain does not metabolize citric acid, no diacetyl is formed and so variety typicity is maintained. With the partial or complete removal of malic acid, labor-intensive chemical deacidification could be circumvented. For use in sequential inoculation, a simple MLF pretest can be applied to predict the success of the MLF in the winery.

*Funding Support: Lallemand*

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### Maximizing Varietal Thiols by an Innovative Approach to Yeast Selection

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Varietal thiols are key compounds of the fruity character in white wines. 3MH, its acetate, A3MH, and 4MMP are among the most-represented thiols, typical of varieties such as Sauvignon blanc or Colombard, but also contributing to the complexity of numerous others. Varietal thiols are present in the must as combined inodorous and non-volatile precursors and are released by yeast enzymatic activity. The precursors and pathways involved are not all known, but the carbon-beta-sulfur lyase family has been identified to be responsible for a significant part of this conversion. However, all yeasts are not equal in their capacity to release varietal thiols. It has been demonstrated that different alleles of the gene IRC7, encoding for a beta-lyase with a high affinity for cys-4MMP, are responsible for huge variations in the volatile thiol release efficiency. We identified a yeast strain from our collection that possesses one copy of the allele encoding for the most efficient version of Irc7p. We implemented a sporulation-based strategy to generate a new strain homozygous for this allele, thus expressing a full potential for volatile thiols release. This new yeast produced very high levels of 4MMP and other volatile thiols in wines and resulted in complex aromatic profiles with more vegetal character and citrus, yellow, and exotic fruit notes.

*Funding Support: Lallemand SAS*

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### Photoselective Device Accelerates Growth and Shortens Time-to-Production of Newly Planted Vines

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The growth of newly planted grapevines in cool-climate regions such as Northern and Coastal California is often encumbered by suboptimal temperatures, strong winds, frost dieback of green tissue, and other extreme environmental events. Replacement vines are additionally constrained by heavy shading from adjacent mature vines in both cool and hot climates. Here we present a novel approach based on surrounding newly-planted vines with greenhouse-like “growth chambers” specifically designed to deliver red-enriched sunlight that is uniformly scattered around individual vines, while providing protection from environmental hazards, creating a favorable microclimate environment. Studies of these devices, named Opti-Gro, were carried out during the past four years in commercial wine, table, and



**indicates corresponding author*

## Enology and Viticulture Research Report Posters—CONTINUED

raisin grape vineyards on both newly planted and replanted vines, in collaboration with major growers in California's Central Coast, Sonoma County, and San Joaquin Valley. All field trials were designed in randomized blocks with 20 to 30 replicates. Opti-Gro units were compared with the growers' common practice vine protectors. Field installations and data collection were conducted by an independent third party. The initial device prototypes were 14-inch diameter, 7-ft tall, color-coated (red, orange, and white) metal units. The trials demonstrated dramatic acceleration of both primary and lateral shoot development, reduced winter dieback (due to enhanced lignification), and advanced fruitfulness within just one season. The red-coated units consistently outperformed the orange and white ones. We infer that the red-enriched light environment is providing regulatory signals to thrive. This, coupled with the protected microclimate, is accelerating canopy and root developmental physiological processes, leading to enhanced photosynthesis, long-term carbohydrate storage, and advanced subsequent fruiting. The advanced Opti-Gro device is a 10-inch-diameter, red polymer chamber with a specifically engineered texture to promote light dispersion and a modular design that enables integration into various trellis dimensions.

*Funding Support: Opti-Harvest, Inc.*

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### Effects of Proteinaceous Soil Bio-Fertilizer Upon Vine Growth

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Vignerons are increasingly adopting the use of exogenous microbial inoculum to improve soil microbial communities and, ultimately, plant performance. With the high costs of these inoculums and their varied success in the field, a proprietary proteinaceous bio-fertilizer was tested on *Vitis vinifera* vines over a three-year period. The long-term longitudinal study was conducted with over 40 participants, 12 different cultivars, and four US States. A proteinaceous bio-fertilizer was applied to the soil at each site at budbreak and flowering. Rate of shoot length and diametric growth increased with the application of the biostimulant on all sites in all years of the study. Across all years and sites, chlorophyll content increased with the use of the biostimulant, according to readings from a soil plant analysis development meter (SPAD). Increases in both berry weight and berry volume with the application of the treatment resulted in greater yields. Juice chemistry at harvest was unaffected by the bio-fertilizer. Proteinaceous bio-fertilizer may improve soil microbial communities, ultimately resulting in better agronomic vine performance.

*Funding Support: Enartis USA, Inc*

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## Enology and Viticulture Research Report Posters—CONTINUED

### A Trellis System with Opti-Panels Protects Vineyards from Environmental Constraints and Reduces Canopy Management Labor

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A novel trellis system technology, Opti-Panel, integrates photo-selective panels into the traditional gable trellis framework. The panels consist of high-density translucent polyethylene with custom red or pearl color, and special UV protection engineered to last 10 years. This system protects table grapes from frost, hail, hot spells, wind, and rain. The trellis/panels position shoots and keep the center of the gable ('Y') free of foliage and well-illuminated all season. The system was evaluated over the past three years in San Joaquin Valley on eight table grape cultivars (Ivory, Krissy, Sweet Globe, Allison, Adora, Autumn King, Autumn Crisp, and Scarlotta). Several rain events in October of 2021 provided an opportunity to evaluate the efficacy of the panel system in reducing cluster rot pre- and postharvest. Adora, Autumn King, and Allison rot levels under panels were one-third of those under the conventional annual white plastic cover. Incipient, postharvest decay levels of *Botrytis cinerea*, *Aspergillus niger*, *Penicillium* spp., and *Cladosporium* were lower. Postharvest *Botrytis* level in Scarlotta under the panels was lower (0.3%), compared to conventional plastic cover (4.6%) or an uncovered control (11%). Similar results were obtained with Adora and Autumn King. In most cases, the red panels outperformed the pearl. The panels and conventional plastic cover both provided rain protection, but condensation and humidity were much less in the well-ventilated trellis/panel system, accounting for the decrease in decay. On 19 June 2021, a hot spell occurred, and the Allison cultivar suffered serious heat damage (51%), while the damage was much less under the panels (17%). The panels naturally positioned and held shoots in place with no additional labor. Shading in the fruiting zone was eliminated by the panels, as was the need for leaf removal to facilitate spray coverage, providing additional labor-saving. Panels increased berry size, with other fruit characteristics unaffected.

*Funding Support: Opti-Harvest, Inc.*

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### A Comprehensive Investigation of Root-System Impacts on Grafted Grapevines

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Recent advances in high-throughput genomics and phenomics have enhanced the current understanding of how perennial crops sense and respond to their environments over multiple years. Here, we used two grapevine grafting experiments to investigate how grapevine rootstocks interact with water availability to affect shoot system phenotype. First, an experimental vineyard in Mount Vernon, Missouri includes Chambourcin growing on its own roots or grafted to 1103P, 3309C, or SO4. We characterized multi-dimensional phenotypes in Chambourcin including berry chemistry, leaf shape, leaf ion concentration, leaf metabolites, and vine physiology, in part through hyperspectral imagery, and wine volatiles. There were complex interactions between rootstock and irrigation that shaped dynamic patterns of

*indicates corresponding author

shoot system phenotypes that varied across seasons and over years. Variation in ion (i.e., elemental) concentrations is also influenced by leaf position along the vine. Root system affected berry volatiles, in some instances with consistent trends across years. For instance, the mean β-damascenone present in own-rooted vines (9.49 µg/L) was significantly lower in other rootstocks (8.59 µg/L), while the mean linalool concentration was significantly higher in 1103P rootstock compared to own-rooted vines. Second, we explored the rootstock scion interaction in a long-term study in California consisting of two grapevine varieties grafted to 15 different rootstocks. This study showed an >50% increase in yield, with changes in pruning weight and Ravaz index, by choosing the optimal rootstock, adding to the evidence that rootstock choice is crucial for grapegrowers looking to improve vine performance. These comprehensive, multi-year projects demonstrate the importance of root system variation for optimized shoot system morphology and suggest future exploration of rootstock genotypic diversity may offer an underutilized source of variation for shoot system phenotypic manipulation (e.g., vine productivity and berry chemistry) under changing climate conditions.

*Funding Support: National Science Foundation*

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### First Year Effects of Vineyard Floor Management on Dry-Farmed Pinot noir Vine Performance in Different Soil Types

**Mathew Lange** and Patricia Skinkis*
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Vineyards in Oregon's Willamette Valley are predominantly planted to perennial grass cover in alleyways for worker and equipment traction and to manage vine vegetative vigor. In dry seasons, spring tillage is implemented to reduce alleyway vegetation competition for available soil water. Previous research in the region shows impacts of till and no-till practices on vine vigor, primarily through altering vine nitrogen (N) status in a volcanic soil. More work is needed to understand the impacts on different soil types, as their physical properties influence water-holding capacity and nutrient concentrations, thereby affecting grapevine growth and productivity. The effects of vineyard floor management practices (till and no-till) were evaluated in one vineyard containing three distinct soil types derived from sedimentary, volcanic, and glacial deposit parent materials. Till and no-till treatments were applied to alleyways in a randomized complete block design with five to 10 field replicates of each soil type, within blocks of the same cultivar, rootstock, age, vine spacing, and training system. Vine growth, water stress, soil moisture, yield, vine nutrient status, and fruit composition were measured. Vineyard floor management did not influence leaf stomatal conductance, stem water potential, or under-vine soil water content. However, vines in tilled treatments had higher leaf blade N concentrations and leaf greenness than no-till treatments in all soil types. While dormant pruning weights were not affected by higher tissue N, there was more berry N (yeast assimilable N) in the tilled treatments within the sedimentary soil only. The results indicate that vineyard floor management had more influence on N availability within the soil rather than impacting undervine soil moisture or reducing vine water stress. These first-year results indicate that vineyard floor management practices have variable impacts based on soil type, and further research will determine longer-term impacts on vine growth and yield.

*Funding Support: Oregon Wine Board, Erath Family Foundation*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Photoselective Shade Films Affect Grapevine Berry Secondary Metabolism and Wine Composition

**Lauren Marigliano**, Runze Yu, Nazareth Torres, and S. Kaan Kurtural*
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Grapevine physiology and production are challenged by forecasted increases in temperature and water deficits. Within this scenario, photoselective overhead shade films are promising tools in warm viticulture areas to overcome climate change-related factors. The aim of this study was to evaluate the vulnerability of Cabernet Sauvignon grape berry to solar radiation overexposure and optimized shade film use for berry development. A randomized complete block design field study was conducted across two years (2020 and 2021) in Oakville, Napa Valley, CA, with four shade films (D1, D3, D4, or D5) differing in the percent of radiation spectra transmitted and compared to an uncovered control (C0). Integrals for gas exchange parameters and midday stem water potential were unaffected by the shade films in 2020 and 2021. By harvest, berries from uncovered and shaded vines did not differ in size or primary metabolism in either year. Despite precipitation exclusion during the dormant season in the shaded treatments, yield did not differ between them and the control in either season. In 2020, total skin anthocyanins (mg/g fresh mass) in the shaded treatments were greater than C0 during berry ripening and at harvest. Conversely, flavonol concentrations in 2020 were reduced in shaded vines compared to C0. The 2020 growing season highlighted the impact of heat degradation on flavonoids. Flavonoid concentrations in 2021 increased until harvest while flavonoid degradation was apparent from veraison to harvest in 2020 across shaded and control vines. Wine analyses from the 2020 vintage highlighted the importance of light spectra to modify wine composition. Wine color intensity, tonality, and anthocyanin values were enhanced in D4, while antioxidant properties were enhanced in C0 and D5 wines. Altogether, our results highlighted the need for new approaches in warm viticulture areas given the impact that light composition has on berry and wine quality.

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TUES/WED POSTER ABSTRACTS

### Calibrating Soil Health Indicators for Washington State Winegrape Systems

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Commodity crop growers in the Midwestern and Northeastern United States can effectively evaluate their soil health using recommendations based on extensive research on typical ranges and benchmark values for physical, chemical, and biological soil health indicators in these areas and crops. However, for growers of specialty crops, such as winegrapes (*Vitis vinifera*) in the Pacific Northwest, there is little information on regional and crop-specific soil health indices or guidance on how management practices may influence soil properties and the surrounding ecosystem. Therefore, this study aims to (1) calibrate soil health indicator scoring curves and benchmark values and (2) explore how management practices may impact soil health in Eastern WA's arid winegrape growing region. We used a survey approach to sample 70 producer-identified paired "good" and "challenging" winegrape

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## Enology and Viticulture Research Report Posters—CONTINUED

vineyard blocks across Washington state's Columbia Basin. Soil sampling occurred midseason, between bloom and veraison, for a suite of soil health indicators, such as permanganate oxidizable carbon (C), mineralizable C, potentially mineralizable nitrogen, bulk density, ACE soil protein, pH, and texture. Additionally, we measured available water-holding capacity and parasitic nematodes. These indicators are not always included in basic soil health tests, but may be critical properties in irrigated winegrape systems. Producers provided management histories for each block through questionnaire-led interviews. Using precipitation, sand content, and soil strata as covariates, we calculated effect sizes and confidence intervals to determine the effects of management on soil health indicators and create scoring curves calibrated to Washington State's primary winegrape growing region. As the first coordinated soil health assessment in Washington State in winegrapes, this study will provide a framework and guidance for further research on soil health relationships. Ultimately this study will guide producers to make informed decisions on soil management in inland Pacific Northwest winegrape systems.

