

Technical Abstracts

Joint 77th ASEV National Conference & 50th ASEV-ES Annual Conference



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Wednesday.....	2-8
Enology – Low Alcohol and Malolactic Fermentation	2
Viticulture – Understanding and Managing Water Stress	2-3
Enology – Non- <i>Saccharomyces</i> Yeasts in Fermentation	3-5
Viticulture – Vineyard Soil Health	5-6
Enology – Smoke Exposure in Grapes and Wine	6-7
Viticulture – Advances in Pest Management.....	7-8

Thursday	8-14
Enology – Oak and Non-Traditional Woods in Alcoholic Beverage Production	8
Viticulture – Breeding & Cultivar Evaluation	9-10
Viticulture – Improved Understanding of Grapevine Nutrients and their Management.....	10-11
Enology – General Winemaking	11-12
Enology – Enological Method Development	12-13
Viticulture – Professional Development for Viticulturists.....	13-14

Wednesday and Thursday	15-35
Enology and Viticulture Research Report Posters.....	15

Presenter Index

Adeniyi, A.....	15	Maioli, F.....	6
Apud, RG.....	15	Makowski, AJ.....	25
Aragon, M.....	9, 15	Mandler, B.....	25
Ball, R.....	12	Mannino, NC.....	2
Bastow, B.....	15	Martin, V.....	4
Bean, Z.....	2	Martinson, T.....	26
Bhattarai, A.....	16	Menendez, D.....	26
Bondada, B.....	16	Montague, T.....	26
Botezatu, A.....	9	Morgenthaler, J.....	26
Caldwell, D.....	16	Moyer, M.....	8, 27
Cataldo, E.....	5	Mullin, B.....	27
Centinari, M.....	5	Nasrollahiazar, E.....	28
Cheng, Y.....	17	Neubauer, J.....	8
Ciccone, R.....	17	Nguyen, TH.....	28
Cooper, P.....	17	Obiero, C.....	2
Copp, C.....	7, 18	Onetto, C.....	28
Davadant, P.....	10	Pargellis, A.....	29
Delavar, H.....	10	Partida, G.....	30
De Quay, C.....	19	Peng, H.....	30
Dietsch, B.....	19	Peterson, W.....	30
Diverres, G.....	19	Phillips Russo, J.....	30
Drop, C.....	4, 19, 20	Pizzinato, D.....	31
du Preez, B.....	20	Poojari, S.....	31
Dyer, D.....	21	Preciado, J.....	31, 32
Eaton, H.....	2	Previtali, P.....	32
Fleming, A.....	4, 11, 21	Richards, G.....	33
Gautam, S.....	21	Rollero, S.....	3
Ghmire, B.....	21	Rowles, T.....	6
Gold, K.....	8	Sartori, C.....	33
Goodman, S.....	22	Scott, Z.....	12
Harner, A.....	10, 22	Singh, S.....	33
Hatterman-Valenti.....	22	Slayden, J.....	33
Heinemann, L.....	3	Smith, J.....	33
Herrera, A.....	5, 24	Sommer, S.....	34
Hervé, M.....	24	Strid, L.....	34
Hibbard, R.....	24	Thrall, J.....	6
Hilland, J.....	6	Threlfall, R.....	9
Hobbs, M.....	14	Tian, T.....	7
Kaur, N.....	11	Ting, J.....	34
Keller, M.....	24	Tomasino, E.....	35
Kelly, J.....	24	Trivedi, MB.....	35
Lagarde G.....	7	WatreLOT, AA.....	11
Liang, C.....	24	Wendrick, N.....	12
Lilly, GE.....	24	Wilwerth, J.....	10
Lin, Y.....	13	Williams.....	13
Luke, M.....	13	Wright, J.....	36
Maccario, J.....	25	Zhai, Y.....	36
		Zhuang, S.....	3

Enology – Low Alcohol and Malolactic Fermentation Session (research reports)

Optimizing Production Methods for Low-Alcohol Wine Using Fungus-Resistant Grape Varieties and Ontario Yeast Strains

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Recent shifts in alcohol consumption trends have led to increased demand for low- and non-alcoholic beverages. In Ontario, Canada, consumers are seeking wines that are lighter, fruitier, and lower alcohol. In this study, we investigated different methods to reduce alcohol in wine, with focus on grape variety selection, use of indigenous yeast strains for fermentation, and using reverse osmosis postfermentation. Sustainable fungus-resistant grape varieties have recently been introduced to Ontario with favorable properties, including potential for producing high quality wines with reduced alcohol. Preharvest ripening data collected during the 2025 season for Sauvignon Rytos, Soreli, and Cabernet Volos indicated ripening patterns distinct from typical *Vitis vinifera* benchmarks, suggesting potential for achieving balanced maturity at lower sugar accumulation. Notably, Cabernet Volos was harvested at 11.4% potential alcohol, compared with 13.7% potential alcohol for Cabernet franc harvested from the same vineyard. Building on prior work with locally isolated Ontario yeast, musts from Soreli (white) and Cabernet Volos (red) were fermented using either a commercial *Saccharomyces cerevisiae* strain (control) or the local *Saccharomyces uvarum* strain CS-6, which has been associated with lower ethanol production. Across all fermentations, wines produced with CS-6 had significantly lower ethanol content compared to the control wines, with an average reduction of 0.5%. In addition, wines fermented with *S. uvarum* had higher glycerol content and generally trended towards reduced acetic acid production. To further explore methods for lowering alcohol content in wine, trials have been conducted using reverse osmosis postfermentation to selectively remove ethanol. This technology successfully reduced ethanol to target final concentrations, with measurable impacts on selected wine parameters (including acidity). Collectively, these results demonstrate a practical framework for producing lower-alcohol wines by combining variety selection, regionally derived yeast, and postfermentation dealcoholization.

Funding Support: Ontario Research Fund - Research Excellence

Screening Fermentation Parameters of Commercial Non-Saccharomyces Yeast for Wine Production with Reduced Ethanol

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With the consumption of no- and low-alcohol wines increasing worldwide, there is potential for using non-*Saccharomyces* yeast (NSY) to reduce ethanol through alternate metabolic pathways during wine production. Six commercial yeast strains (one *Saccharomyces* and five NSY), two aeration methods (none and air), and two replications were screened for reduced ethanol levels during Vignoles (*Vitis* hybrid) wine production. Five commercial strains of NSY, including three *Metschnikowia pulcherrima* (MP1, MP2, and MP3), one *Metschnikowia fructicola* (MF), and one *Pichia kluyveri* (PK), were compared to *Saccharomyces cerevisiae* (SC) as a control. Aeration occurred in the first 48 hr of fermentation for treatments with air (SC+Air, MP1+Air, MP2+Air, MP3+Air, MF+Air, and PK+Air). The NSY treatments were sequentially inoculated with SC 48 hr after NSY inoculation. Samples of juice/must were taken during fermentation at 21°C (0, 3, 6, 9, and 12 days) for analysis of organic acids, sugars, glycerol, and ethanol using high-performance liquid chromatography. On day 0, total sugars of the juice were

19.42%. All treatments completed fermentation (total sugars <0.3%) by day 10, with SC and SC+Air treatments completing fermentation prior to NSY treatments. At day 12, ethanol ranged from 10.84 to 11.38%, with SC and SC+Air treatments producing 11.14% and 10.96% ethanol, respectively, while PK (11.38%) and PK+Air (11.28%) had highest ethanol and MP2+Air (10.84%) had the lowest. In addition, at day 12, air reduced ethanol production for all MP strains. Fermentation treatments with less ethanol than SC at day 12 included SC+Air (-0.18%), MP1+Air (-0.21%), MP2+Air (-0.30%), MP3+Air (-0.21%), MF (-0.01%), and MF+Air (-0.15%). The NSY strains with the greatest ethanol reduction in this study (MP1, MP2, MP3, and MF) will be evaluated for larger scale wine production using United States native and hybrid grapes.