*Funding Support: Washington State Department of Agriculture Specialty Crop Block Grant*

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### Comparison of Calcium-Based Amendments and Their Effects on Vines and Soils. A Three-Year Study in a Sodic Soil in San Joaquin Valley

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The objective of this study was to monitor the response of soil physics, grapevine physiology, and fruit composition to different dosages and forms of $CaSO_4$ (anhydrite, $CaSO_4$, and gypsum $CaSO_4.2H_2O$) in synergy with organic matter (biosolids). The experiment was performed for three years (2019 to 2021) in a Merlot vineyard located in a sodic soil of the Bakersfield area. The experiment was carried out as a completely randomized block design, with six treatments replicated four times. Each experimental unit had a 30  30 m surface that overlapped with a pixel from Landsat 8. Soil amendments were broadcast in winter 2019/20 (2.5 t/ac gypsum, 5.1 t/ac gypsum, 10.2 t/ac gypsum, 5.1 t/ac anhydrite, and 5.1 t/ac gypsum + biosolids) after the first season of measurements to ensure no differences across treatments before application. Biweekly measurements of stem water potential and leaf gas-exchange showed moderate to severe water stress, but did not evidence significant differences across treatments in plant water status, carbon assimilation, stomatal conductance, or water use efficiency in all years. Treatments had similar values in grape soluble solids, pH, and titratable acidity during ripening in 2020 and 2021. Yield was greatest in the 10.2 t/ac gypsum in 2020 and in the 5.1 t/ac gypsum + compost in 2021. Soil infiltration measurements showed that gypsum treatments increased infiltration more than the control or the anhydrite treatments in both years. For vegetation indexes measured from Landsat 8, we determined the Spearman's correlation with in situ measurements such as $\psi_{stem}$. This parameter associated significantly with various indices. The Green Normalized Difference Vegetation Index ($r = 0.56$) had strongest correlation, followed by the Normalized Difference Moisture Index ($r = 0.54$). These results will help evaluate best reclamation practices for San Joaquin Valley vineyards.

*Funding Support: American Vineyard Foundation*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Relationships of Temperature and Precipitation with Brix and pH at Harvest in Arizona

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As temperatures continue to trend higher, winegrape growers in warm-climate viticultural regions will increasingly be challenged by the many effects that temperature has on fruit composition. Warmer ripening conditions in recent years for such growing regions around the world have resulted in higher sugar concentrations, less acidity from declines in malic acid, and higher pH. Precipitation during ripening can influence winegrape composition by interacting with effects caused by temperature. As such changes in the fruit make unbalanced composition more likely, there is increasing industry concern over the effects of climate on winegrape production. Detrimental changes in fruit composition due to variations and changes in climate also are an issue for Arizona viticulture, as most vineyards in the state are located in warm-climate growing areas. However, how recent climate conditions in Arizona potentially have affected winegrape composition is unknown. Here, we quantify relationships between elements of fruit composition and exposure to temperature and precipitation during the ripening season. Our hypothesis is that more heat and moisture correlate with less-balanced composition values. For data, we use measures of Brix and pH at harvest for several varieties across multiple vintages from vineyards in each of the three state American Viticultural Areas, along with those of temperature and precipitation from station and gridded sources. By determining how exposure to heat and moisture during ripening potentially has influenced fruit composition in recent vintages, our work provides an initial model for growers and winemakers in warm-climate viticultural regions, with which to predict impacts of climate conditions in future growing seasons and to consider vineyard and winery adaptations to produce quality fruit and balanced wines under continued regional warming.

*Funding Support: Funding for this presentation was made possible by the U.S. Department of Agriculture (USDA) Agricultural Marketing Service through grant SCBGP-FB21-19.*

TUES/WED POSTER ABSTRACTS

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### Late-Season Source Limitation Practices to Delay Ripening and Improve Color of Cabernet Sauvignon Grapes and Wine

**Guadalupe Partida**, Luca Brillante,* Miguel Pedroza, Khushwinder Singh, and Kaylah Vasquez
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Recent increased temperatures are accelerating grape ripening, leading to unbalanced wines with high alcohol content, but poor aroma and phenolic composition. Late-season canopy manipulation practices to reduce the size of the photosynthetic apparatus after veraison can delay technological ripeness in cool climates. These methods have not been tested in areas with high irradiance and temperature, where berry composition is negatively affected from late fruit exposure. 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 during late stages of ripening, with an untouched control. We monitored the vines weekly by measuring stem water potential, gas exchange, and fruit zone light exposure. We sampled berries to measure berry weight, total

**indicates corresponding author*

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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 stem water potential. Inversely, leaf removal and topping increased water potential, but did not affect leaf gas exchange. Late topping was the only treatment that decreased sugar content (up to 2 Brix), increase titratable acidity and pH, and improve anthocyanin content, because of less 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 speed 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.

*Funding Support: n/a*

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### Mitigating Heat Wave Damage to Cabernet Sauvignon Winegrape with Partial Shading under Two Irrigation Amounts

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Rising temperatures in most agricultural regions of the world are associated with a higher incidence of extreme weather events such as heat waves. We performed an experiment to mitigate the impact of heat waves and exposure of berries in grapevine (*Vitis vinifera* cv. Cabernet Sauvignon) with untreated vines (Exposed) or with fruit-zone partial shading (Shaded) under 40% and 80% replacement of crop evapotranspiration ($ET_c$) with sustained deficit irrigation in a factorially arranged experiment. The trial was performed in a vineyard with vertically shoot-positioned trellis with a row orientation that concentrated solar radiation exposure on the southwest aspect of the fruit zone. Leaf stomatal conductance ($g_s$) and net carbon assimilation (AN) were significantly lower in shaded leaves under partial fruit-zone shading that resulted in lower pruning mass for Shaded treatments. Stem water potential ($\Psi_{stem}$) responded to a large extent to increased irrigation. However, grapevines with fruit-zone shading had transiently better water status under 40% $ET_c$. Cluster maximum temperatures were 3.9°C greater in Exposed grapevines. Exposed clusters had transiently lower acidity and higher pH. However, Exposed clusters on 40% $ET_c$ had higher total soluble solids (TSS). The experimental vineyard suffered a four-day heat wave 21 days before harvest, resulting in 25% of the clusters being damaged in the Exposed treatment, regardless of irrigation amount. Furthermore, berries in Exposed treatments suffered a great loss of anthocyanins and flavonols, even if they were not damaged by direct solar exposure. The pre-planting decision of using a vertically shoot-positioned trellis that concentrated solar radiation on the Southwest aspect offered mild protection in a hot climate region with a sunny growing season and extreme heat events during the execution of study.

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The extreme conditions under which this study was conducted are not unusual and have become more expected. Our work provided evidence of the vulnerability of grape berry to heat waves and exposure during heat wave events and possible protection methods to mitigate these effects in situ in the context of climate change.

*Funding Support: UC ANR*

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### Optimal Ranges and Thresholds of Grape Berry Solar Radiation for Flavonoid Biosynthesis in Warm Climates

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In commercial winegrape production, canopy management practices are used to control the source-sink balance, and improve the cluster microclimate to enhance berry composition. The aim of this study was to identify the optimal ranges of berry solar radiation exposure (exposure) for upregulation of flavonoid biosynthesis and thresholds for their degradation, to evaluate how canopy management practices such as leaf removal, shoot thinning, and a combination of both affect the grapevine yield components, berry composition, and flavonoid profile. Three experiments were conducted in Oakville, CA. The first assessed changes in grape flavonoid content driven by four degrees of exposure. In the second, individual grape berries subjected to different exposures were collected from two cultivars (Cabernet Sauvignon and Petit Verdot). The third experiment examined three canopy management treatments i) LR (removal of five to six basal leaves), ii) ST (thinned to 24 shoots per vine) and iii) LRST (a combination of LR and ST) and an untreated control (UNT). Berry composition, flavonoid content and profiles, and 3-isobutyl 2-methoxypyrazine were monitored during berry ripening. Although increasing canopy porosity through canopy management practices can be helpful for other purposes, this may not be the case of flavonoid compounds after a certain proportion of kaempferol is achieved. Results revealed different sensitivities to degradation within the flavonoid groups; flavonols were the only monitored group that was upregulated by solar radiation. Within different canopy management practices, the main effects were due to ST. Under environmental conditions in this trial, ST and LRST hastened fruit maturity; however, a clear improvement in flavonoid compounds (more anthocyanin) was not observed at harvest. Methoxypyrazine content decreased with canopy management practices studied. Although some berry traits were improved (2.5 Brix increase in berry total soluble solids) due to canopy management practices (ST), this resulted in a four-fold increase in labor operations cost, a two-fold decrease in yield, with a 10-fold increase in anthocyanin production cost per hectare that should be assessed together.

*Funding Support: UC ANR*

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### Beta: A Novel Index of Physiological Stress in Grapevine

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Seasonal management of plant water deficits and the accompanying physiological responses is a critical aspect of viticultural production. Presently, water deficits are examined via in-season measurements of stem water potential or *post*-season analysis of must carbon isotope ratios, with the former limited by reliance on arduous measurements and the latter providing information post-season. Therefore, leaving a gap in reliable, real-time measurements of plant water deficits. Technological advances in the field of surface renewal have provided a cheap and reliable method to quantify the actual evapotranspiration of an agricultural production. This work used surface renewal calculations to derive a novel index of grapevine water stress, the *b*-index, and relates *b* to measurements of stem water potential, leaf-gas exchange, and must carbon isotopes from three experimental vineyards over the 2020 and 2021 growing seasons. We offer the *b*-index as a reliable indicator of real-time vineyard water status and as a proxy for physiological responses in water-stressed vineyards. The coupling of atmospheric controls on evapotranspiration with plant physiological responses makes *b* a powerful tool for irrigation management.

*Funding Support: UC ANR*

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### Tailoring Irrigation for White Wine Grapes in Arid Eastern Washington

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Regulated deficit irrigation (RDI) is a common irrigation strategy for winegrape production in many regions, including eastern Washington. In addition to the potential to improve water use efficiency, the adoption of this technique usually favors quality attributes associated with red wines. This, added to a lack of specific irrigation guidelines for white wine grapes, can lead to mismanagement and suboptimal fruit quality. We tested the performance of Riesling in response to RDI and partial rootzone drying (PRD) for high-end white wine grape production. Fully irrigated vines (FULL) were used as a control. Soil moisture and vine water status were monitored to determine the effect of irrigation regimes on growth, yield, sun exposure, and fruit composition over three years in a research vineyard in Prosser, WA. Our results support the notion that PRD could save up to 30% irrigation water while maintaining canopy growth (shoot length) and vine size (pruning weight). Unlike PRD, RDI resulted in smaller canopies, reduced vine size, and increased sun exposure of the clusters. Yields were similar between PRD and RDI. Fruit total soluble solids, pH, and titratable acidity did not differ among the three irrigation treatments. However, the higher fruit sun exposure in RDI might increase the bitterness of the resulting wines. To determine whether higher levels of sun exposure promoted the accumulation of compounds related to bitterness, wines were made and will be evaluated at the WSU Wine Science Center to quantify phenolic composition. As increased levels of water stress and sun exposure may be counterproductive for aromatic grapes like Riesling, PRD has the potential to conserve water and maintain white wine grape quality in arid climates.

*Funding Support: NSF/USDA Cyber Physical Systems Program and the Washington State Grape and Wine Research Program*

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### Control Algae Ultrasonically in Irrigation Water Without Using Chemicals

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The latest ultrasonic algae-control technology eliminates algae growth without chemicals. The technique works on 95% of known algae by causing internal damage to the cells, causing them to lose buoyancy and thus light availability or to lose natural internal cell wall protection from bacterial attack. Simplify your irrigation process without having to worry about chemicals impacting your harvest. A single sound-producing head can control green algae and diatoms out to 150 m radially or ~17.5 acres and out to 400 m radially, or ~120 acres for blue-green algae with gas vesicles. The process uses thousands of frequencies generated with enough sound volume to cause internal damage to the various types of algae. The process is called critical structural resonance and operates on two ultrasonic bandwidths where this phenomenon occurs in these algae types. Power consumption is <$100 per year and can be delivered at 24, 120, or 240 volts AC or with solar power. Viticulture irrigation practitioners can hear the impact and benefit ultrasound can bring to their irrigation water quality while minimizing the use of chemicals and lowering operational costs.

*Funding Support: WaterIQ Technologies*

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### CropManage Application for Vineyard Irrigation Decision Support

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CropManage is a free web application developed by U.C. Cooperative Extension to support evapotranspiration-based irrigation scheduling and nutrient management for major specialty crops. Prescribed phenology curves are used to develop daily estimates of canopy cover within a given field, based on days since planting (annual crops) or budbreak (trees, vines). These curves are modulated by a MaxCan parameter representing seasonal maximum canopy cover. Crop development observations can be used to adjust for factors such as weather anomalies or non-standard agronomic practices, as needed. Canopy cover is converted to crop coefficient and combined with reference evapotranspiration to derive daily water consumption. Guidance on crop water requirement is then conveyed to users in terms of system runtime issued on-demand for a given date, largely based on total evapotranspiration since last irrigation event. In this study, CropManage was adapted to vineyards by adding modules accounting for early-season soil moisture depletion and cover crop presence. A crop stress parameter was added to accommodate deficit irrigation practice, allowing the user to specify percentage departure from full water requirement along with start/stop dates. An initial verification exercise was performed in three winegrape vineyards located in California's Central Coast (2020), North Coast (2020), and Central Valley (2019). Daily crop evapotranspiration was monitored by eddy-covariance fluxtowers. MaxCan was measured by ground and satellite observation. Stress regime was specified by grower practice, where available; otherwise, stress levels were inferred from applied water records.



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Mean absolute error and mean bias error of modeled cumulative evapotranspiration were computed with respect to the eddy covariance measurements collected throughout the growing season. Results indicate the modified CropManage water management module performs reasonably well for winegrape. Additional effort is planned to modify the nutrient module for vineyard use.

*Funding Support: California Dept Food & Agriculture, Specialty Crop Block Grant Program*

### Mechanical Shaking to Reduce Bunch Rot in Grapevines

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Crop losses due to *Botrytis cinerea* bunch rot can be significant in cooler-climate vineyards, such as those in New Zealand. Using a mechanical harvester to shake the vines between set and bunch closure reduces the severity of rot at harvest by ~50%. Harvester settings can be chosen to shake hard enough so that crop is removed, or for a lighter shake so that the crop is maintained, but "floral trash" (unpollinated berries, caps, and anthers) is removed from the bunch. This reduces the potential Botrytis inoculum present inside bunches as they ripen. There is evidence that the shaking, in addition to removing floral debris, induces tougher skins and a biochemical defensive response within berries. All of these would reduce *Botrytis* infection and/or spread within the bunch. Benefit can be gained from shaking soon after set (5 to 10 g bunches) all the way through to bunch closure (40 to 50 g bunches). Mechanical shaking offers a cost-effective, sustainable, and nonchemical means to protect fruit from bunch rot losses. This practice is already commonplace in New Zealand vineyards, but offers great promise in other winegrowing regions, especially those that receive rain around harvest and where bunch rots are a common problem.

*Funding Support: New Zealand Winegrowers*

### Vigor and Canopy Size are Key to Irrigation Scheduling for Different Winegrape Varieties

**Charles Obiero*** and Markus Keller
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Irrigation management in winegrape production is progressive and water-conserving due to the widespread use of regulated deficit irrigation, but little information is available to guide growers on irrigation scheduling for different varieties. This study optimized vineyard irrigation management by winegrape variety. A field trial was conducted in 2021 at a WSU research vineyard, Prosser, to evaluate the responses of 30 winegrape varieties to imposed water deficit. Varieties were fully irrigated through bloom, then the soil was subjected to two dry-down cycles to create a gradual soil water deficit. The first cycle began at fruit set and the second, at veraison, following irrigation to replenish soil moisture to near field capacity. There was an approximately two-fold difference in canopy size among the 30 varieties and the soil dried down faster under varieties with bigger canopies. Contrary to expectations, all varieties were isohydric under mild water stress, but became anisohydric as stress intensified below a common soil moisture threshold.

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While predawn $\Psi_l$ was similar in the two dry-down cycles, midday $\Psi_l$ was consistently (i.e., across the soil moisture spectrum) 0.4 to 0.6 MPa below predawn $\Psi_l$ during the first dry-down but only 0.2 to 0.4 MPa below predawn $\Psi_l$ during the second dry-down. These findings suggest that varietal differences in canopy size are a poor predictor of the physiological behavior of a variety under water deficit and that varieties with bigger canopies may need more frequent irrigation than do varieties with a smaller canopy to maintain the same plant water status.

*Funding Support: Washington State Department of Agriculture Specialty Crop Block Grant Program and Washington State Grape and Wine Research Program*

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### Impact of Cordon Height and Water Deficit on Yield and Berry Composition of Mechanically-Pruned Grapevines in Central California

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Grapegrowers in the southern San Joaquin Valley (SJV) struggle to achieve profitability due to increased labor costs. Since manual pruning accounts for >30% of production cost, mechanical pruning is an attractive alternative on bilateral cordons. In addition, SJV's hot climate make it difficult to achieve an optimal berry color for red *Vitis vinifera* cultivars. To study the effect of mechanical pruning on yield and berry composition, we selected Cabernet Sauvignon and Petite Sirah for a two-way factorial split-plot study in a commercial vineyard located near Kerman, CA, in 2021. Bilateral cordon, spur-pruned, Cabernet Sauvignon and Petite Sirah vines grafted on 1103 Paulsen were chosen. Vines were planted in 2018 and hand-pruned before mechanical pruning was implemented in January 2021. Two cordon heights and two levels of water deficits, replicated three times, were used in this study with five vines designated as an experimental unit. Cordon height is 54" and 68" above the vineyard floor. One water deficit is the sustained deficit irrigation (SDI): 80% $ET_c$ from berry set until harvest and the regulated deficit irrigation (RDI), of 50% $ET_c$ from berry set to veraison, then back to 80% $ET_c$ until harvest. Midday leaf water potential ($\Psi$) and fruit-zone photosynthetically active radiation (PAR) were measured to assess vine water stress and the fruit-zone light environment. Higher cordons improved berry TSS for both cultivars, but improved berry anthocyanins only in Petite Sirah. Cordon height had no effect on any yield components. RDI reduced the berry size of Cabernet Sauvignon and the cluster size of Petite Sirah, but improved berry anthocyanins only in Petite Sirah. The study will be repeated in 2022.

*Funding Support: No external fund*

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*indicates corresponding author

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### Field Evaluation of 10 Pinot gris Clones Grown in the San Joaquin Valley of California

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Pinot gris has the sixth-largest variety in CA based on the crush volume and the growing interest in Pinot gris in the San Joaquin Valley (SJV) has encouraged growers to look for a more productive clone to improve profitability. A field trial under a randomized complete block design evaluating 10 clones, replicated six times, was established near Mendota, CA. Quadrilateral cordon, spur-pruned, Pinot gris vines were planted in 2017 and went through the normal training in 2018 and 2019. Yield and berry chemistry data were collected in 2020 and 2021. Two adjacent vines from the same clone were designated as an experimental unit. Pinot gris FPS 10 yielded the most in two consecutive seasons: 21.1 kg/vine in 2020 and 11.0 kg/vine in 2021. The main driver for the increased yield was cluster number per vine: 208 cluster/vine in 2020 and 219 cluster/vine in 2021. A significant year-to-year variation was found and the overcropping in 2020, with a significant higher Ravaz index (>15), may have led to the 50% yield reduction in 2021. No significant difference in berry chemistry was found among clones. The varietal tendency to overcrop from the quadrilateral cordon, spur-pruned system may require growers to adopt: 1) additional crop load management; 2) switch to bilateral cordon, spur pruning; or 3) cane pruning to achieve consistent yield of Pinot gris in the SJV.

*Funding Support: American Vineyard Foundation*

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### Long-Term Effects of Rootstocks on Vine Productivity and Fruit Quality in a Autumn King Vineyard

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In the past three decades, numerous trials were established in central and southern California to assess rootstock impacts on vine performance and fruit quality in young vineyards, while rootstock effects in older vineyards (>10-years-old) remain less known. To understand the long-term influences of rootstocks on vine growth and berry composition, we obtained data in 2021 from a 13-year-old Autumn King vineyard in Ducor, CA, where own-rooted vines and vines on 12 rootstocks (Freedom, Harmony, Teleki 5C, Salt Creek, 1103 Paulsen, Crimson, 10-17A, RS-3, GRN-1, GRN-2, GRN-3, and GRN-4) were evaluated. Each rootstock was replicated five times and there were five vines in each experimental plot. Vines on Salt Creek, GRN-2, GRN-3, Teleki 5C, 1103 Paulsen, and Freedom were the top performers, with higher yields and larger canopies than others. Vines on RS-3, Harmony, and Crimson had intermediate yield and canopy size. Vines on 10-17A and GRN-4 had intermediate yield as well, but their pruning mass matched the top performers.
Vines on GRN-1 and own-rooted vines had much lower yields than other rootstocks, due to limited canopy growth and over-exposure of the fruit. For berry composition,

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rootstocks had small influences on berry weight, juice pH, and juice titratable acids at harvest. Yet, the level of juice total soluble solids was lower in vines on Salt Creek, GRN-2, and 10-17A, suggesting a delayed fruit ripening for those three rootstocks. Overall, GRN-2, GRN-3, and Teleki 5C had similar impacts on vine performance to Salt Creek, Freedom, and 1103 Paulsen, which are the most-used rootstocks in the warmer areas of California. This ongoing trial is expected to provide the grape industry with valuable information on the long-term impacts of traditional and newer rootstocks on vine productivity and facilitate appropriate rootstock selections for new vineyards.

*Funding Support: UC ANR*

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### Long Live the King (of the North): Yield Stability Analysis Unveils Critical Grapevine Production Gaps in North Dakota

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Grapevines for wine production are a new agricultural crop for North Dakota, with commercial cultivation initiated in the 21st century. The >20-year history of winegrape production coincides with the advent of state laws allowing legal production of local wine and developments in breeding material leading to newly generated cold-hardy grapevine genotypes. In response to the lack of existing knowledge concerning genotype adaptability, at the dawn of North Dakota grapevine production, a variety trial was planted in eastern North Dakota. With consistent yield a critical need under North Dakota's unrelenting winter conditions, cumulative yield data (2007 to 2019) was examined using analytical stability metrics and multivariate approaches to assess genotype  environment interactions and make cultivar recommendations for the region. The most stable genotypes according to multiple stability metrics were MN1200 and Marquette; however, their yield stability stems from consistently low production levels rather than commercially acceptable yields. Marquette, MN1200, E.S.5-4-71 and La Crescent produced the lowest mean yields. King of the North and Valiant were the highest-performing genotypes according to the grand mean; they were individually ranked as most stable genotypes according to one stability metric each (King of the North for CV% and Valiant for superiority measure [Pi]). The stability metrics most closely associated with top-yielding lines included CV%, bi, Pi, Si1, and Si2. High-performing lines ranked poorly based on Sd, S2di, R2, ri2, Dji, and Wi. New techniques for differentiating genotypes, such as stability analysis, may become increasingly pertinent under changing climate conditions and to anticipate performance of newly-developed cultivars for their capacity for future planting into challenging landscapes.

*Funding Support: ND Specialty Crop Block Grant*

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### The King has Left the Bottle: Characterizing 'King of the North' Rosé Wines Fermented with Five Different Yeast Strains

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'King of the North' is among a few consistently productive grapevines (*Vitis* spp.) with cold-hardiness traits adapted to eastern North Dakota and northwestern Minnesota growing conditions. Despite nearly two decades of cultivation in North Dakota, minimal research has addressed wine characteristics or fermentative properties of 'King of the North' musts, which may present challenging fermentation environments for wine yeast due to acid levels. Thus, we investigated one main fermentation treatment yeast strain, using five different commercial strains (71B, EC1118, Maurivin B, Rhone 4600, and W15) to ferment rosé wines from commercially grown 'King of the North' grapes harvested in Fertile, MN, on 1 Oct 2020. Initial must characteristics at harvest indicated high acidity (13.4 g/L malic acid by enzymatic assay). Three replicate fermentations for each yeast strain were monitored for dynamic shifts in colorimetric properties, total soluble solids, malic acid, pH, red pigments, and total phenolics. Final wines were presented to a sensory panel for assessment of aroma and taste characteristics. Prominent aroma characteristics for 'King of the North' wines included apple, apricot, cranberry, grape, pear, plum, raspberry, raisin, rose, jasmine, raisin, and watermelon. Specific aromas noted included lemon, cranberry, grape, apple, rose, black pepper, raspberry, plum, pineapple, and watermelon. The overall fruity aromas were more subdued in 71B and EC1118 wines than in Maurivin B, Rhone 4600, and W15. This study improved the overall knowledge of potential yeast strain effects on 'King of the North' wine, while quantitatively characterizing 'King of the North' aroma and flavors. However, to improve the overall quality of regional wines made from high-acid grapes, further work is necessary to unravel the role and fate of phenolics, pigments, and aroma constituents in light of specific fermentation treatments.