Funding Support: none

Managing Malolactic Fermentation to Drive Changes in Pinot noir Wine Characteristics

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Malolactic fermentation (MLF) is a key step in producing cool-climate red wines such as Pinot noir. While deacidification is the primary purpose of MLF, the process also alters wine aroma, flavor, and mouthfeel and is influenced by several factors. This study evaluated the combined effects of ML strain, MLF timing, and prefermentation nutrient additions on the fermentation kinetics, chemical composition, and sensory characteristics of Oregon Pinot noir wine produced in 2024 and 2025. In both years, MLF timing influenced MLF kinetics, tannin content, and color development. Compared with co-inoculation, sequential MLF inoculation consistently increased polymeric pigment formation at the end of MLF and after aging. Differences in protein-precipitable tannin were observed after MLF for ML strain and MLF timing treatments. However, these differences were no longer present after aging. Hunter Lab L*, a*, and b* color values differed at the end of MLF across all treatments, and these shifts continued during aging. Wines were assessed for volatile aroma composition using headspace solid-phase microextraction coupled to gas chromatography-tandem mass spectrometry. Wine aroma composition differed significantly as a function of MLF timing, strain, and vintage. Despite analytical differences, trained consumer sensory evaluation of 2024 wines showed limited discrimination among treatments, suggesting that subtle fermentation-driven aroma differences may fall below the resolution of trained consumer panels. Ongoing work compares volatile aroma data with results from an expert winemaker sensory panel to assess whether professional tasting expertise provides greater sensitivity to aroma variation linked to MLF management. Collectively, the results demonstrate that altering MLF timing and ML strain can affect Pinot noir wine properties. Understanding these effects could help winemakers optimize MLF management to achieve desired wine styles.

Funding Support: Oregon Wine Board #2024-2870

Viticulture – Understanding and Managing Water Stress Session (research reports)

Extreme Drought Causes Persistent Impacts on Vine Growth and Productivity After Renewed Irrigation

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As weather extremes intensify, grapegrowers in the western United States and other dry regions face increasingly difficult decisions during prolonged droughts, including whether to replant vines

after repeated stress or reduce crop load in hopes of supporting vine recovery. In 2025, we assessed shoot growth, yield, and fruit composition in field-grown Cabernet Sauvignon and Riesling vines that had been exposed to three consecutive years (2022 to 2024) of drought stress in the arid Yakima Valley of Washington. Stress was imposed annually by suspending irrigation from either fruit set or veraison (no irrigation until postharvest), combined with 0, 50, or 100% fruit removal. Relative to the regulated deficit irrigation control, early-season shoot length in 2025 declined by one-third in Cabernet Sauvignon and by one-quarter in Riesling following drought initiated at fruit set in the preceding 3 yr. Fruit removal during the drought years enhanced subsequent shoot growth only in Riesling. In Cabernet Sauvignon, up to 10% cordon dieback occurred in vines previously stressed from fruit set, and fruit removal did not reduce this damage. Relative to the control, yield during the recovery year declined by 50 to 60% in vines previously stressed from fruit set, and by 34 to 38% in those stressed from veraison, when no fruit had been removed. In Riesling, but not in Cabernet Sauvignon, 100% fruit removal with drought starting at fruit set in previous years alleviated yield losses during the recovery year. Unlike with drought from fruit set, 50% fruit removal with drought starting at veraison alleviated subsequent yield losses in both cultivars. Fruit composition remained largely unaltered by the previous 3-yr drought stress and fruit removal. These results demonstrate that extreme drought imposes persistent constraints on vine growth and productivity, and recovery is slow and incomplete, necessitating multiyear management strategies, such as severe pruning, to renew cordons.

Funding Support: the USDA Northwest Center for Small Fruits Research, USDA National Institute of Food and Agriculture, the Washington State Grape and Wine Research Program, and Chateau Ste. Michelle Distinguished Professorship

Rootstocks Reduce Viticultural and Enological Impacts of Severe Early-Season Drought in Sauvignon blanc

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Viticulture has historically depended on relatively stable climate patterns to support consistent grape and wine quality. However, ongoing shifts in weather patterns threaten many established winegrowing regions, including California's Central Coast. More frequent and severe drought is posing a significant challenge to the region's grape and wine industry. Drought negatively affects grapevine growth and vigor, reduces vine water status and photosynthesis, and lowers yield, berry composition, and wine quality. While grapevines generally tolerate water stress postveraison, early-season stress can severely limit canopy and root development, reduce berry size, and decrease bud fruitfulness, resulting in long-term declines in vine productivity. As severe drought events become more frequent, identifying drought-tolerant plant material is essential to maintain vineyard health and sustain wine quality in California's minimally irrigated regions. Traditionally bred for resistance to Phylloxera and nematodes, grapevine rootstocks can serve as a long-term solution to drought, given that vineyards are typically managed for 25 to 30 yr and deliver sustained economic benefits. To evaluate this potential, we conducted a field trial at a commercially managed block in Cal Poly's research vineyard. In this randomized field trial, we tested the effects of three irrigation regimes: 80% ET_c over the course of the season (sustained deficit irrigation), 0% ET_c prebloom followed by 80% ET_c postbloom (prebloom deficit), and 0% ET_c preveraison followed by 80% ET_c postveraison (preveraison deficit) on viticultural and enological properties of Sauvignon blanc grapevines grafted onto six rootstocks (101-14, 1103P, 110R, 1616C, 420A, and 5C). Rootstocks significantly influenced bloom date, vine physiology, yield, and berry composition under early-season water-deficit conditions. Additionally, rootstocks influenced the volatile and phenolic composition of resulting wines. These findings

highlight the role of rootstocks in mitigating seasonal drought stress and provide valuable insights for long-term rootstock selection tailored to regional growing conditions and winemaking objectives.

Funding Support: This research was supported by the California State University Agricultural Research Initiative. Additional funding for student involvement during the summer was provided by Joe and Florence Silva and the CSU Summer Undergraduate Research Program.

Rootstock Selection for Drought and Boron Tolerance in the San Joaquin Valley of California

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Rootstock selection is critical when vineyard replanting decisions are made, particularly under increasing boron (B) toxicity and water limitation in the San Joaquin Valley of California. Two scions (Barbera and Colombard) grafted onto five rootstocks were planted in 2021 to evaluate B tolerance and drought response. Freedom, RS-3, 140 Ruggeri, and 1103 Paulsen were compared with own-rooted vines under elevated irrigation water B (>1 ppm) and deficit irrigation conditions imposed in 2024 and 2025. The experiment was arranged as a two-way factorial split-block design with five rootstocks, two irrigation levels, replicated four times, with three vines per experimental unit. Two deficit irrigation treatments (40% and 80% ET_c) were applied from fruit set to harvest in both seasons. Own-rooted vines exhibited the lowest B uptake in bloom leaf blades, while Freedom consistently had the second-lowest B uptake for both cultivars. Water deficit increased veraison leaf blade B concentrations in both Barbera and Colombard. No significant differences in leaf gas exchange or midday leaf water potential were found among rootstocks; however, both parameters were significantly reduced under water deficit. Yield per vine was reduced by water deficit due to decreased berry size, while rootstock did not significantly affect yield. Among the rootstocks evaluated, Freedom showed the greatest yield potential while maintaining relatively low B uptake and produced fruit with higher juice pH and lower titratable acidity at harvest.

Funding Support: California Grape Rootstock Commission

Enology - Non-Saccharomyces Yeasts in Fermentation Session (research reports)

Innovative Applications in Winemaking: Yeast Derivatives as Functional Lipid Sources

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Climate change brings multiple challenges to the wine industry, including higher sugar/alcohol content, lower acidity, and imbalances in yeast nutrients. Winemaking practices such as low-temperature fermentations and excessive clarification of white grape to produce fruitier wines in response to consumer demand may create conditions leading to sluggish or stuck fermentations. These challenging conditions can be overcome by *Saccharomyces cerevisiae* by enriching its membrane composition in fatty acids and ergosterol. However, in the absence of oxygen, the yeast cannot produce the necessary lipids and therefore relies on those occurring in grape must or by supplementation. Until recently, only products derived from *S. cerevisiae* have been permitted, which limits the scope of use and the efficacy of these products. Recent changes allowing use of non-*Saccharomyces* yeasts offers an opportunity to tap into their composition diversity (Mbuyane 2021). In this work, a wide selection of non-*Saccharomyces* yeasts isolated

from the broader wine environment were screened for their lipid content. Six strains were selected based on the quantity and diversity of lipids produced. In the next step, inactivated dry yeasts were produced from these innovative yeasts and tested as lipid supplements in over-clarified Chenin blanc juice. The addition of inactivated yeasts enhanced fermentation performance compared to the reintroduction of fine lees and the control with no addition. Furthermore, experiments with addition of pure analytical standard lipids in the same concentrations yielded similar results, correlating the change in fermentation kinetics to the lipid additions. Overall, the data showed that novelty derivatives from diverse yeasts may serve as a sustainable improved source of nutrient for fermentation under challenging conditions. The work also paves the way for further research on the selection, optimal production, and use of new lipid rich yeast derivatives for wine fermentations. Mbuyane: DOI: 10.1016/j.foodres.2021.110142

Funding Support: 1. Fermentis by Lesaffre, 90 rue de Lille, 59520 Marquette-Lez-Lille, France 2. South African Grape and Wine Research Institute, Stellenbosch University, Private bag X1, Matieland, 7602, South Africa

Fast Yeast Lysis in *Hanseniaspora vineae*: Increasing White Wine Complexity and Mouthfeel in Days Instead of Months