*Funding Support: ND grape and wine research grant*

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### Effect of Fermentation Temperature Gradient and Skin Contact on Ester and Thiol Production in Chardonnay Wines

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Wines with tropical fruit aromas have become increasingly preferred by wine consumers. This increase in access to tropical aromas leads to greater interest in the aroma compounds that cause these tropical fruit aromas in wine. Previous work using microfermentations showed that higher fermentation temperatures and increased time on skins resulted in an increase in thiol and ester compounds postfermentation. The aim of this work was to scale up those microfermentations that successfully increased thiols and esters. Descriptive sensory analysis was conducted on these wines to determine the aroma profile associated with the thiol and ester content of the wines. Future work will evaluate consumer acceptance of these wines, as very little information is available linking tropical fruit aroma to consumer preference. Four treatments were tested at varying fermentation temperatures and skin contact times. A change in winemaking scale did not alter

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the pH, residual sugar, or alcohol of the wines. Postfiltration, thiol, ester and thiol precursor analysis will be conducted. Sensory analysis used check-all-that-apply (CATA) to determine the best attributes to focus on for descriptive analysis, followed by Just-About-Right (JAR) testing to determine the best training standards for the terms determined from CATA. Descriptive analysis using trained panels was conducted to determine the intensity of the different aromas presented in the wines. Overall, this study will display if specific winemaking processes can significantly influence the tropical aroma of Chardonnay through increased levels of thiols and esters. Understanding the causes of tropical fruit aromas in wine and processes that alter these compounds is necessary to ensure winemakers can achieve tropical fruit quality consistently.

*Funding Support: American Vineyard Foundation*

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### A Capillary Electrophoresis Method for Measuring Free $SO_2$ in Traditional and Rosé Style Ciders

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The most commonly used approaches for quantifying free SO2 in ciders, the Ripper and aeration-oxidation (AO) methods, can overestimate the amount of free SO2 in the presence of weekly-bound adducts, particularly anthocyanin sulfonates in red-pigmented products. Recent attempts to rectify this issue include the use of headspace gas detection tubes (HS-GDT) and headspace gas chromatography with sulfur chemiluminescence detection (HS-GC-SCD). The HS-GDT method has a notably limited linear range and high detection thresholds, while the HS-GC-SCD method is costly, with relatively long run times. A capillary electrophoresis with direct spectrophotometric detection (CE-UV/vis) method was developed to provide an inexpensive, rapid, and sensitive alternative that requires minimal sample preparation. The resulting method was fast (6 min per injection, 4 min with manual replenishment of buffer vials), sensitive (LOD = 0.03 mg/L, LOQ = 0.8 mg/L), repeatable (average RSD = 4%), and exhibited excellent linearity ($R^2$ = 0.9999) and linear range (3 to 100 mg/L free SO2). This method was compared to measurements taken by Ripper, AO, and pararosaniline method measurements by clinical analyzer, in both unpigmented and rosé-style ciders. The method agreed with results by Ripper and clinical analyzer methods in unpigmented ciders, but differed slightly from AO measurements (two-way analysis of variance [ANOVA], $p$ = 0.004), while measuring significantly lower in rosé ciders than Ripper and AO (two-way ANOVA, $p < 0.0001$). The CE method provides a more accurate result in rosé ciders than the most commonly used techniques, is more rapid and repeatable, and requires less sample preparation..

*Funding Support: Washington State University*

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TUES/WED POSTER ABSTRACTS

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### Fermentation Model Parameters in Commercial-Scale Wine Fermentations Using Alternative Searching Methodologies

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The density-time curves of 32 commercial-scale wine fermentations from the 2021 harvest were analyzed using a fermentation model and several alternative methods of parameter estimation. The fermentations included both white and red fermentations that ranged in volume from 1200 to 420,000 L (320 to 110,000 gallons), across 17 different yeast strains and at temperatures between 10 and 35°C (50 and 95°F). The estimated model parameters included lag period, initial assimilable nitrogen concentration, specific maintenance rate, cell viability constant, and ethanol inhibition constant. The methodologies investigated were the benchmark parameter estimation algorithm developed by Bard, a differential evolution approach, a particle swarm optimization, and a new seeded search technique applied to the Boulton fermentation model. The method efficiencies were compared and the model parameters used to classify the fermentations using multivariate methods. The results demonstrate the ability of these methods to analyze complete fermentation curves to obtain useful characteristics of fermentation performance at full scale and over a wide range of winemaking conditions. The methods also have applications to real-time fermentation monitoring and the prediction of peak energy transfer rates and fermentation completion..

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### Control of Redox Potential during Wine Fermentations at Research, Pilot, and Commercial Scales

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Redox potential (oxidation-reduction potential or ORP) is an electrochemical measurement of the active oxidation and reduction components in a chemical system. The extracellular ORP during microbial fermentation determines whether certain redox reactions take place, affects the intracellular redox potential of microbes and therefore the whole metabolic process, and is easily measured with an ORP probe in the fermentation media. During wine fermentation, controlling ORP above its natural levels is expected to affect yeast metabolism and the formation of certain products, such as mitigate the formation of $H_2S$ from elemental sulfur. While control of ORP during wine fermentation has previously been demonstrated at a research volume (100 L), the purpose of this project is to demonstrate that control of ORP can be scaled to large volumes common in commercial winemaking. There are no known examples of wine fermentations with controlled ORP at commercial volumes. Typically, commercial fermentations lack mixing and at larger volumes, the measurement of any process parameter such as density, temperature, or ORP will be affected by stratification. We measured and controlled ORP in 100, 1500, and 10,000 L Cabernet Sauvignon fermentations under identical fermentation conditions.

## Enology and Viticulture Research Report Posters—CONTINUED

A controller was developed to add air into the juice if the ORP dropped below the setpoint of 160 mV (-40 mV Ag/AgCl), while non-aerated fermentations fell below 120 mV (-80 mV Ag/AgCl). The system properties of redox potential during wine fermentation were also studied. Across the three volumes (100, 1500, and 10,000 L), we will demonstrate the redox potential effect of a typical red winemaking extraction method coupled with venturi introduced air versus direct injection of compressed air into the fermentation. While a simple on-off controller was used in this work, this study of the system properties may motivate more complex control systems with improved performance.

*Funding Support: T.J. Rodgers Fellowship in Electrical and Computer Engineering, Treasury Wine Estates, Stephen Sinclair Scott Endowment in Viticulture and Enology*

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### Acidity Modification in Wine Fermentations from Arkansas-Grown Chambourcin Grapes using *Lachancea thermotolerans* Yeast

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The interest in using non-*Saccharomyces* yeast, such as *Lachancea thermotolerans*, to modify acidity and other wine attributes has increased. Chambourcin (*Vitis* hybrid) red wine grapes were harvested in 2020 from a commercial vineyard in Arkansas, randomized into eight 17.5 kg batches, crushed, and destemmed. Four fermentation treatments in duplicate were done using *S. cerevisiae* (SC) with and without malolactic fermentation (MLF) and *L. thermotolerans* with a sequential inoculation after 48 hrs with *S. cerevisiae* (LT-SC) with and without MLF. Basic composition, sugars, and organic acids of the must/wine were evaluated daily during fermentation for seven days at 21°C. Prior to inoculation, must had 21.34% soluble solids, 3.43 pH, 0.78% titratable acidity, 19.51% total sugars, and 0.90% total organic acids (primarily 0.35% tartaric, 0.33% malic, and 0.18% lactic). Regardless of MLF, SC wines completed fermentation (<0.3% sugar and 10% ethanol) at five days, while LT-SC wines completed fermentation at seven days. At five days, there was no difference in tartaric acid and, regardless of MLF, LT-SC wines were lower in pH (3.26 to 3.33) and higher in lactic (0.65 to 0.66%) and total organic acids (1.25 to 1.27%) than SC wines (3.46 to 3.49 pH, 0.24 to 0.29% lactic, and 0.84 to 0.91% total organic acids). Titratable acidity was greater in LT-SC wines, regardless of MLF (1.21 to 1.22%), than in SC-MLF wines (0.82%), but was not greater than SC wines (0.90%). From 0 to five days, LT-SC-MLF had a greater reduction (12%) in malic acid than SC-MLF wines (9%). At day five, lactic acid production for SC-MLF was 12%, while production for LT-SC and LT-SC-MLF was tripled (46% and 47% increase, respectively). Increases in lactic acid using *L. thermotolerans*, with or without malolactic co-inoculation, broadens options for achieving smoother, more complex wines due to higher lactic acid production while achieving greater stability due to lower pH values.

*Funding Support: Lallemand Inc, Danstar Ferments AG*

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**indicates corresponding author*

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### *trans*-Resveratrol Derived from Cabernet Sauvignon Pruning Waste an Additional Revenue Source for Grapegrowers

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*Trans*-resveratrol is a stilbenoid that is produced when grapevines are attacked by pathogens, under stress, or injured. The health benefits of *trans*-resveratrol make it a prime target of the cosmetic and medical business sectors. The California grape and wine industry generates much agricultural waste, some in the form of grape canes, which can contain notable amounts of *trans*-resveratrol. Thousands of dollars' worth of this high-value compound are potentially being burned or left to dry in the vineyards each season. In this work, a series of Cabernet Sauvignon vineyards in California were investigated for the first time for their *trans*-resveratrol concentrations in grape canes in the 2021 and 2022 growing season. The purpose of this project was to analyze *trans*-resveratrol in grape canes with different forms of extraction techniques. The influence of selected pre-extraction parameters on resveratrol concentrations were also investigated; for example, time of storage, age of vineyard, location, and water stress levels. Specifically, we intend to use the results from high-performance liquid chromatography (HPLC) analysis to determine resveratrol concentration. A microwave-induced atomic emission spectrometer (MP-AES) was used to analyze the drought stress markers calcium, magnesium, sodium, and potassium in the grape canes and a combustion analyzer was employed to determine the content of carbon and nitrogen in the grape canes before and after extraction, which gives an indication of the suitability of the waste material to be used as fertilizer.

*Funding Support: Qun Sun & PLD Marketing*

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### Evaluating Foliar Applied Calcium Carbonate on Table Grapes and Observing Cold Storage Potential

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California is a leader in producing table grapes, making postharvest storage an essential component of worldwide distribution. A common struggle in the table grape industry is grape waste due to berries with poor integrity. There have been studies to extend postharvest storage by applying preharvest applications like calcium chloride, calcium nitrate, and sodium bicarbonate. Yet no study has indicated calcium carbonate usage, especially in agriculture. Calcium carbonate could be useful in plant physiology, as calcium is important for berry cell wall structural components and carbonate can be essential in photosynthesis. However, calcium carbonate is insoluble, and due to its large particle size, not easily absorbed by plants. This study evaluated OR-244B, a calcium carbonate-based product that has a small particle size, in the Fresno State Vineyard. Sweet Scarlet, a red midseason seedless table grape, was used to evaluate calcium carbonate uptake and its effect on grapes after commercial cold storage trials. The cultural and harvest practices followed a conventional operation, with grapes packed into 19 lb boxes. The experimental layout consisted of eight treatments, including a control, with six replicates. OR-244B was compared with the individual components and

## Enology and Viticulture Research Report Posters—CONTINUED

standard industry products containing calcium. The treatments included foliar and soil applications during the growing season. After harvest, grapes were stored for four and eight weeks at a commercial cold storage facility. Berry texture, size, color, and fungal infection rates were used to evaluate OR-244B as a cheaper and safer calcium-based product to increase postharvest storage quality.

*Funding Support: ORO AGRI, Inc., Agricultural Research Institute*

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### Dried Grape Pomace for Remediation of Cork Taint in Wine

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Cork taint is a global issue within the wine industry. Finding ways to remove the responsible chemicals, trichloroanisole (TCA) and tribromoanisole (TBA), without stripping the wine of aromas and flavors, while maintaining desirable color characteristics is imperative. We investigated dried grape pomace as a fining agent for effective removal of TCA and TBA from wine. Dried grape pomace was procured from a local winery and added to Chardonnay wine at two addition rates: 5 or 10 g/L. After 48 hrs in contact with the pomace, the wine was strained and samples were tested for haloanisole analysis. Headspace gas chromatography-mass spectrometry showed that the addition of dried pomace significantly decreased TBA in wine. The 5 g/L addition resulted decreased TBA by 69.41% and the 10 g/L addition, by 74%. No significant effect was found on TCA. Dried grape pomace as a fining agent for TBA shows excellent promise. Grape pomace is a by-product of wine production, making it very easily accessible and cost-effective to winemakers. The grape pomace is added at manageable levels for wineries of all sizes. No adverse effects were measured in the wine and color was maintained. Experiments are underway testing lower rates of pomace addition, different wine types, and lengths of time in contact with pomace. Sensory analysis is also being conducted.

*Funding Support: San Antonio Livestock Expo (SALE)*

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### Examining the Role of Fructose in Stuck or Sluggish Fermentation: A Correlation, not a Cause

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Grape juice is fermented into wine in part by yeast cells (Saccharomyces cerevisiae) converting sugar to carbon dioxide and ethanol. The sugar naturally present in grape juice primarily consists of glucose and fructose in approximately equal quantities. Despite being a carbon source for yeast, fructose has also been implicated as one of the many potential causes of stuck or sluggish fermentations. This is largely based on the observation that stuck fermentations have more residual fructose levels than glucose. However, some evidence indicates that fructose levels simply correlate with stuck fermentations, including growth rates from laboratory strains of yeast, biochemical details of sugar metabolism in yeast, and an increased fructose-to-glucose ratio during fermentations that achieve dryness.
This study directly examines the role of fructose in causing stuck or sluggish fermentations through fermentation trials in a variety of matrices (grape juice,

**indicates corresponding author*

synthetic grape juice, laboratory growth medium) while controlling glucose and fructose concentrations. For 70 commercially available wine yeast strains, we observed no consistent growth rate differences between glucose- and fructose-containing growth media. Further, a mathematical model suggests that differences in glucose and fructose anomeric structures underlie differential use of glucose and fructose, rather than regulatory discrimination by yeast cells. Thus, while excess fructose correlates with stuck or sluggish fermentations, it is unlikely to be a cause. This work provides evidence to better understand the role of fructose in fermentations and provide winemakers with more knowledge for making data-based decisions about remediating stuck or sluggish fermentations.

*Funding Support: Start-up funding provided to Dr. Patrick A. Gibney by the Department of Food Science, Cornell University.*

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### Fungicide Resistance of *x* Populations on Winegrapes in the Central Coast of California

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Botrytis bunch rot, caused by *Botrytis cinerea*, is a major concern to grapegrowers and wine producers in California due to significant crop losses and reduction of fruit and wine quality. The increasing occurrence of fungicide resistance in *B. cinerea* populations poses a challenge for effective management of this disease in vineyards. In 2020, 35 *B. cinerea* isolates were screened against the fungicides Scala, Flint, Endura, Elevate, Rovral, and Scholar to determine their sensitivities to these different active ingredients. Grape cluster samples exhibiting Botrytis growth were collected randomly from six conventional and two organic vineyards in five geographically different locations in the Central Coast of California. Pure culture isolates of *B. cinerea* were tested against discriminatory doses of each fungicide. Radial mycelial growth was measured following a five to seven day incubation. Measurements were converted to percent relative growth values for four single-colony replicates per isolate. Isolates were separated into four sensitivity categories: highly sensitive, moderately sensitive, highly resistant, and moderately resistant. Of the 35 isolates screened, 88.6, 97.1, and 74.3% were highly resistant to Scala, Flint, and Endura, respectively. Only 5.7 and 2.9% of isolates showed moderate resistance to Scala and Endura, respectively. 62.9 and 50% of the isolates were moderately sensitive to Rovral and Elevate, respectively. Isolates exhibited high sensitivity to Scholar (82.9%), Elevate (41.2%), and Rovral (37.1%). A mixed model statistical analysis was then used to identify the effect of type of fungicide and fungicide dosage (mg/mL) on the growth (cm) of resistant and sensitive *B. cinerea* isolates. Pathogen isolates were obtained again in 2021 to determine if similar resistance frequency patterns were repeated. These results can be used by grapegrowers to implement effective fungicide spray programs for control of Botrytis bunch rot in the Central Coast of California.

*Funding Support: CSU Agricultural Research Institute (ARI)*

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## Enology and Viticulture Research Report Posters—CONTINUED

### The Grape Health Index: Validation of a New Methodology for Quantifying Grape Spoilage by Means of FT-MIR Spectroscopy

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For wineries processing hand-harvested grapes, a visual inspection of microbial grape spoilage is expedient and cost-effective. However, increased adoption of machine harvesters, which frequently rupture berry skins and make visual inspection less precise, and the high degree of error of visual inspections between individuals make a quantitative approach to assess spoilage necessary. Fourier transform infrared spectroscopy, combined with multivariate analysis, is being investigated as an approach to predict grape health, as a sample can be analyzed in less than one minute. Calibration data was obtained from grape samples of Chardonnay, Riesling, Petite Sirah, and Zinfandel that were sorted into fractions of 0, 5, 10, 15, or 20% microbially-impacted clusters in healthy grape material and run on the FOSS Winescan. Spectral data was analyzed in R Studio using the partial least squares package with spoilage level being the dependent variable. Attributes under consideration include volatile acidity, gluconic acid, ethanol, lactic acid, glucose-fructose content, total soluble solids, titratable acidity, tartaric acid, malic acid, pH, and yeast assimilable nitrogen. Based on previous research, positive correlations have been found between the degree of microbial spoilage and volatile acidity, gluconic acid, ethanol, lactic acid, and glucose-fructose content, so these predicting factors will be overweighted. A model will be selected that optimizes for a high correlation coefficient and a low difference between the root mean squared error of the model and the ten-fold cross-validated model. As the correlation improves, by using more predicting factors with training data, the predictive power of the model on new data decreases, due to low correlation between some predicting factors and the dependent variable. Therefore, the ideal combination of predicting factors, predicting factor weights, and number of components will be selected to provide accurate Grape Health Index scores.

*Funding Support: California Winegrape Inspection Advisory Board & The Agricultural Research Institute*

TUES/WED POSTER ABSTRACTS

### Emerging Technology Alternatives to Sulfur Dioxide for Postharvest Decay Control in California Table Grapes

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Sulfur dioxide ($SO_2$) is a reactive fumigant commonly used to prevent postharvest fungal decay in California table grapes. Fumigation with SO2 is highly effective at controlling several postharvest pathogens, including *Botrytis cinerea*, *Penicillium digitatum*, and *Penicillium expansum*. Although highly effective, the use of $SO_2$ is problematic and the table grape industry would benefit if alternative decay control strategies were available. $SO_2$ can lead to injury, bleaching, and general phytotoxicity of table grape skins and can create "off flavors" that can cause adverse reactions to consumers. $SO_2$ is a very strong oxidizer and causes damage to grape storage facilities and can create a hazardous work environment for employees of storage and shipping facilities. $SO_2$ released into the environment may contribute to air quality concerns. To investigate alternatives to $SO_2$ use, we intend to compare the efficacy

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of existing and emerging decay management strategies with current $SO_2$ use to determine if alternatives are practical and commercially viable. Factor X is a novel fungicide tested for its efficacy against common postharvest fungal pathogens, such as *B. cinerea* in table grapes, *P. digitatum* in citrus fruits, and *P. expansum* in apples. Pyrimethanil is a registered postharvest anilinopyrimidine fungicide. Fludioxonil is also a registered postharvest phenylpyrrole fungicide. Primary data suggests that Factor X, pyrimethanil, and fludioxonil are more effective than $SO_2$ at controlling fungal decay. All three fungicides were administered in liquid formulations. Commercial use of a liquid fungicide would greatly decrease the environmental impacts on air quality and employee workplace safety $SO_2$ use poses. We foresee significant reportable outcomes from this thesis on the feasibility of current and potential future alternatives to $SO_2$ use and the practicality of implementing these by the California table grape industry.

*Funding Support: AgroFresh Solutions, Inc. and Fresno State Department of Viticulture and Enology*

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### Impact of Grapevine Red Blotch Virus on Cell Wall Composition and Phenolic Extractability During Winemaking

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Grapevine red blotch virus (GRBV) significantly impacts berry ripening and variably influences primary and secondary metabolites, depending on site and seasonal factors. Recent studies showed wines made from red blotch (RB) diseased fruit left longer on the vine to reach a similar sugar level as their healthy counterparts achieved riper fruity flavors and better mouthfeel. Research showed this was partly due to increased phenolic extraction during winemaking, instead of higher grape phenolic content or ethanol production. The impact of RB disease on cell wall composition is unknown. Therefore, this study investigated the impact of GRBV and ripening on cell wall composition and phenolic extractability during winemaking. In this work, phenolic extractability of Merlot from Napa County, CA, was investigated over two continuous vintages (2019 and 2020), with grapes harvested at 23, 25, and 27 Brix. The phenolic profile of samples obtained by exhaustive extractions and microfermentations of grapes were determined by Adam-Harbertson assay and RP-HPLC. Cell wall (CW) materials isolated from berry skins were subsequently characterized (lignin, lipids, uronic acids, protein, phenolic, total glucose, cellulose, and non-cellulosic glucose). With partial least square regression analysis, the relationship between phenolic extractability and cell wall composition was investigated. Results confirmed that longer hang time increased phenolic extractability of RB-diseased grapes, potentially because GRBV causes delayed ripening and reduced degradation of skin cell walls. This was further substantiated by the larger amount of CW found in GRBV grapes. Furthermore, CW characterization indicated that GRBV-infected fruit contained more soluble proteins and pectins, which could bind with phenolics and decrease extraction under winemaking conditions. Further study will investigate whether these are pathogen-related proteins as a result of the plant defense mechanism against the virus and ways to mitigate impacts of GRBV on grape and wine composition.

*Funding Support: American Vineyard Foundation*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Implementation of a New Oxygenate Treatment Against Fungal Diseases in Viticulture

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Over the last decades the use of pesticides such as copper in vine protection has come under severe discussion and restrictions, causing concern in viticulture. Since the efficacy of oxygenates against various microorganisms has been proved in the medical field, a strategy for oxygenate-based plant protection was developed. Treatments of vineyards with classical $O_3$ has shown to be not effective due to the short reaction time. We examined a longer-lasting, effective oxygenate treatment to reduce harmful environmental pesticide residues. The production of the oxygenate is following the Criegee-mechanism using $O_3$ and natural, plant-derived unsaturated fatty acids forming so called ozonides. Therefore the effect of the treatment was evaluated in a holistic approach, covering its efficiency against fungal diseases, protection of desired beneficial insects, the micro flora, and various secondary metabolites of the grapevine, such as aroma precursors and the resulting sensory profile of the wines. The biological efficacy was measured over three years using different in vivo and in vitro studies. The influence on desired berry compounds such as anthocyanins, glutathione, or aroma precursors was determined by classical gas chromatography-mass spectrometry and high-performance liquid chromatography methods. Positive effects against downy and powdery mildew were demonstrated. No negative effects against insects, naturally occurring microorganisms, or desired berry compounds was observed. Even spontaneous fermentation was not inhibited. Quantitative descriptive sensory analysis and CATA showed no negative effect of the treatment. In viticulture, the use of oxygenates could lead to a reduction in the use of copper-based pesticides and lower soil contamination with pesticide residues.

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TUES/WED POSTER ABSTRACTS

### Reduction of Ochratoxin A by Proteolytic Activity of *Oenococcus oeni*

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Ochratoxin A (OTA) is a mycotoxin with harmful effects on health. Its occurrence in grapes and wine is mainly caused by Aspergillus carbonarius and Aspergillus niger. OTA decontamination using microorganisms is a safe and environmentally friendly control method. Several acid lactic bacteria with a proteolytic system have the ability to hydrolyze OTA. This is possible because OTA is the only mycotoxin with a peptide bond in its molecular structure. We demonstrated that *Oenococcus oeni*, the major species found in wine during malolactic fermentation, express proteolytic and peptidasic activities on grape juice and wine proteins under stress conditions. The aim of this work was to determine the ability of the *O. oeni* RAM 11 proteolytic system to reduce OTA concentrations. *O. oeni* RAM 11 was grown in MRS broth supplemented with 15% (v/v) tomato juice (pH 4.8) at 28°C until its exponential growth phase (OD560 0.8). Harvested and washed cells were suspended in 0.05 M citrate buffer, pH 5.0, and incubated at 28°C for two hours. The supernatant was collected to assay proteolytic activity and OTA reduction. Proteolytic activity was determined using sterile grape juice as substrate and the amino acids released

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were measured by Doi using ninhydrin reagent. Additionally, the supernatant was supplemented with 10 µg/L commercial OTA and incubated at 28°C for four hours. The OTA concentration was determined by ELISA competitive method using the OTA Ridascreen-Fast kit (R-Biopharm, Germany). Proteolytic activity was evidenced with a value of 0.230 mmol/L. This activity reduced 3.25 µg/L OTA in four hours. Thus, the proteolytic system of *O. oeni* RAM 11 can reduce OTA concentration enough to reduce or eliminate this mycotoxin during malolactic fermentation.

*Funding Support: CONICET*

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### Malolactic Fermentation: Malolactic Potential and Metabolism of Nitrogenous Compounds by Different Strains of *Oenococcus oeni*

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*Oenococcus oeni* can develop adaptation mechanisms to avoid nutritional stress, such as the release of proteases. These proteases release peptides and amino acids that help maintain bacterial viability, necessary for a successful malolactic fermentation (MLF). Pasteurized apple juice was fermented with a strain of *Saccharomyces cerevisiae* and then divided into two batches. One batch was centrifuged, filtered, and pasteurized. The other was reserved without pasteurization (lees batch). Both batches were used to perform the MLF with three strains of *O. oeni*. Strains RAM10 and RAM11 were isolated from Argentinean Malbec wine. Strain VP41 was purchased from Lallemand. Both batches of fermented apple juice were individually inoculated with the three strains of *O. oeni*. Bacterial viability was determined by colony count in MLO agar. Cell concentration was determined by measuring absorbance. Malic acid concentration was determined enzymatically. Supernatants obtained at different times were used to determine proteins (Bradford method) and peptides, amino acids, and proteolytic activity (ninhydrin reagent by Doi method). During MLF, the three strains maintained viability at 107 to 108 CFU/mL. The presence of lees did not modify malic acid consumption by the RAM10 and VP41 strains; however, an improvement in this parameter was detected in the RAM11 strain. Without lees, any bacterial proteolytic activity detected derives from protein breakdown, evidenced by increased concentrations of peptides and amino acids during MLF. Peptide release was not detected in the media with lees. The maximum proteolytic activity of the studied strains occurred after 24 hrs MLF, in the presence or absence of lees, but greater in the absence of lees.