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Yeast-derived compounds released during lees contact play a central role in wine mouthfeel, stability, and aroma development, but conventional autolysis of *Saccharomyces cerevisiae* typically requires several months under barrel, tank, or bottle aging conditions. We evaluated the lysis behavior of the non-*Saccharomyces* yeast *Hanseniaspora vineae* during white wine fermentations and compared it with commercial *Saccharomyces* strains under identical conditions. The objective was to determine whether species-dependent differences in cell stability can significantly modify the timing of intracellular compound release and therefore affect wine texture and sensory development. Flow cytometry confirmed that fermentations conducted in model grape medium and Chardonnay must showed that *H. vineae* undergoes rapid loss of membrane integrity, accumulation of reactive oxygen species (ROS), and cell lysis within days at the end of alcoholic fermentation, while *S. cerevisiae* maintains cell integrity and delays autolysis for months. Interestingly, it was confirmed that this fast lysis phenotype is species-specific and is not observed in *Hanseniaspora uvarum*. Further genomic studies may explain this characteristic of some *Hanseniaspora* species. Rapid cell breakdown in *H. vineae* fermentations was associated with earlier release of polysaccharides and mannoprotein-rich material, as well as medium chain fatty acids, amino acids, short peptides, and nucleic acid derivatives into the wine matrix. From an enological perspective, this accelerated release pattern enhanced mouthfeel, palate volume, and aromatic complexity in a significantly shorter timeframe, potentially reducing the need for prolonged lees aging and extended barrel or bottle storage. This approach may help lower production time and cost while reducing risks associated with over-aging or excessive oak impact. The effect is relevant not only for premium white varieties such as Chardonnay, Viognier, Chenin blanc, Albarrío, and Albillo, but also for large-volume tank-fermented wines including Glera, Trebbiano, Macabeo, and Airén, where faster development of lees-derived attributes can provide technological and economic advantages.

Funding Support: Agencia Nacional de Investigación e Innovación ANII Universidad de la Republica, Uruguay Lage y Cia S.A., Uruguay Oenobrand, France

Assessing Aroma of Chambourcin Wines Produced with Different Strains of *Lachancea thermotolerans* Yeast

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Using non-*Saccharomyces* yeasts can enhance wine quality and complexity. *Lachancea thermotolerans* (LT) aids in pH reduction during fermentation and can improve a wine's aroma profile. In 2024, 263 kg of Arkansas-grown Chambourcin (*Vitis* hybrid) grapes were hand-harvested, randomized into batches, processed, and fermented. Seven inoculation treatments, in duplicate, were conducted using *Saccharomyces cerevisiae* (SC) and three LT strains, including a commercial strain (Laktia™) and two experimental strains (LT1 and LT2), receiving sequential SC inoculations after 24 or 48 hr. All treatments were co-inoculated with malolactic bacteria 24 hr after inoculation with SC. Volatile compounds were analyzed at bottling via solid phase microextraction-gas chromatography-mass spectrometry (SPME-GC-MS). There were 86 volatile compounds identified, comprised of esters (29), higher alcohols (21), acids (10), aldehydes (10), ketones (10), terpenes (2), acetals (1), glycols (1), lactones (1), and sulfides (1). Total volatiles ranged from 45,401 ug/L (Laktia-SC-24 hr) to 77,641 ug/L (LT1-SC-24 hr). LT1-SC-24 hr wines had the highest total volatile concentrations compared to other treatments. All treatments were dominated by esters and higher alcohols; however, LT wines showed higher total esters and alcohol concentrations at 24 hr compared to 48 hr sequential inoculation. Principal component analysis indicated that SC wines were associated with fruity, tropical, herbal, green, and fermentation-related esters and higher alcohols. Laktia wines, regardless of inoculation timing, were linked to higher alcohols, esters, terpenes, and aldehydes contributing floral, citrus, and green aromas. LT1-SC-24 hr and LT2-SC-24 hr wines were associated with esters and higher alcohols, while LT1-SC-48 hr was dominated by esters and ketones and LT2-SC-48 hr by higher alcohols. Overall, LT fermentations shifted aromatic composition and increased potential complexity compared to *S. cerevisiae*-only wines, with sequential inoculation timing playing a key role within each strain.

Funding Support: Lallemand Enology

Effects of Skin Contact and Acid Management Strategies on Grüner Veltliner Wines from the Central Coast of California

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Grüner Veltliner wines from the Central Coast of California were produced under three treatments in addition to a control: skin contact, fermentation with the lactic acid-producing *Lachancea thermotolerans* (Omega strain), and ion exchange (IE) treatment of juice followed by blending at a 30% proportion before alcoholic fermentation (AF). Control and skin contact had similar average oxidation-reduction potentials during AF (-82 and -81 mV, respectively). Compared to the control, skin contact increased pH by 0.11 units and decreased titratable acidity (TA) by 0.71 g/L, while also increasing total phenolics by 324%, potassium by 12.2%, and hue. *Lachancea* produced 4.75 g/L of lactic acid and was most effective at increasing TA (11.07 g/L versus 6.87 g/L in the control). *Lachancea* wines had the highest odor activity values for ethyl butyrate, isoamyl acetate, and hexyl acetate (38, 82, and 92% more than the control). Skin contact wines had the highest ethyl cinnamate (1092% higher than the control), while *Lachancea* and 30% IE juice wines increased trans-nerolidol by 26% and 22%, and geraniol by 62% and 71%, respectively, compared to the control. The 30% IE juice wines decreased potassium by 9% compared to the control and were most effective at lowering pH, reducing it by 0.32 units. 30% IE juice wines had higher tartaric acid concentrations

(4.06 g/L versus 2.68 g/L in the control), indicating improved tartrate stability. In contrast, skin contact wines had less tartaric acid (2.14 g/L), likely due to higher potassium concentrations. Pivot profile sensory analysis showed that skin contact wines had more bitterness and resinous aromas, *Lachancea* wines had the highest overall aroma intensity with more banana and citrus aromas, and 30% IE juice wines had the most perceived acidity and apple aroma.

Funding Support: Ryan Scott Williams (Monterey Pacific Vineyards) and Treasury Wine Estates (St. Helena, California, USA) are thanked for their donation of fruit and logistical support, respectively.

Viticulture – Vineyard Soil Health Session (research reports)

Clinoptilolite-Enriched Soil Amendments Improve Vine Water Status and Phenolic Balance under Warm and Dry Conditions

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Climate change is increasingly challenging viticulture by intensifying heat waves and water deficits, which often leads to unbalanced ripening and reduced phenolic quality in red cultivars. In Sangiovese, excessive exposure to high temperature and radiation may also enhance flavonol accumulation, including quercetin derivatives, potentially affecting wine stability. Sustainable soil management strategies based on circular economy principles may help mitigate these constraints while valorizing winery by-products. A 2-yr field experiment was conducted in a Sangiovese vineyard in central Italy to assess the effects of innovative soil amendments on vine ecophysiology and berry composition. Three soil treatments were compared: a new land conditioner obtained from composted winery residues enriched with clinoptilolite (ZW; 30 t/ha); natural zeolite (Z; 10 t/ha); and organic compost (C; 20 t/ha). Seasonal measurements included single-leaf gas exchange, midday stem water potential, leaf temperature, chlorophyll fluorescence, and extrinsic water-use efficiency. At key ripening stages and at harvest, yield components, technological maturity, yeast assimilable nitrogen, and detailed phenolic profiling (anthocyanins, hydroxycinnamic acids, flavonols, and quercetin derivatives) were determined. Across both seasons, ZW and Z improved vine physiological performance more than compost, showing higher photosynthesis, less negative water potential, lower leaf temperature, and higher photochemical efficiency. These physiological benefits were associated with enhanced berry phenolic quality, including increased anthocyanin accumulation and reduced accumulation of quercetin derivatives. Compost-treated vines generally exhibited lower performance and higher quercetin levels during ripening and at harvest. By-product compost with clinoptilolite-based soil management represents a promising, climate-resilient strategy to improve vine water relations and phenolic balance in Sangiovese, while supporting circular approaches through the recovery of winery wastes.