*Funding Support: CONICET Consejo Nacional de Investigaciones Científicas y Técnicas*

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### Tiramine Production by Lactic Acid Bacteria from Tucuman Wines Detected by a New Colorimetric Method

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Biogenic amines (BA) are low molecular weight metabolites produced during vinification, primarily by lactic acid bacteria (LAB), that affect human health and the quality of the final product. Tyramine can produce hypertension by releasing the vasoconstrictor noradrenaline. Thirty bacterial isolates from the 2013 vintage in

Tucuman-Argentina were screened to detect the tyrosine decarboxylase enzyme (TDC) in agar medium using Maijala procedures. Six isolates positive for TDC were grown in commercial decarboxylating Moeller broth at 28°C. The supernatants obtained after 96 hr incubation were assayed for tyramine quantification using a rapid, inexpensive, and simple new colorimetric method. This method was validated using a high-performance liquid chromatography technique for tyramine quantification through recovery of added tyramine. The gene coding for the enzyme TDC was detected in the selected bacteria by PCR. The TDC-positive isolates were identified by amplification, and sequencing of the 16S DNA ribosomal gene and typification was performed by RAPD. The new method shows a linear relationship (correlation coefficient = 0.9959) between the color intensity at 450 nm and tyramine concentration in the range 0 to100 mg/L. Six positive isolates with the TDC gene were detected. These isolates were identified as *Lactobacillus paracasei* and through RAPD were identified as four different strains (AT38, AT45, RA39, and RA49). The supernatants obtained from decarboxilating culture broth showed tyramine at different concentrations. The higher concentration of the amine was found in the supernatant obtained from *L. paracasei* AT38 (40.45 mg/L). These results evidence the presence of *L. paracasei* strains in Tucuman wines with a functional TDC gene. Additionally, an inexpensive and rapid method for tyramine quantification in culture medium was developed.

*Funding Support: CONICET*

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### Comparing Machine Learning Methods in Classifying Red Blotch and Leafroll Viruses in VIS Hyperspectral Images of Leaves

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Hyperspectral imaging spectrometry offers new opportunities for viral disease scouting. We compared two machine-learning methods, Random Forest (RF) and 3D-Convolutional Neural Network (CNN), to identify and distinguish leaves from red blotch-infected vines, leafroll-infected vines, and vines co-infected with both viruses using spatiospectral information in the visible domain (510 to 710 nm). As assessed with a five-fold cross-validation scheme, when binarily classifying infected versus non-infected leaves, the CNN model outperformed the RF model with 85.5% accuracy versus 80% for the RF model at mid-ripening. The accuracy of both models decreased when leaf samples collected at veraison were analyzed. Based on a multiclass categorization of leaves, the CNN and RF models had an accuracy of 70% and 68% (averaged across both healthy and infected leaf categories) at mid-ripening, and 60% and 63% at veraison, respectively. A comparative analysis of PCR-based virus identification and machine learning outcomes revealed that the leafroll-infected category was better solved, followed by the non-infected, red blotch-infected, and double infection categories. When two leaves were imaged per plant and predictions were obtained independently for each leaf, variability in symptom expression between leaves affected the RF model more than the CNN model. The CNN model equally classified two leaves from the same plant with ~75% frequency while the RF model achieved the same results with only a 55% frequency. When using two leaves to predict the infection status, the prediction accuracy increased in both models, especially in harder-to-predict categories. Interpretation of the RF data showed that the most important wavelengths were in the green, orange, and red subregions, and associated with pigment concentration change, chlorophyll,

**indicates corresponding author*

and carotenoid absorption. While differentiation between plants co-infected with GLRaVs and GRBV proved challenging, both models showed promising accuracies across categories.

*Funding Support: CDFA-SCBGP, CSU-ARI System Grants*

### Identification of Phenolic Compounds in the Phenolic Fraction of Young and Aged Wines from Argentina

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The wine industry is an important sector of the Argentine economy. Phenolic compounds (PCs) are important wine compounds due to their biological activities. The aim of this study was to obtain qualitative and quantitative characterization of the PCs in the low-molecular weight phenolic fractions (LMF) of young (Y) and aged (A) Tannat red wines produced in Colalao del Valle, Tucumán, Argentina. Both LMF were obtained from 750 mL dealcoholized wine (pH 2.0) by successive extractions with ethyl acetate. Total PC concentrations in wine were determined using the Folin reagent and expressed in mg/L GAE. The LMF was characterized using a liquid/liquid extraction method coupling diode-array and fluorescence detectors (LC-DAD-FLD) to quantify PCs. The presence of PCs in both fractions was confirmed by thin-layer chromatographic profiles, comparing the similar Rf to pure PCs used as standard. The total PC content in the wine was 3320.38 and 3094.66 mg/L GAE for Y and A wines, respectively. Twenty PCs were quantified in the LMF by LC-DAD-FLD. PC concentrations detected were higher in the LMF-Y (26938.80 µg/g dry extract) than in the LMF-A (17400 µg/g dry extract). Gallic acid, epigallocatechin gallate, and caffeic acid were the most abundant compounds, with concentrations between 9363.9 and 2003 µg/g dry extract in LMF-Y and 6956.60 and 1606.70 µg/g dry extract in LMF-A, followed by (+)-catechin and p-coumaric acid. The decrease of low molecular weight PCs evidenced in this work after aging of Tannat wine could be explained by complexing and condensation reactions between anthocyanins and the PCs, as demonstrated previously in the scientific literature. These results constitute an important contribution to the knowledge of the effects of wine maturation on low molecular weight phenolic composition.

*Funding Support: CONICET*

### Application of Parallel Factor Analysis (PARAFAC) to the Regional Classification of Vineyard Blocks Using Remote Sensing

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Monitoring winegrowing regions and maximizing the value of production based on regional and local specificities requires accurate spatial and temporal monitoring. The increasing amount and variability of information from remote sensing data is a potential tool to assess this challenge in the grape and wine industry. We examined the capacity of a multiway analysis method applied to the Sentinel-2 time-series to assess the value of simultaneously considering spectral and temporal information

to differentiate production differences at a regional scale. PARAllel FACtor analysis (PARAFAC) was used as an unsupervised technique to recover pure spectra from multi-way spectral imagery of vineyards in the Languedoc-Roussillon region in the south of France. The model was developed using a time series of Sentinel-2 satellite imagery collected on 4978 vineyard blocks between May 2020 and June 2021. The Sentinel-2 signal was resolved into spectral and temporal profiles in the form of pure compounds, which are potentially specific to both vegetation and soil. The PARAFAC analysis indentified two pure compounds strongly related to characteristics and dynamics of vineyard cultivation on a regional scale. A conceptual framework was proposed using the simultaneous integration of spectral and temporal attributes from Sentinel-2 time-series at regional scale with the PARAFAC methodology and was validated with a practical framework of expert winegrowers' opinions from the Languedoc Roussillon region. The introduction of PARAFAC insights into the analysis approach, from a conventional grapegrower's perspective, opens the possibility to identify spectro-temporal profiles of vineyard blocks relevant for understanding and characterizing them on a regional scale.

*Funding Support: This work was supported by the French National Research Agency under the Investments for the Future Program, referred as ANR-16-CONV-0004.*

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### Monitoring Grapevine Water Status at the Regional Scale of the San Joaquin Valley Using Remotely-Sensed Actual ET

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Water insecurity, as a result of erratic environmental behavior, has become a familiar concern for growers across California and water restriction has increased demand for precision farming techniques. Satellite sensors can provide useful information in space and time to monitor vegetation characteristics, as multispectral imagery can inform about plant composition and structure. This project aims to validate if the application of a spatial model of energy balance and actual evapotranspiration from satellite images and agrometeorological data can be used by growers to monitor grapevine water status in the San Joaquin Valley. In 2021, we selected 50 experimental units of Chardonnay grapevines in five vineyards located in different counties across the San Joaquin Valley. We selected the location of experimental units by maximum dissimilarity sampling based on soil texture and hydraulic conductivity obtained from the USDA-SSURGO database and normalized difference vegetation index measured in late spring of the same year from Landsat 8. We geolocated all experimental units and assessed grapevine water status at the end of ripening by measuring the carbon isotope discrimination ($\delta^{13}C$) of grape juice at harvest. To estimate actual grapevine evapotranspiration, we applied the simple algorithm for evapotranspiration retrieving (SAFER) model based on satellite imagery from Landsat 8, reference evapotranspiration and solar radiation from the spatial version of CIMIS (California irrigation management information system), and average temperature from the PRISM (parameter-elevation regressions on independent slopes model) climate mapping system. Finally, we compared pixel-level actual evapotranspiration to carbon isotope discrimination to evaluate the ability of model estimates to assess grapevine water status and inform irrigation decisions.

*Funding Support: ARI-HSI*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Effects of Six Commercial *Oenococcus oeni* Cultures on Volatile Smoke-Taint Compounds during Malolactic Fermentation

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Smoke taint in wines, resulting from grapes affected by smoke from nearby wild or man-made fires, is a serious problem in many winemaking regions. The molecules responsible for smoke taint are present in wines in two forms: 'free' volatile molecules or non-volatile glycosides 'bound' to sugar moieties. To date, little knowledge exists regarding the impact of the bacteria responsible for malolactic fermentation (MLF) on the release of free taint compounds from their bound counterparts. To determine whether the unbound 'free' concentration of seven known taint compounds was increased during MLF, six commercially available *Oenococcus oeni* strains were studied. MLF was carried out in three commercial wines, all categorized as highly tainted by the wineries producing them. The concentrations of 'free' and 'bound' smoke taint compounds were measured before and after MLF. Upon completion of MLF with the six cultures, no significant increase in the concentration of 'free' taint compounds was found. This suggests that for wines with a low level of smoke taint, conducting MLF with these six *O. oeni* strains will not increase the negative effects of smoke taint. Furthermore, MLF with these cultures could be combined with a suite of other winemaking techniques such as carbon-fining, shortened maceration, yeast selection, and the addition of oak adjuncts and tannin products to manage the level of smoke taint in an impacted wine.

*Funding Support: Chr. Hansen A/S*

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### Effectiveness of Applied Materials in Reducing the Absorption of Smoke Components in a Simulated Wildfire Scenario

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The increasing incidence of wildfires in winegrape-producing regions of the West Coast of the United States has highlighted the need to develop mitigation strategies to manage the impact of smoke exposure on grapes and the resulting wines. There are now several products and processes available to mitigate smoke in the vineyard and treat smoke-impacted wine. Therefore, it is important to investigate different potential ways to manage the impact of grape smoke exposure, especially as it seems unlikely that a single tool will solve this problem. The objective of this experiment was to compare the relative efficacy of applying different potential protective barrier sprays to grapes in a simulated wildfire scenario. Four Cabernet Sauvignon vines were exposed to smoke in Robert Mondavi Institute vineyards at UC Davis. Three bunches from each vine were treated with different products to compare the effects of applied materials in reducing absorption of smoke marker compounds (13 different treatments were applied). Individual clusters were submerged in the potential barrier spray for 30 sec. The vines were exposed to smoke three days after treatment for two hours. Control samples were taken prior to smoke exposure (buffer samples) and smoked control grapes were sampled at different times after exposure. All treated bunches were harvested a week after

## Enology and Viticulture Research Report Posters—CONTINUED

smoke exposure. Grapes were analyzed for free and total volatile phenols using the acid hydrolysis methodology (GC-MS) and for glycosylated volatile phenols (UHPLC-qTOF MS). Results from untreated grapes indicate that glycosylation of the free volatile phenols takes place within hours. Additionally, kaolin consistently lowered the amount of volatile phenols absorbed during smoke exposure under these conditions.

*Funding Support: USDA-AR*

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### Sequential Inoculation with *Pichia kluyveri* and Agitation as an Enological Technique to Enhance Wine Quality

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Sequential inoculation techniques using non-Saccharomyces yeasts have become a valuable winemaking tool to diversify the aroma, taste, and mouthfeel attributes of wines. Within the commercially available yeasts for sequential inoculation, *Pichia kluyveri* is distinguished for its aerobic metabolism and film-forming qualities. Due to the recent commercial introduction of this yeast, there is a need to determine the fermentation conditions that maximize the impact of *P. kluyveri* on wine quality. This research aims at evaluating the effect of agitation as a strategy to enhance film formation of *P. kluyveri*, and its impact on the chemical composition and sensory attributes of white and rosé wines made with Sauvignon blanc and Zinfandel grapes, respectively. Three experimental conditions were studied: agitation, no agitation, and a control without sequential inoculation. The agitation treatment used a pump to recirculate the fermenting juice underneath the film layer for 10 min during the first three days of fermentation (total 30 mins). The no-agitation treatment allowed *P. kluyveri* to develop without recirculation following the manufacturer's recommendations. Film formation monitored with digital images showed that agitation encouraged faster implantation of *P. kluyveri* and a thicker film than the non-agitated wines. Basic wine chemistry parameters showed that both sequential inoculation treatments (agitation and no-agitation) had significantly less ethanol and more glycerol than the control. A preliminary sensory evaluation with 15 consumers showed that the aroma intensity increased in wines with sequential inoculation, although no differences were found between agitation treatments. Ongoing analysis of the volatile composition by gas chromatography-mass spectrometry is expected to identify differences between the agitation treatments, particularly in fermentative esters and terpenes.

*Funding Support: Gusmer Enterprises*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Volatile Phenols Release from Ash over Time and its Potential Impact on Wine

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Grape smoke exposure has become a recurring issue on the west coast of the United States. During wildfires, a substantial amount of volatile phenols (VPs) are released into the air from wood burning through lignin pyrolysis. VPs break down within hours in the atmosphere (gas phase); however, when absorbed onto particulate matter or droplets, their stability is unknown. VPs can absorb onto ash and it has been shown that collected ashes can release VPs for up to a week. VPs can absorb through the berry skin, where they are quickly glycosylated, potentially as part of the defense mechanism of the plant. During winemaking and aging, free VPs can be released from the bound precursors through slow hydrolysis. However, there is no published data available regarding the impact of ash on grapes in vineyards and during winemaking. This study measured the changes in VP markers in ash over time and determined how these changes translate to the final wine composition. Ash was made by burning a commercial pinewood until only ash remained and sieving the ash through a mesh to ensure particulate size homogeneity with a commercial sieve (mesh 40). After homogenization, ash samples were collected at one, four, and seven days and analyzed for VP composition. VP profiling was by headspace solid phase microextraction of the head space above the ash and by liquid-liquid extraction followed by gas chromatography-mass spectrometry (GC-MS). In parallel, ash of similar ages (one, four, and seven days) was added to small-scale fermentors and the resulting wines analyzed with solid-phase microextraction. Preliminary results indicate that fresh ash released VPs under the conditions tested and the decrease in released VPs are not linear, but exponential. Additionally, fresh ash can change the VP composition of the resulting wines.

*Funding Support: The American Vineyard Foundation*

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### Preventing Smoke Phenol Absorption in Pinot noir Grapes: Evaluation of Film Coatings as Mitigation Techniques

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For decades, the wine industry has been searching for solutions to protect grapes from wildfire smoke. Grapes exposed to smoke have increased levels of volatile phenols that cause undesirable sensory characteristics in wine. To address this problem, new mitigation techniques are needed to preserve the quality of the grapes. Due to limited smoke taint reduction techniques, innovative film coatings were developed to prevent volatile phenols from entering the grapes. Pinot noir grapes harvested from Woodhall III Vineyards in Oregon were sprayed with four different coating treatments. The coatings consist of cellulose nanofiber (CNF) as the base and other functional ingredients. Uncoated grapes were used as a control. Specially designed cages covered in low density polyethylene greenhouse film were used to smoke the groups. Smoke was generated using $^{13}C$-labeled barley as a fuel source. The grapes were smoked for six hours, achieving a constant smoke

density between 20 and 100 mg/m3 for smoke particles >1 µm. Half of the grapes were washed after they were smoked to determine whether smoke compounds are blocked or bind to the film coatings. Gas chromatography-mass spectrometry was used to determine the amount of smoke compounds in the grapes. This study will determine if the novel film coating is a promising mitigation technique to prevent wildfire smoke compounds from entering grapes. If so, the wine industry will have an effective tool in their arsenal to combat wildfire smoke events and prevent smoke taint in wine and the potential loss of product.

*Funding Support: USDA-NIFA-SCRI, USDA-NIFA-ARS*

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### Preventing Migration of Smoke Compounds into Pinot noir (*Vitis vinifera*) Winegrapes using Edible Coatings

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Smoke taint from recently increased wildfires in the United States has led to undesirable sensory characteristics in wine due to smoke compounds absorbed into the grapes and released during fermentation. Edible coatings may be used to entrap or block smoke compounds from entering grapes, preventing smoke taint. This study developed polysaccharide-based coatings to prevent smoke taint in winegrapes. Three coating suspensions consisting of cellulose nanofiber (CNF), β-cyclodextrin (βCD), and/or chitosan (CH) were evaluated at Southern Oregon Research and Extension Center Vineyard on Pinot noir grapes. Coatings were applied at three different times during grape growth: bunch closure, veraison, and both bunch closure and veraison, with uncoated grapes as control. Each coating group and application time contained three to four trellises. Harvested grapes were analyzed for total soluble solids (TSS), pH, titratable acidity (TA), size, weight, and appearance. Half of the grapes in each treatment were washed to remove the coating and the other half were unwashed prior to analysis. Coating suspensions were cast into films to evaluate water vapor permeability (WVP), water solubility, strength, and elongation. Complexation between coating suspensions and guaiacol (model smoke compound) was analyzed by UV-vis spectroscopy scanning (200 to 400 nm). Field study showed that all three coatings did not influence ($p > 0.05$) size, weight, appearance, TSS, pH, or TA of grapes compared with uncoated control. Washed and unwashed grapes also showed no significant differences for TSS, pH and TA. Water adsorption, solubility, and tensile strength differed for each film. Developed coatings demonstrated capability to prevent smoke taint for winegrapes without affecting grape growth physiology. Coatings can be easily removed from grapes as needed. This study provides an effective solution to prevent smoke taint in winegrapes and ensure wine quality..

*Funding Support: Oregon Department of Agriculture USDA-ARS*

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## Enology and Viticulture Research Report Posters—CONTINUED

### Impact of Smoke Exposure on Berry and Wine Chemistry of Cabernet Sauvignon under Leafing and Deficit Irrigation

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Smoke exposure can negatively affect grapes and resulting wines by absorption of smoke-related phenols released into the air during wildfires. Currently, studies investigating the impact of canopy management on volatile phenol absorption have been inconclusive, with no clear benefit from pulling leaves after smoke exposure or thicker canopies to protect grape bunches during smoke events, even though it has been shown that translocation of volatile phenols between leaves and grapes is possible. The main objective of this study was to determine the interactive effect of water deficit and mechanical leafing on canopy structure and grape smoke exposure risk. The field experiment was conducted at a commercial Cabernet Sauvignon vineyard (clone 08) on Freedom rootstock planted in 2013 in Madera County, CA. The vine spacing is 4’ 10’ (vine row), with the row planted at a 45° angle on a Northeast-Southwest orientation. This experiment was a two (sustained deficit irrigation/regulated deficit irrigation) three (leaf removal at bloom ~400 GDD/fruit set ~630 GDD/no leaf removal) factorial design with five replicated blocks. Sample analysis for both grape and wine free and total volatile phenols was conducted using liquid-liquid extraction (LLE) combined with gas chromatography-mass spectrometry (GC-MS). There were two large wildfires in 2020 in the vicinity of the experimental vineyard, the River Fire (from 16 Aug to 4 Sept) and the Creek fire (from 4 Sept to 24 Dec 2020). In 2020, there were 14 days with an AQI >150 during the growing season, compared to an average of <1 day in the previous three years. Results indicate that smoke impact was generally low, resulting in relatively small differences in the volatile phenol composition of the grapes and wine. Further studies under more extreme conditions are needed to determine the potential impact of canopy on smoke exposure risk.

*Funding Support: The Wine Group (TWG) JASTRO & SHIELDS GRADUATE RESEARCH AWARD*

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### Synergetic Effect of Accentuated Cut Edges (ACE) and Pectinase on Marquette Wine Quality

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One of the challenges of cold-hardy wines is their low concentration of tannins and high acidity, which leads to unbalanced wines, associated with low quality red wines. In a previous study, using the accentuated cut edges (ACE) technique on Marquette grapes showed an improvement of the concentrations of phenolics and tannins compared to a control and use of macerating enzyme. We hypothesized that the combination of those two techniques would help disrupt cell wall material and therefore maximize extraction of phenolic compounds during the winemaking process. At crush, the Marquette musts were processed with ACE, followed by addition of pectinases, and were compared to a control and an ACE control without pectinases. Phenolic compounds such as tannins, anthocyanins, and other monomeric phenolics were quantified by HPLC-DAD/FLD and aroma compounds

were quantified by solid-phase microextraction gas chromatography-mass spectrometry in wines at bottling and after six months of aging. The combination of ACE and pectinase addition significantly enhanced the concentrations of flavan-3-ols, tannins, polymeric pigments, and iron-reactive total phenolics at bottling. No difference in phenolic compounds content between treatments was observed during vinification, which suggested that ACE and pectinases had a limited effect on cell wall degradation, as evidenced by scanning electron microscopy analysis, and that chemical reactions most probably occur between phenolic compounds over time. ACE and pectinases did not negatively impact the floral and fruity aroma attributes of Marquette wines at bottling. To evaluate how the combination of ACE and pectinases would help improve the quality of wines made from cold-hardy grapes, Marquette wines after aging will be sensory evaluated and compared with the chemical data.

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### Comparison Between Traditional Fining and Plant-Based Fining Agents

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Fining agents are employed in modern winemaking for different purposes: they decrease astringency, soften bitterness, reduce color, and remove substances responsible for haze formation. The particle size of these undesirable substances is not large enough to be removed by filtration and need a chemical treatment to be eliminated later by precipitation or filtration. However, some fining agents may face increasing challenge in consumer acceptability. For example, gelatin, egg whites, and casein are food allergens and are of animal origin. An increased awareness about the impact of the western diet on global warming has convinced many people to change their habits in food consumption, with a growing number of them embracing the vegan philosophy. The objective of this study was to compare traditional fining agents to plant-based agents in treatment efficacy and their impact on wine quality. A total of seven agents were tested in four wines: Albarinho, Chardonnay, Zinfandel, and Touriga nacional.

*Funding Support: California State University Fresno*

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### Chemical Effects of Intrinsic Variations in Berry Size in Fruit and Wines of Three Pinot noir Clones

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It is widely accepted that smaller berries provide better extraction of phenolic, chromatic, and aromatic compounds than large berries. This paradigm is founded upon smaller berries having a much greater solid (skins and seeds) to liquid (pulp) ratio than larger berries. To explore this notion, three different clones of Pinot noir (2A, 115, and 96), were examined over two consecutive growing seasons. At harvest, berries from each clone were manually separated into berry size classes (raisins, 8 mm, 10 mm, 12 mm, and 14 mm), crushed, and made into wine in triplicate



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## Enology and Viticulture Research Report Posters—CONTINUED

fermentations. A 15% saignée was performed on 10 mm berries of clone 115 and the subsequent juice was transferred to another vessel at a rate of 15% must. Across all three clones, 12 mm berries had more seeds/berry, skin and seed dry weights, and a significantly higher solid:liquid ratio than 8 mm berries, the latter in the case of clones 115 and 96. Eight mm berries had higher Brix, higher pH, and less malic acid content than 12 mm berries. Wines made from 8 mm berries had significantly more anthocyanins, tannins, total phenolics, and polymeric pigments than those of 10 and 12 mm berries. For example, in clone 96 a three-fold and a two-fold increase in wine tannins and polymeric pigments, respectively, was observed in 8 mm wines, relative to 12 mm wines. In clone 115, a 15% saignée and an equivalent must addition to 10 mm berries barely changed the phenolic composition of their respective wines relative to untreated 10 mm wines, suggesting phenolic extraction and retention in clone 115 is not limited, nor negatively affected, within the limits herein set, to the amount of solvent available to solubilize these phenolic classes.

*Funding Support: Oregon Wine Board Commission—Agricultural Research Institute*

### Investigation of Accelerated Red Wine Aging Using Microoxygenation in Combination with Barrel Aging

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Aging wines, especially red wines, in wood barrels improves their complexity and organoleptic characteristics. Barrel-maturated wines are enriched in aromatic compounds, the color is more stable, and mouthfeel complexity is improved. The extraction of oak phenolics has been shown to be governed by diffusion kinetics, following a curve in which the rate of extraction is initially high, decreasing as the concentration in the wine approaches that on the surface of the wood. Additionally, oxygen plays an important role in wine aging, facilitating polymerization reactions and more. Thus, the use of techniques such as microoxygenation (MOX) have become popular during red winemaking. MOX in combination with barrel aging could accelerate aging, reducing the time that wine needs to be in barrel while still obtaining the benefit of oak aromas. In this project, a red wine blend was aged in barrel and stainless steel vessels using different rates of oxygen dosing (0, 1 and 2 mg/L/month). Dissolved oxygen (DO), volatile acidity, and free and total SO2 levels were measured weekly showing that, although DO wasn't significantly different between treatments, a larger decrease in free $SO_2$ was found in those vessels with MOX treatments, with a greater decrease in the oak barrels. Acetaldehyde-adducts and phenolics were determined by RP-HPLC. Using spectral data and tasting, the 2 mg/L/month treatment was stopped after three months, while the 1 mg/L/month treatment was applied for six months. The barrel treatments without MOX continued for 12 months. Results indicate that, for the red wine blend studied, the 2 mg/L/month oxygen dose was excessive and the wine showed browning after three months of treatment. However, the six months oxygen treatment at 1 mg/L/month showed comparable aging to the barrel treatment without MOX after 12 months. Wine controls in stainless steel barrels showed the least amount of aging, but lacked the positive oak aromas.