Funding Support: No funding

Long-Term Under-Vine Grass Cover Alters Root-Soil-Microbe Interactions Without Persistent Root Avoidance

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Increased plant diversity through vineyard floor management is widely promoted to enhance soil health and agroecosystem resilience, yet concerns persist regarding belowground competition between grapevines and under-vine cover crops. In eastern North American vineyards, perennial grasses such as creeping red fescue

(*Festuca rubra*) are used or considered as under-vine management options to moderate vegetative growth and reduce reliance on herbicides; however, their long-term effects on grapevine root systems and root-associated microbial communities remain poorly understood. We synthesized results from a series of multiyear field studies conducted in a high-resource vineyard in Pennsylvania to evaluate belowground responses to long-term (>9 yr) under-vine grass cover. Using complementary approaches—including soil coring, deep root observation boxes, and root interaction assays—we assessed grapevine root distribution and morphology, soil resource availability, and rhizosphere microbial composition, with particular emphasis on soil depth and nutrient context. Across years, under-vine grass altered soil resource dynamics and microbial community composition in a depth-dependent manner, with stronger responses in fungal communities and minimal effects on overall microbial diversity. These microbiome shifts were most pronounced in shallow soils and under nutrient-limited conditions. In contrast to earlier observations in younger vineyards, long-term grass adoption did not result in persistent shallow root avoidance or reductions in fine root length density or root diameter, suggesting functional acclimation of grapevine root systems over time. Together, these findings indicate that long-term under-vine grass cover can influence belowground ecological processes without imposing sustained belowground stress on mature grapevines in high-resource systems. This integrative perspective provides a foundation for region-specific vineyard floor management recommendations that balance vine growth control with long-term soil health.

Funding Support: USDA-NIFA; Pennsylvania Department of Agriculture (Wine Marketing and Research Board)

Soil Hydraulic and Thermal Responses to Combined Regenerative Management Practices in a Commercial Sonoma Vineyard

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Regenerative practices such as reduced tillage, organic amendments, and managed grazing are promoted in vineyards for their potential to support soil health and drought resilience. Yet, the effects of these practices on soil water dynamics in commercial settings are not well understood. To address this gap, we are monitoring soil hydrology in a field experiment in Sonoma County, CA, where cover cropping is used across all management systems. The study compares one conventional treatment with alternate-row tillage (CT) and two regenerative treatments that combine compost and sheep grazing: one managed as no-till (RN) and the other with alternate-row tillage (RT). Since spring 2023, hourly soil moisture and temperature at 30, 60, and 90 cm in both vine and tractor rows have been monitored. Continuous sensor monitoring focuses on three primary treatments: the conventional system, the regenerative no-till system, and the regenerative alternate-till system. In parallel, seasonal infiltration tests were conducted using mini-disk infiltrometers across the treatments, and cumulative infiltration was modeled using the Philip equation to estimate infiltration parameters. Preliminary results show that treatment-level differences in infiltration have been small, with most variation occurring between years rather than among different treatments or management regimes. Continuous soil moisture and temperature records exhibit expected seasonal patterns, with only modest and inconsistent separation among treatments. In some periods, regenerative treatments show slightly higher mid-profile moisture, though these differences remain subtle relative to temporal variability. Ongoing work centers on event-based analyses (heatwaves and major rainfall) and the integration of weather station data, evapotranspiration estimates, and soil physical properties such as aggregate stability. These integrations and analyses will help refine the interpretation of whether stacked

regenerative practices provide measurable hydrologic benefits relevant to irrigation planning and climate adaptation.

Funding Support: Foundation for Food & Agriculture Research (FFAR) and the California Department of Food and Agriculture (CDFA)

Long-Term Under-Vine Creeping Red Fescue: Water and Nitrogen Dynamics in an Eastern US Vineyard

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Perennial under-vine cover crops are a sustainable alternative to herbicide strips that can improve soil health and reduce erosion in vineyards. In the eastern United States, perennial grasses, including creeping red fescue, can also moderate excessive vegetative growth by altering key soil processes such as soil water and nitrogen (N) availability. As a result, growers may need to adjust water and nutrient management in vineyards with under-vine grasses. However, the long-term effects of under-vine grasses on N and water availability remains poorly understood. In this study, we evaluated the long-term (9 yr) effects of under-vine creeping red fescue on soil water and N dynamics in a Pennsylvania Noiret (*Vitis* hybrid) vineyard grafted on two rootstocks with different vigor potential. We leveraged multiyear soil measurements with field and laboratory assessments conducted in 2025. Soil moisture data, from 2019 to 2025 (3 to 9 yr after creeping red fescue was established), showed consistently greater water availability and storage at shallow soil depth (20 cm) compared with under-vine herbicide across growing seasons. Higher soil saturated hydraulic conductivity and lower soil bulk density (15-cm depth) indicated greater soil porosity and water infiltration in creeping red fescue plots, contributing to the increased water availability. Despite differences measured in previous years, leaf petiole N concentration at veraison did not differ between grapevines with and without under-vine creeping red fescue in 2025, following 7 yr without fertilizer application. Furthermore, soil under creeping red fescue maintained higher inorganic N concentrations throughout much of the 2025 growing season. Laboratory soil incubations also indicated greater potential for soil N mineralization in these soils. Together, these findings combined with vineyard production metrics provide a framework for developing long-term nutrient and water management recommendations for vineyards adopting under-vine grasses, such as creeping red fescue.

Funding Support: Penn State College of Agricultural Science, USDA-NIFA

Enology – Smoke Exposure in Grapes and Wine Session (research reports)

Influence of Berry Skin Cuticular Wax on Smoke-Derived Volatile Phenol Uptake in Grapes

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Wildfire smoke exposure can alter grape composition and cause “smoke taint” in the resulting wines, causing significant economic losses (USD 3.7B in the United States in 2020). Moreover, rising fire intensity and duration due to climate change are increasing the relevance of smoke exposure across viticultural regions worldwide, including Portugal, Spain, and Chile. While the chemical nature and sensory implications of smoke-derived volatile phenols (VPs) have been widely reported in the literature, comparatively less attention has been given to the role of grape berry skin properties in modulating smoke compound uptake. This study examined the

role of cuticular wax quantity and composition in influencing the uptake of smoke-derived compounds by grapes. Seven grape genotypes characterized by differing berry skin wax were selected for controlled smoke exposure experiments. Grape clusters and individual berries were separated into four treatments in a factorial design defined by cuticular wax status (intact or removed using chloroform) and smoke exposure (present or absent). Berries and clusters were exposed to artificial smoke under controlled conditions at two phenological stages of maturity. VPs in grapes were quantified by gas chromatography-tandem mass spectrometry (GC-MS/MS). Cuticular wax was determined gravimetrically and chemically characterized, after derivatization, by GC-MS/MS. Grape berry skin and tissue morphology and thickness were also evaluated using scanning electron microscopy and light microscopy. Smoke exposure increased VP concentrations across all genotypes and sample types (WAX or NO WAX). In particular, smoke-exposed berries differentiated according to wax presence, abundance and composition, clearly highlighting the protective role of cuticular wax against VP uptake. These findings identify cuticular wax influencing grape response to smoke exposure and provide new insights into genetic variability in smoke taint susceptibility, with implications for vineyard risk assessment and mitigation strategies under increasing wildfire pressure.

Funding Support: USDA-ARS

Wine Volatile Phenol Glycoside Compositional Change During Rapid Aging and Characterization of Acid Hydrolysis Reactions

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During aging, wine produced from smoke-exposed grapes can develop undesirable sensory characteristics. Given the negative on wine quality, reliable methods to measure “free” volatile phenols (VP) and “bound” (VP-glycosides) in wine are critical to evaluate smoke impact severity. Although the stability of VP-glycosides in smoke-affected wine has been studied in long-term aging trials, potential hydrolysis reactions (in smoke-affected wines, spiked non-affected wines, and spiked model wines) during rapid aging in commercial incubators have not been evaluated. Gas chromatography mass spectroscopy (GC-MS) is used to measure “free” VP while “bound” VP, released from VP-glycosides during wine aging, are indirectly measured through the coupling of laboratory acid hydrolysis followed by GC-MS quantification. Currently, there is no standard protocol for acid hydrolysis. The lack of standardization leads to analytical variability among laboratories as it affects the degree to which VP-glycosides are hydrolyzed. This study has two objectives: evaluate compositional changes of VP and VP-glycosides in smoke-affected wine, spiked non-affected wines, and spiked model wine during rapid aging; and characterize hydrolysis reactions of individual VP-glycosides at specific time points using a controlled acid hydrolysis method. Rapid aging was conducted by incubation at 35°C. Samples were collected at 3-wk intervals. Using closely controlled acid hydrolysis conditions, VP and VP-glycosides were analyzed in a time course study, with sampling at regular intervals for quantification throughout hydrolysis. In each objective, the use of both GC-MS and high-pressure liquid chromatography coupled quadrupole time of flight (QTOF) MS allowed for mass balance and percent recovery calculations for the novel hydrolysis methodology as well as insight into VP-glycoside hydrolysis behavior throughout the hydrolysis procedure.