*Funding Support: Lyon-Cisneros Family Research Fund*

## Enology and Viticulture Research Report Posters—CONTINUED

### Investigation of the Viticultural Performance of Four Petite Sirah Clones and Their Respective Wine Characteristics

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Viticulturists and winemakers use winegrape cultivar clones to achieve specific goals related to yield, quality, and desired wine characteristics. *Vitis vinifera* cv. Petite Sirah, also known as Durif, has become an important cultivar in California in the production of varietal wines and as a means to improve the color/tannic structure of red wines through blending. Four Petite Sirah clones (FPS-01, FPS-03, FPS-04, FPS-05) were monitored and evaluated to compare their viticultural and enological characteristics over the course of three growing/winemaking seasons (2019 to 2021). Eighty vines of each of the four clones were organized into four biological replicates in a randomized block design in the Robert Mondavi Institute vineyard (Davis, CA). Five vines per biological replicate were evaluated for stem water potential, canopy density, ripening chemistry, veraison progression, harvest chemistry, and cluster quality/morphology. Grape phenolic profiles were subsequently determined by RP-HPLC and the Harbertson-Adams assay. Clones were harvested at similar ripeness levels, yields determined, and winemaking performed in triplicate. Wine phenolic extraction during fermentation was monitored daily by Wine-Xray. Both phenolic and aroma profiles of final wines were determined by RP-HPLC and SPME-GC-MS, respectively. Results indicate that there is no significant difference in ripening chemistry (sugar accumulation, pH, titratable acidity, malic acid) and yield components of the clones. Grapes from clones FPS-03 and FPS-05 were more similar to each other, containing higher levels of anthocyanins and flavan-3-ols than clones FPS-01 and FPS-04. In correlation with sensory analysis, wines made from each clone also showed differences in the composition of volatile compounds. Therefore, the wines from the four Petite Sirah clones showed differences in both chemical and sensory composition

*Funding Support: Bogle Family Fund, Knights of the Vine, Rossi Graduate Scholarship*



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## Enology and Viticulture Research Report Posters—CONTINUED

### How Using Whole Clusters Impact Red Wine Quality

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Wines made from Marquette and Frontenac grapes are relatively low in tannins, the phenolic compounds responsible for astringency mouthfeel and ageability of red wines. In this study, the effect of adding whole clusters (WC) at 25 or 50% as a prefermentative technique was evaluated for basic wine chemistry and phenolic compounds content. Two grape cultivars, Marquette from Iowa and Minnesota and Frontenac, were processed following the same winemaking procedure in 2021. The basic chemistry, including organic acid and alcohol content, were evaluated throughout the process using HPLC-DAD/RID. Total iron-reactive phenolic compounds content and color intensity and hue were evaluated by UV-vis spectrophotometry and tannins content was quantified by HPLC-DAD/FLD. The percentage of alcohol in finished wines was not affected by the use of whole clusters, but was greater in Marquette wines from Minnesota and Frontenac wines than Marquette wines from Iowa. Addition of 50% WC led to significant increases in total phenolics and tannins content in all wines at bottling compared to control. However, the content of tannins was lowest in Marquette wines from Iowa and highest in Marquette wines from Minnesota. Aroma profile of wines made under the different conditions will be determined and the benefits of the WC addition on wine quality will be evaluated.

*Funding Support: Midwest Grape and Wine Industry Institute*

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### Isolation and Characterization of Polysaccharides from Grape and Yeast and their Interaction with Wine Volatile Compounds

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Organoleptic properties are an important factor in wine quality. The polysaccharides from winegrapes and *Saccharomyces cerevisiae* yeast could be important in wine characteristics. Elucidation of structural information of grape and yeast polysaccharides is necessary to understand their interaction with other wine components and organoleptic contribution to wine quality. In this study, polysaccharide extracts from Pinot noir grapes and *S. cerevisiae* were purified on a DEAE Sephacel column (5.5 cm  60 cm). After the samples were loaded on the column, the polysaccharides were sequentially eluted with 1.2 L aqueous NaCl solution (0, 0.1, 0.3, and 0.5 M) at a flow rate of 5 mL/min. The eluents were saved with a fraction collector. The polysaccharide in each tube was analyzed with the phenol-sulfuric acid method. Subsequently, the different polysaccharide fractions were obtained and concentrated by ultrafiltration with a molecular weight cut-off of 2 kDa. The purified polysaccharides were characterized by size exclusion chromatography, by ultraviolet-visible spectroscopy with a scanning range of 190 to 600 nm, and by attenuated total reflection-Fourier transform infrared spectroscopy in the wavelength range of 400 to 4000 $cm^{-1}$. The nucleic acid and protein (characteristic absorption peaks at 260 nm and 280 nm) in purified polysaccharides

were minimal. ATR-FT-IR spectroscopy showed different structural features of polysaccharides. Moreover, the interactions between wine volatile compounds and polysaccharides were studied.

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### Comparison of Hyperspectral Data and Photosynthetic Pigments of Cold-Hardy Grapes Growing on Different Training Systems

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Training systems influence the microclimate of grapevines in the vineyard, which can affect overall plant health and productivity. Spectral data obtained through remote sensing techniques can provide information regarding plant health. In 2019, we conducted a study in an experimental vineyard at the University of New Hampshire (Woodman Research Farm, Durham, NH) to compare the leaf spectral signatures of grapevines growing on two different training systems, vertical shoot-positioning and Munson. Two cold-hardy seedless table grape varieties, Canadice and Mars, were followed throughout the growing season. Leaf samples were collected weekly, from flowering to harvest, to generate hyperspectral curves using an analytical spectral device. The spectral data were used to calculate the following indices: Normalized difference vegetation index (NDVI), red edge inflection point (REIP), and moisture stress index (MSI). The same leaf samples were used to determine pigment content (chlorophyll a, chlorophyll b, and carotenoids). The vegetative indices NDVI and REIP correlated strongly with leaf chlorophyll a and b contents in both varieties. Concentrations of chlorophyll and carotenoids can vary when plants respond to stress, and sometimes additional pigments can build up within the leaves. These variations can appear as subtle spectral changes in the visible and red-edge regions of the spectral curves. We found decreased chlorophylls, which correlated well with the vegetative indices values and is likely related to reduced net photosynthesis and growth responses when grapevines were approaching the end of the growing season. The indices and pigment content of the grapevine leaves varied significantly across time (from start to end of the growing season), but were not significantly different among the two training systems.

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## Enology and Viticulture Research Report Posters—CONTINUED

### Widening the Curtain: Can Productivity of Pinot noir be Enhanced by Opening the Top of a Traditional VSP Trellis

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The primary goal of this work was to assess whether a wider vertical shoot-positioned (VSP) trellis achieved by using cross arms can improve yield without compromising quality for Pinot noir grown in a cool region. A second goal was to understand how vine density influences the response to a wider trellis. These questions are being examined in a 2 2 2 factorial vineyard experiment with the following factors: a wide versus narrow VSP trellis; a high versus low in-row vine density; and a low versus high crop load. The vineyard was planted in 2015 (clone 115, 101-14 rootstock) and was irrigated and fertilized to avoid stress during establishment. By 2019, vines were only irrigated in late summer when leaf water potential fell below -1.3 MPa. The crop level treatment was first implemented in 2021 by cluster thinning. Vines grown on the wider VSP trellis intercepted more sunlight near midday and produced larger canopies than vines grown on the narrow VSP in 2021. Leaf area and pruning weights were both 12% greater in the wide VSP vines, although sunlight interception increased by only 7%. Greater pruning weights were also recorded in the wide VSP vines in 2019 and 2020. High-density vines also had greater pruning weights in the prior two years, but this effect was lost in 2021. Leaf water potential was lower in the wide VSP vines on a single measurement day in 2021, but soil moisture was not altered by any treatment. Yield was only altered by the crop load treatment imposed, with nonthinned vines producing 40% more fruit. Soluble solids were reduced slightly in these high-crop vines, but pH and titratable acids were not affected. It will be interesting to see how these factors influence productivity and fruit composition in future years.

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### Solute Accumulation in Grapevine: Winegrape Cultivars Vary Widely in Osmotic Adjustment and Solute Chemistry

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Water-stressed grapevines accumulate solutes in their leaf cells to decrease osmotic potential (i.e., osmotically adjust) and reduce leaf vulnerability to wilting and stomatal closure. The magnitude of osmotic adjustment and types of solutes accumulated varies widely across other plant species and has not been characterized in many grape cultivars. Determining cultivar-specific osmotic adjustment performance could provide insights into stress tolerance and viticultural solutions under continually drier climate conditions. We examined whether cultivars from climatically diverse wine regions vary in osmotic adjustment and leaf biochemistry under hot growing conditions. We compared seven commercially important cultivars from different climate regions (i.e., cool: Riesling and Pinot noir; warm: Chardonnay, Merlot, and Syrah; and hot: Zinfandel and Sangiovese) grafted onto 420A and established in the same experimental vineyard block in a hot region (Davis, California). We measured changes in leaf osmotic potential at full hydration ($\pi_o$) and the concentration of major leaf cell solutes (i.e., the sugars glucose, sucrose, and fructose and cations K, Na, Ca, and Mg) from veraison to harvest (monthly from July to Sept) using HPLC and ICP analysis. For all cultivars, $\pi_o$ significantly decreased

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over the season. All of the sugar and ion concentrations, except for Na, increased significantly over the season, and all mean concentrations, except for Na and the total ion concentration, were significantly different across cultivars. Interestingly, significant differences in $\pi_o$ and solute concentrations between cultivars were not explained by their optimal climate. Together, these findings indicate cultivar variation is a driver of the types of solutes formed in response to osmotic adjustment. A better understanding of the processes plants use to mitigate water stress at the leaf level will improve breeding programs developing more drought-tolerant cultivars.

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### Different Soil Types Modulate Pinot noir Vine Growth and Fruit Composition in Oregon's Willamette Valley

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There is increasing concern about vineyard water management given climate variability and recent widespread drought in the American West. Traditionally, growers in Oregon's Willamette Valley could produce winegrapes without irrigation due to sufficient annual rainfall and soils with high water-holding capacity. Since the majority of vineyards in this region are dry-farmed, understanding soil water availability and vine response is imperative when making early season management decisions, such as vineyard floor management practices. A multi-year observational study was conducted to understand seasonal vine growth response to soil water content, with a focus on summer, when rainfall is minimal. The research was conducted in a Pinot noir vineyard with soils from sedimentary, volcanic, and glacial flood parent materials. Vineyard blocks were uniform in rootstock, age, vine spacing, training system, and management. Soil moisture was monitored continuously throughout the year undervine and between rows at 46 cm and 91 cm soil depths at two monitoring locations within each soil type. Soil type primarily impacted vine vegetative growth and productivity, with vines in the glacial soil having the greatest dormant pruning weights, vine leaf area, and tissue nitrogen status. This soil type also produced greater yields and cluster weights. Vines in the other two soil types had greater vine water stress, as measured with leaf water potential, smaller canopy sizes, and more advanced ripeness at harvest. Interestingly, soil moisture undervine was reduced in the glacial soils, yet the canopies grew larger, suggesting the soil profile was deeper, thereby facilitating deeper vine rooting, or that the vines used up more water in the upper soil profile due to greater water demand. This project provides important information on vine response to soil moisture dynamics that may assist future vineyard management decision-making

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### Impact of Cluster-Thinning Timing and Severity on Winegrape Yield and Quality: A Meta-Analysis of 50 Years of Research

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To attain high-quality fruit, winegrape producers utilize management practices to achieve a balance between vegetative and reproductive growth (leaf area-to-yield ratio [LAY]). A commonly used strategy to obtain a balanced ratio is cluster thinning (CT). This practice has been researched extensively over the past 50 years; however, no consensus has been established regarding the influence of CT timing and severity on fruit quality. The main objectives of this work were to understand whether CT timing (bloom [B], pea-size [PS], lag phase [LP], or veraison [V]) or severity (low [15 to 35%], moderate [36 to 55%] or high [56 to 75%]) influences vine performance and fruit quality. We surveyed 160 publications on CT in *vinifera* winegrapes and subsequently reduced this pool to 78 studies via 10 data curation steps. We reported the influence of CT timing and severity on production (vine yield, LAY, berry weight) and quality (total soluble solids [TSS], pH, titratable acidity, total anthocyanins, total phenolics) parameters. We also specifically evaluated whether CT timing or severity altered the tradeoff between the decrease in yield and the subsequent increase in TSS. Regardless of timing or severity, CT significantly enhanced the LAY, TSS, and pH, while reducing yield. CT timing showed little influence on quality parameters, although the tradeoff between yield reduction and the increase in TSS was slightly more efficient when applied later in the season (LP and V) than early (B and PS). Moreover, CT severity affected TSS; only the moderate range (36 to 55%) increased this parameter. Interestingly, cultivar greatly influenced the capacity of CT to increase fruit quality, while climate (growing degree days, precipitation) during the experimental season did not. Winegrape quality was more influenced by CT severity than timing. This work has important implications for grape producers and their approach to improving grape quality.

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