Funding Support: USDA/SCRI, USDA-ARS

Chemical Composition Versus Sensory Reality: Investigating Smoke Phenol Interactions in Red Wine Matrices

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As wildfires around the world threaten vineyards and wineries, it is becoming increasingly important for winemakers to understand the sensory impacts of smoke compounds. The sensory impact of volatile compounds is governed not only by their individual concentrations, but by complex interactions within the aroma matrix. Traditional approaches to aroma prediction have relied heavily on odor activity values (OAVs), which compare compound concentrations to detection thresholds. Mounting evidence suggests OAVs alone are insufficient to predict aroma perception in complex mixtures, as discrepancies are often found between analytical and sensory outcomes. Many aroma compounds are involved in creating the off-flavor in smoke-exposed wines, primarily seven phenolic compounds: guaiacol, 4-methylguaiacol, o-cresol, m-cresol, p-cresol, syringol, and 4-methylsyringol. This study uses these phenols as a model to observe how changes in compound mixtures can alter aroma perception. Three experimental scenarios were designed to investigate interaction effects: (1) constant total phenol concentration with varying compound ratios, (2) inclusion versus omission of syringols to assess their sensory relevance beyond marker status, and (3) mixtures with identical compound ratios presented above and below individual odor thresholds. Three specific ratio groupings were evaluated in Pinot noir and Cabernet Sauvignon wines by check-all-that-apply and descriptive analysis using intensity scales to determine the intensity of aroma descriptors in the wines. It was revealed that aroma perception was primarily driven by overall concentration. Syringols showed no significant sensory impact, supporting their role as exposure markers rather than aroma-active contributors. Differences between Cabernet Sauvignon and Pinot noir perception confirm that base matrix affects resistance to changes in aroma. These findings emphasize the importance of matrix interactions in predicting aroma outcomes from chemical data. A deeper understanding of volatile phenol interactions enhances the interpretability of analytical results and supports more informed decision-making for winemakers faced with smoke events in the vineyard.

Funding Support: USDA National Institute of Food and Agriculture and USDA-Agricultural Research Service (ARS) project number 2072-21000-057-00D. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and should not be construed to represent any official USDA or U.S.

Insight into the Occurrence and Evolution of Thiophenols in Wine

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Volatile thiols are key contributors to wine aroma due to their strong odor properties and low sensory thresholds. While tropical smelling varietal thiols have been widely studied, thiophenols were identified only recently and remain poorly characterized. Baseline data on these ultra trace thiols is limited, and the influence of grape variety, winemaking practices, and wildfire smoke exposure on thiophenols is still unclear. In this study, an ultra-high-performance liquid chromatography-high resolution mass spectrometry (UHPLC-HRMS) method was developed and validated to quantify 11 thiophenols, including seven previously unreported thiophenols in three wine matrices. This method was applied to screen a wide selection of Californian wines, establishing an initial baseline of their occurrence. In wines produced from smoke affected grapes, volatile phenols were also measured and compared with thiophenol levels. Additional trials examined thiophenol stability and evolution in both control wines and smoke exposed wines. Concentrations of volatile phenols and added thiophenols were tracked over time under varying conditions. By combining method adaptation, baseline screening, and targeted stability trials, this work provides new insight into the distribution and evolution of thiophenols in wine.

Funding Support: Department of Viticulture and Enology, UC Davis

Viticulture – Advances in Pest Management Session (research reports)

Kaolin Clay Reduces Fruit Sunburn and Leafhopper Abundance While Minimally Affecting Vine Water Stress in Oregon

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Kaolin clay can be used to manage abiotic stress and pests for horticultural crops like winegrapes. The changing climate in Oregon and the greater Pacific Northwest demands more tools to adapt particularly susceptible perennial systems like vineyards. Multiple field experiments were conducted in northeastern Oregon between 2022 and 2024 to measure the effect of kaolin on vine water stress, fruit sunburn, and leafhopper populations. Kaolin was applied to Syrah at 0, 11, 22, and 45 kg/ha and vine stress responses were observed. Kaolin was applied to Syrah, Tempranillo, and Mourvèdre prior to postveraison (2023) and preveraison (2024) multiday heat events ($T_{air} > 40^{\circ}\text{C}$) to evaluate the effect on fruit sunburn symptoms. Western grape leafhopper populations were monitored in an organic Cabernet Sauvignon vineyard with some kaolin-treated blocks. In 2022, the Syrah vines treated with 45 kg/ha had 25% higher stomatal conductance at moderate leaf water potential values ($> -1.4\text{ MPa}$); leaf water potential was unaffected in 2023 and 2024. Leaf temperature trended lower and stomatal conductance trended higher, mediated by increased leaf reflectance scalar with kaolin application rate. Kaolin application prior to pre- and postveraison heat events reduced fruit sunburn symptoms. Treated clusters had up to 85% fewer shriveled berries, up to 34% fewer berries with sunburn browning, up to 11% fewer necrotic berries, and up to 25% higher anthocyanin concentration. Kaolin application at 22 kg/ha reduced the abundance of leafhopper nymphs on leaves but did not reduce the number of adults trapped with sticky cards. The second-generation peak nymph populations were 54% and 80% lower in kaolin-treated blocks in 2023 and 2024. Ultimately, kaolin clay is an effective tool for grapegrowers to mitigate specific abiotic (e.g., sunburn, water) and biotic (e.g., insect) stresses and its use should be tailored to specific climatic and environmental conditions.

Funding Support: Agricultural Research Foundation Oregon Wine Research Institute ETS Laboratories

Using Organic Herbicides and Steam for Weed Control in California Vineyards

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Organic growers in the San Joaquin Valley, California rely on both mechanical methods and plant-based herbicides for weed management in vineyards. Interests in alternative methods, such as steam and electric discharge weeders, keep increasing in recent years. In 2023 and 2024, we evaluated the efficacy of organic herbicides, a rubber finger weeder, and a steam weeder for under-vine weed control in three table grape vineyards in Kern County, CA. Our study examined three herbicides: Suppress (caprylic acid and capric acid), WeedZap (clove oil and cinnamon oil), and Perish (eugenol and thyme oil). The predominant weed species included prickly lettuce (*Lactuca serriola* L.), hairy fleabane (*Erigeron bonariensis* L.), horseweed (*Erigeron canadensis* L.), purple nutsedge (*Cyperus rotundus* L.), silverleaf nightshade (*Solanum elaeagnifolium* Cav.), crabgrass (*Digitaria sanguinalis* L.), fiddlenecks (*Amsinckia* spp.), and common lambsquarters (*Chenopodium album* L.). Across 2 yr, the steam weeder demonstrated comparable weed control efficacy to Suppress when applied at a high rate. With four applications between April and

October, both methods reduced weed coverage by ~80%. Both methods proved more effective against broadleaf weeds than grasses. In contrast, WeedZap and Perish, even when applied at high label rates, reduced weed coverage by ~35% after four applications, indicating lower efficacy than Suppress, a widely used herbicide in organic systems. The rubber finger weeder effectively controlled small weeds (<10 cm) in vineyards with coarse-textured soils, yet had limited effectiveness against larger weeds, especially those with deep root systems. Overall, our findings suggest that steam weeding is a viable and cost-effective alternative to herbicide application in organic vineyard systems. The success of the rubber finger weeder depends significantly on weed growth stages and soil texture within the vineyard. Future studies aim to assess the effectiveness of electric discharge weeders in comparison to steam and finger weeders.

Funding Support: California Table Grape Commission

Long-Term Effects of Preplant Fumigation and Rootstocks on Northern Root-Knot Nematode Population Dynamics

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This work followed *Meloidogyne hapla* (Northern root-knot nematode) population dynamics over a 10-yr period in a commercial vineyard where pre-plant fumigation and the use of rootstocks were adopted to mitigate nematode-induced vine decline. The rootstocks 101-14 MGT, 1103P, Harmony, and Teleki 5C, and own-rooted *Vitis vinifera* controls were planted in plots that were fumigated (metam sodium), nonfumigated, or nonfumigated + inoculated with additional *M. hapla* at planting. By the second year after establishment, the fumigation effect was no longer detectable. By the fifth year, all evaluated “resistant” rootstocks supported similar nematode densities as own-rooted vines. In highly susceptible own-rooted vines, non-fumigated plots supported higher nematode densities early in establishment; however, population densities did not significantly increase over the 10-yr study. In fumigated plots, nematode population densities rebounded to pre-plant densities ~3 yr postfumigation and subsequently entered a recurring boom-and-bust cycle with an ~3 yr periodicity. The non-fumigated + inoculated plots immediately exhibited this cyclical pattern. Chronic nematode buildup on own-rooted vines exceeded that observed on rootstocks ($p < 0.0001$); Teleki 5C and 1103P maintained slower buildup of *M. hapla* densities compared to 101-14 MGT and Harmony. Over the long term, improved vine vegetative growth was maintained when using rootstocks relative to own-rooted vines, averaging an ~20% increase in pruning weights. This work demonstrates that nematode population densities in vineyards are variable both within and between seasons, and that population disruptions—whether through fumigation or the introduction of additional individuals—can trigger large population fluctuations. When populations are not disturbed, a natural carrying capacity appears to exist, even in the presence of a susceptible host. Rootstocks were an effective long-term management option to mitigate symptoms of nematode-induced vine decline by maintaining more predictable vine vegetative growth and avoiding the major population swings observed in own-rooted vines.

Funding Support: The Washington State Grape and Wine Research Program, supported by Washington State University, Auction of Washington Wines and all Washington State wine grape growers and wineries through the Washington State Wine Commission; The USDA National Institute of Food and Agriculture, Hatch project 7005262.

From Hyperspectral Pixels to Vineyard Decisions: Lessons from the AVIRIS4Acres-NY Campaign

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High-resolution airborne visible-shortwave infrared (VSWIR) imaging spectroscopy is emerging as a practical way to translate research-grade sensing into vineyard-scale decision support, but few campaigns have been designed around the spatial, temporal, and communication needs of commercial management. In July 2025, the AVIRIS4Acres-NY campaign acquired 0.5 to 1.25 m narrow-band hyperspectral imagery over research and commercial vineyards in upstate New York, co-designed with growers and extension partners through stakeholder listening sessions to prioritize actionable products. Near-real-time, cloud-delivered Level-2 outputs were generated during flight and shared through an interactive viewer, enabling rapid evaluation of canopy condition, within-block vigor variability, and stress “hotspots” relevant to targeted scouting and intervention. We present an end-to-end workflow that links calibration/validation protocols and coincident leaf and canopy sampling for trait reference libraries; initial retrievals of foliar traits associated with canopy function and stress; preliminary AI/ML approaches for early grapevine disease detection; and an extension-integrated engagement model that supports real-time ground truthing and iterative refinement of maps. Results demonstrate a feasible pathway for converting hyperspectral imagery into vineyard management intelligence, supporting prioritization of scouting, identification of spatial patterns consistent with nutrient or water stress, and early detection research while also de-risking future satellite applications by informing band selection and processing architectures. This campaign provides a replicable template for aligning advanced airborne sensing with viticulture stakeholder needs and for accelerating development of decision-ready tools for regional early-warning systems.

Funding Support: NASA Acres Domestic Agriculture Research Consortium

Enology – Oak and Non-Traditional Woods in Alcoholic Beverage Production Session (research reports)

Commercial Wine Aging Potential of Selected New York Hardwood Species

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Barrels and adjuncts from *Quercus* spp. are commonly used for aging wine. Alternative wood species can contribute new flavor profiles and increase product differentiation, elevating “terroir” concepts in regional wine aging. Preliminary research established sensorial and qualitative volatile chemistry differences in New York-sourced *Quercus alba*, *Prunus serotina*, *Robinia pseudoacacia*, and *Acer saccharum*. Volatile profiles, focused on hemicellulose and lignin derivatives with potential aroma impact, will allow the NY wine, spirits, and cooperage industry to assess the potential of these species for value-added forest products. Four to six logs per species were sourced from the Finger Lakes, NY. Wood was milled, seasoned, and vacuum toasted to simulate commercial adjunct production. Sixty 50-mL model solution extractions per species, traced to tree level, were aged in contact with wood for 21 days. Targeted aroma compounds, primarily lignin and hemicellulose derivatives from preliminary research, were quantified using reference compounds via gas chromatography-mass spectrometry. Species profiles were differentiated by both hemicellulose and lignin derivatives. *R. pseudoacacia* and *A. saccharum* had the

lowest concentrations of furfural and 5-methylfurfural, while *P. serotina* and *A. saccharum* were lowest in 4-methylguaiacol and guaiacol. *P. serotina* was differentiated by a lack of isoeugenol and was the only species with 5-hydroxymethylfurfural and p-anisaldehyde. *R. pseudoacacia* had the highest guaiacol, syringol, and guaiacol derivative concentrations, while *Q. alba* was differentiated by the presence of cis- and trans-whiskey lactones. *A. saccharum* was the lowest in guaiacol and highest in eugenol, isoeugenol, methoxyeugenol, and vanillin. In *A. saccharum*, vanillin increases correlated to eugenol and methoxyeugenol decreases; alternatively, these compounds were positively correlated in other species. Distinct species volatile profiles suggest New York woods may impart unique aroma characteristics.

Funding Support: Climate and Applied Forest Research Institute, The Oak Lab via Scott Labs (toasting services)

Effect of Entry Proof on the Extraction Kinetics of Volatile Compounds from Convection-Toasted Oak Segments

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Distilled spirits are primarily aged in oak casks/barrels and at varying ethanol concentrations. The decision of entry proof ultimately has both financial and chemical implications. With higher entry proof, fewer barrels are required for aging, but entry proof affects the extraction of aroma and flavor compounds from the wood. This study explored the effects of ethanol concentration/entry proof on the kinetics of volatile compound extraction from alternative oak products. Heavy convection toasted oak segments were sequentially cut in half by length (25.4, 12.7, 6.35, 3.18, and 1.59 cm), resulting in treatments with the same total weight and volume of oak. The overall surface area increases, but more slowly than the increase of the end-grain to cross-grain ratio with progressively shorter segments. All treatments used a dosage rate of 20 g/L and were extracted in fresh-make spirits at 125-, 115-, 105-, 95-, and 85-proof for 90 days. Samples were collected throughout extraction and analyzed by headspace solid-phase microextraction-gas chromatography-mass spectrometry (HS-SPME-GC/MS) for furfurals, guaiacols, and lactones. A modified first-order Lagergren extraction model in two dimensions was fitted to each volatile compound at each entry-proof and at varying grain ratios, using a differential evolution parameter estimation routine. The outcome of this model supports the importance of the grain ratio on both extraction rate and concentration. The resulting kinetic parameters produced an adjustable predictive model for oak volatiles extracted from chips to puncheons. Additionally, the extraction rates (k values) support a multivariate kinetic model for comparing and predicting the effects of ethanol on the extraction of volatile compounds. The model describes and predicts the extraction rate for both grain types and entry proof.

Funding Support: Scott Labs

Positioning Texas-Grown *Quercus alba* Among American White Oaks: Volatile and Sensory Perspectives

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Oak-derived aroma and flavor compounds play a central role in shaping wine sensory profiles, yet limited data exist on regional variation within *Quercus alba* grown across different areas of the United States. This study investigates whether geographic origin influences the volatile composition and sensory impact of American white oak used in winemaking, with a particular focus on Texas-grown *Q. alba* relative to white oak sourced from four other U.S. states. Standardized oak alternatives produced from *Q. alba* harvested in Texas and comparator states were applied to model wines and

wines under controlled aging conditions at equivalent toast levels and dosages. The experimental design aims to isolate geographic origin as the primary variable while minimizing confounding effects related to processing or application format. Wine samples are being monitored over time for oak-derived volatile compounds using headspace solid-phase microextraction-gas chromatography-mass spectrometry (HS-SPME-GC-MS). Target analytes include oak lactones, phenolic aldehydes, furanic compounds, volatile phenols, and other key contributors to oak aroma. Sensory evaluation is being conducted using trained descriptive panels to characterize aroma, flavor, and mouthfeel attributes associated with each oak origin. Chemical and sensory data sets will be integrated to explore relationships between volatile composition and perceived sensory differences attributable to oak provenance. This work seeks to clarify whether regional growing conditions impart measurable and sensorially relevant differences within *Q. alba* used for enological purposes. By providing a systematic comparison of Texas white oak with American white oak from other major sourcing regions, the project aims to generate data that inform oak selection strategies, support regional diversification of oak resources, and expand the scientific understanding of terroir effects in cooperage materials. The findings are expected to be particularly relevant for winemakers operating in warm-climate regions and for stakeholders interested in locally sourced oak alternatives.

Funding Support: Standard Cooperage

Viticulture – Breeding & Cultivar Evaluation Session (research reports)

Assessing Fresh-Market Potential of *Vitis* × *Muscadinia* Wide Hybrids through Consumer Sensory Analysis

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The genus *Vitis* has two subgenera, *Vitis* and *Muscadinia*. *Muscadinia* are uniquely flavored grapes grown across the Southeast United States that are resistant to many pathogens that affect *Vitis* grapes grown worldwide. A 33-person team from 12 institutions is investigating *Vitis* × *Muscadinia* wide hybrids for enhanced disease resistance and quality (USDA NIFA SCRI #2024-51181-43236). In 2025, 20 fresh-market *Muscadinia* and *Vitis* × *Muscadinia* hybrid grape genotypes (cultivars and breeding selections) from grape breeding programs in AR, GA, and NC were evaluated in a consumer study at the University of Florida, Gainesville. The grapes were evaluated for visual, texture, and taste attributes by four consumer sensory panels (n = 130 per panel) with five genotypes per panel as well as physical and composition attributes of the grapes. Panelists were also asked demographic questions and grape consumption and purchasing habits. For this consumer panel, 65% were female, 53% were aged 22 to 34, 45% had a graduate degree, 95% had consumed bunch grapes, and 71% had consumed Muscadine, with 28% consuming four to 10 times per year with 53% likely to purchase. Genotype affected all physical and composition attributes. Berry weights ranged from 2.8 to 18.1 g. For soluble solids/titratable acidity ratio, 12 of the 20 genotypes were within the ideal range of 16 to 70. Mighty Fine had the highest flavor and overall liking and Altus had the highest appearance liking (both new University of Arkansas System seeded Muscadine grapes released in 2023), JB12-12-A14-29 (Gardens Alive! seedless selection) had highest skin texture liking, and AM-303 (University of Arkansas System selection) had highest pulp texture liking. This consumer study provided information to assist the goal of the project to introduce disease-resistant cultivars with enhanced fruit quality for a more resilient United States grape industry.

Funding Support: USDA NIFA SCRI #2024-51181-43236

Evaluating ABA Analogues to Improve Dormancy Maintenance and Cold Hardiness in Multiple Grapevine Cultivars

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Erratic winter temperatures increasingly threaten grapevine cold hardiness by disrupting dormancy and accelerating deacclimation, raising the risk of freeze injury in cool climate viticulture. Since abscisic acid (ABA) plays a central role in regulating dormancy and cold acclimation, ABA based plant growth regulators may offer a promising strategy to enhance winter resilience. However, rapid degradation of natural ABA in plant tissues limits its effectiveness, leading to development of longer-lasting ABA analogues with greater biological activity. From 2017 to 2023, we evaluated the efficacy of two ABA analogues: 8'-acetylene ABA and tetralone ABA. Exogenous applications of each analogue were applied postharvest at 1.00, 0.50, and 0.25 g/L in *Vitis vinifera* Merlot and the interspecific *Vitis* hybrid Marquette. Treatments were compared with S ABA and an untreated control. Cold hardiness and deacclimation dynamics were assessed using differential thermal analysis, budbreak timing was recorded based on the first visible leaf tips, and fruit composition at harvest was analyzed for soluble solids, pH, and titratable acidity. Across the six dormant seasons, ABA analogues variably enhanced cold tolerance and improved resistance to deacclimation, particularly under late winter conditions. Budbreak was consistently delayed in Marquette, while responses in Merlot were more variable among seasons. Overall, 8'-acetylene ABA and tetralone ABA were effective in promoting and maintaining cold hardiness and delaying budbreak, while S-ABA did not influence dormancy maintenance or budbreak timing. Treatment effects on fruit composition were minimal even in seasons with significant delay in budbreak. These results demonstrate that ABA analogues have potential as tools for extending dormancy and reducing cold related risk in grapevines. Their efficacy is influenced by genotype and seasonal conditions, highlighting the need for adaptive management strategies and further evaluation under laboratory and commercial production settings.

Funding Support: Ontario Grape and Wine Research Inc., Canadian Grapevine Certification Network, Agriculture Agri-Food Canada Sustainable CAP Agri-Science Cluster, OMAFRA's Marketing and Vineyard Improvement Program

Genetic Analysis of Budbreak and Cold Hardiness in an Interspecific Grapevine F₁ Population Using rhAmpSeq markers

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Cold hardiness and deacclimation play crucial roles in grapevine survival and productivity in cool and cold climates. Although midwinter cold tolerance has long been used to assess cultivar suitability, increasing temperature fluctuations associated with climate change have accentuated the importance of deacclimation behavior and budbreak timing in determining frost risk. A better understanding of how these traits vary within populations and how they are genetically controlled is needed to improve grapevine adaptation to cold stress and dormancy release. An interspecific F₁ population resulting from a cold-hardy *Vitis riparia* parent and the cold-sensitive *Vitis vinifera* cultivar Fresno Seedless was evaluated in Fargo, ND, using an alpha-lattice design with three replications. Genotyping was conducted using rhAmpSeq markers, resulting in 1235 polymorphic loci, of which 642 were retained after quality filtering for linkage map construction. The genetic map consisted of 19 linkage groups corresponding to the grape genome and spanned 1023 cM, with an average marker interval of 1.62 cM. Cold hardiness was evaluated using differential thermal analysis, revealing wide variation in lethal temperature exotherm values

among progenies. Genotypes exhibiting greater cold hardiness during midwinter were not consistently those with greater tolerance to spring frost, indicating that midwinter hardiness alone does not predict frost vulnerability. Substantial variation was observed in both deacclimation behavior and budbreak progression within the population. When integrated with the high-density genetic linkage map, these phenotypic data provided insight into the genetic architecture underlying cold hardiness and budbreak in grapevine. This study represents a foundational step toward improving selection strategies for grapevine breeding programs targeting cold and variable environments.

Funding Support: VitisGen3

Viticulture – Improved Understanding of Grapevine Nutrients and their Management Session (research reports)

Partitioning of Foliar and Fruit-Applied Nitrogen in Grapevines

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Grapegrowers in dry regions face challenges with low nitrogen (N) in harvested grapes, affecting winemaking due to insufficient yeast assimilable nitrogen (YAN). Foliar N application at veraison may enhance grape and wine composition without inducing excessive vigor, yet its effect on phenolic compounds and plant N partitioning remains unclear. We conducted a 3-yr field trial and two separate pot experiments in arid eastern Washington to test whether foliar-applied N moves to the fruit and other plant organs, enhancing berry ripening and quality, and potentially replenishing the available N pool to support next year's crop. In a field trial with own-rooted Syrah, we applied liquid urea ammonium nitrate (0, 22.5, 45, 90 kg N/ha) to the soil at bloom or foliar urea (15 kg N/ha) at veraison. We also tested the impact of supplementing a foliar urea spray at veraison (20 g N/L) on potted Cabernet Sauvignon vines that had received four different rates of soil N at bloom (0 to 3.75 g N per pot). Finally, using potted Riesling vines, we applied 15N-labelled urea at veraison on whole canopies, leaves only, or clusters only to trace N partitioning. Results showed that foliar N application at veraison significantly increased YAN in field-grown Syrah and potted Cabernet Sauvignon, especially in low-N vines. Higher YAN in Cabernet Sauvignon berries at harvest was negatively correlated with skin tannins, but not seed tannins. 15N applied on Riesling fruit remained in the clusters, while 15N applied on leaves was translocated to both the clusters and the perennial plant organs for storage. Pot experiments showed that foliar N also effectively enhanced vine growth in the following year.

Funding Support: USDA-NIFA Specialty Crop Research Initiative (award number 2020-51181-32159), Washington State Grape and Wine Research Program, Ste. Michelle Wine Estates (in-kind)

Nitrogen Management in the Mid-Atlantic: Insights from Four Fertilization Field Experiments in Virginia

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Nitrogen (N) is essential for vine growth and grape production. In the cellar, fruit N contributes to fermentation and wine sensory characteristics. Achieving optimal vine N status in Mid-Atlantic vineyards can be challenging, as heterogenous soils and variable environmental conditions interact to mediate soil N availability. High seasonal precipitation can promote supraoptimal N availability

and excessive vegetative growth, while periods of drought may reduce N absorption. To investigate how N fertilization affects grape production, vine growth, and fruit composition, and how environmental conditions mediate these relationships, we conducted four field experiments in Virginia Chardonnay and Chardonnay vineyards as part of an SCRI-funded initiative. We tested three rates of soil-based calcium nitrate applications (0 kg/ha; 33 kg/ha, applied at full bloom; 65 kg/ha, split into applications at full bloom and 4 wk after) and two rates of foliar urea applications (0 kg/ha; 5.7 kg/ha) at veraison. We sampled petioles and leaf blades to determine nutrient status at key phenological stages, harvest yield parameters, chlorophyll content index, juice maturity traits, juice amino acid composition at harvest, and pruning weights. We hypothesized that soil amendments would be more effective at improving vine N status than foliar fertilizers, with all amendments increasing fruit N. The following themes emerged: soil applications elicited the greatest overall plant response, although differences were subtle between moderate and high rates of soil fertilization; foliar applications only consistently affected chlorophyll content and fruit N pools at harvest; leaf blades were optimal for detecting changes in vine N status; vine size was greater following soil applications in seasons with ample precipitation; and fruit N pools were sensitive to all applications. These results emphasize the role of environmental conditions in mediating N uptake and can be used to inform N management strategies in vineyards experiencing variable seasonal conditions.

Funding Support: USDA NIFA SCRI CAP Award Number #2020-51181-32159, Virginia Wine Board, Virginia Agricultural Council, and Virginia Tech College of Agriculture and Life Science

Water, Not Nitrogen, is the Main Driving Force for Vine Growth and Yield

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Vine vigor across a vineyard varies due to many factors such as soil water availability, elevation, or proximity to subsurface water. Vines with greater vigor will demand more plant nutrients, especially nitrogen (N). Contrarily, vigor can be controlled by limiting the N supply. In view of this, Riesling vines exhibiting different levels of vigor (high and low) due to differences in subsurface water availability were fertilized with two rates of N (high = 34 kg/ha, and low = 0 kg/ha) in the WSU Roza vineyard in the arid Yakima Valley of Washington, and data were collected from 2023 to 2025. Nutrient composition was determined in leaf tissues (blades and petioles) at veraison and berries at harvest. Yield components and pruning weights varied strongly by vigor class (i.e., water supply) while N application had no significant impact. High vigor vines produced 11% more and 24% heavier clusters, resulting in 36% higher yield, than low vigor vines. Similarly, canopies of high-vigor vines were 117% bigger than low-vigor vines. The berries from the high-vigor vines were more acidic and accumulated less total soluble solids. Additionally, the clusters from high-vigor vines were prone to sour rot infection. Like yield components, nutrient composition in leaf tissue and berries was mainly affected by vigor, but yeast assimilable nitrogen (YAN) was affected by both vigor and N application. High-vigor vines with higher N fertilization had 104% more YAN than low-vigor vines with low N across the three years. N application had a more prominent effect on YAN in the later years, suggesting that fertilizer effects can take time to appear. These results indicate that water availability has a greater effect on the growth and yield of grapevines than N availability.

Funding Support: USDA/WSDA Specialty Crop Block Grant Program (grant number K3944), Washington State Grape and Wine Research Program.

Enology – General Winemaking Session (research reports)

Integrating Grape Stems into Red Winemaking: Consequences for Wine Quality

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An increased interest in the use of grape stems in winemaking has emerged, yet their actual impact on wine quality remains understudied, despite stems being rich in fiber and phenolic compounds. Given the potential of whole-cluster fermentation to increase tannin concentration, particularly in wines from interspecific grape cultivars, this study evaluated the effect of adding stems under fresh and dry form from two grape cultivars on Marquette and Frontenac wine quality. In 2023, Marquette and Frontenac grapes were crushed and destemmed and the stems were collected and either kept fresh, oven-dried or oven-dried and ground prior to addition to the musts. A control treatment without stems was included for comparison. In 2024, the same treatments were used in addition to using stems from Itasca grape cultivar in Marquette musts. Frontenac and Marquette wines were made following a standard red winemaking protocol. Chemical parameters including color, and phenolics composition and concentration were evaluated in Marquette and Frontenac wines throughout the process. The aromatic profile was evaluated on wines after 7 mo of aging by gas chromatography-mass spectrometry and a sensory descriptive analysis was performed at the same time. In Frontenac wines, dry ground stems yielded the highest anthocyanin and flavanol concentrations, while whole cluster wines were the richest in tannins. In 2023 Marquette wines, fresh and dry ground stems significantly increased iron-reactive phenolics and flavanol concentrations relative to the control. Methyl salicylate (wintergreen/rootbeer) was identified as a marker for fresh stem addition in both Frontenac and Marquette wines, with odor activity values (concentration/threshold) ranging from 2 to 3.5. Overall, stem additions altered the extraction of non-volatile and volatile compounds and led to wines that were hotter and drier, highlighting their potential to significantly modulate wine style.

Funding Support: U.S. Department of Agriculture (USDA) Agricultural Marketing Service 23SCBPIA1187 and SCBP24000621 (CFDA # 10.170 " Specialty Crop Block Grant Program - Farm Bill)

Assessing Aroma of Wines Produced from Cofermentation of Noble (*Vitis rotundifolia*) and Merlot (*Vitis vinifera*) Grapes

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While Muscadine grapes (*Vitis rotundifolia* Michx) used for wine production can have issues with color and phenolic stability, they contain unique aromas and flavors. Noble (*V. rotundifolia*) and Merlot (*Vitis vinifera*) grapes were harvested to investigate cofermentation, fermenting two or more grape varieties together, to enhance wine quality. After harvest, the grapes were randomized into five cofermentation treatments in duplicate (100% Noble, 75% Noble + 25% Merlot, 50% Noble + 50% Merlot, 25% Noble + 75% Merlot, and 100% Merlot), processed, and fermented. Volatile compounds were analyzed at bottling via solid-phase microextraction-gas chromatography-mass spectrometry (SPME-GC-MS). Five sensory panelists identified aromas of the 100% Merlot, 100% Noble, and 50% Merlot + 50% Noble wines by gas chromatography-olfactory-flame ionization detection (GC-O-FID). In 2024 wines, 77 volatile compounds were identified, including esters (32), higher alcohols (21), terpenes (4), ketones (3), glycols (2), sulfides (2), and lactones (1). Total volatiles ranged from 73,328 ug/L (100% Noble) to 89,358 ug/L (100% Merlot). Increasing Noble in treatments shifted the aroma profile toward aldehydes, terpenes,

higher alcohols, and esters contributing waxy, soapy, green, floral, fruity, and citrus aromas. Wines with Merlot were characterized by esters, higher alcohol, ketones, and acids, contributing, fruity, apple, honeyed, nutty, fermented and wine-like aromas. GC-O-FID analysis showed that 100% Noble wine was characterized by strawberry and apple juice aromas, contributed by esters, 100% Merlot wine was distinguished by red berry, leafy, herbal, and fatty aromas, contributed by a combination of acids, esters, and higher alcohols, while 50% Merlot + 50% Noble wine had alcohol/solvent, melted butter, butterscotch, citrus, and wine-like aromas contributed by terpenes, esters, aldehydes, higher alcohols, and ketones. While postfermentation or prebottling blending is common for improving wine quality, cofermentation can achieve benefits earlier in production while enhancing the consumer appeal of Muscadine wines by leveraging their unique aromas.

Funding Support: Southern Region Small Fruit Consortium

Application of Alternative Enological Regimens for Aromatic Enhancement of Vidal Table Wine

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Vidal blanc is grown widely for Icewine production in Ontario, Canada, but local industry has expressed interest in enological techniques to enhance volatile thiols in table wine made from this grape. To assess the impact that increased fermentation temperature, yeast strain, and yeast micronutrients have on Vidal wine aroma, seven fermentation treatments were tested: a control using *Saccharomyces cerevisiae* EC1118 at 14°C without Stimula Sauvignon blanc, *S. cerevisiae* Sauvy with and without Stimula Sauvignon blanc at 14°C, *S. cerevisiae* Sauvy with and without Stimula Sauvignon blanc at 20°C, and *S. cerevisiae* Sauvy with and without Stimula Sauvignon blanc with a temperature regime that went up to 26°C for one day. Sixteen aromatic compounds were quantified in the resulting wines using gas chromatography-mass spectrometry. Only one analyte, hexanol, was significantly higher in the control than in the treatments. Ethyl acetate, 2-methylpropanol, ethyl isobutyrate, isoamyl acetate, and 2-phenylethyl alcohol were significantly higher across the treatments than in the control. Varying differences for the remaining compounds were seen between treatments, but general trends showed that the 26°C temperature regimen wines tended to have significantly greater concentrations of the measured compounds than wines from other treatments. Sensory bench trials confirmed that wines from the 26°C temperature regime had the most favorable aroma profile. Preliminary work for volatile thiol analysis via liquid chromatography-tandem mass spectrometry has indicated the presence of 3-mercaptohexanol in the samples. Quantification of this compound, as well as of 3-mercaptohexyl acetate and 4-mercapto-4-methyl-2-pentanone, is currently underway. Building on these results, additional commercial yeast strains and a locally isolated non-*S. cerevisiae* yeast strain are now being trialed with Vidal using the 26°C temperature regime supplemented with Stimula Sauvignon blanc.

Funding Support: Ontario Grape and Wine Research Inc.; Canadian Grapevine Certification Network.

Chemical Changes in Carbonated Blueberry Wine Packaged in Three Materials Under Ambient Storage Conditions

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Blueberry wine is a fruit-based alcoholic beverage with a sensory profile influenced by chemical components that can interact with packaging materials, which serves a critical role in preserving wine quality. As alternative packaging formats gain popularity, there is a research gap regarding their effects on wine. This study compared

the chemical stability of carbonated blueberry wine packaged in aluminum cans, polyethylene terephthalate (PET) bottles, and glass bottles under ambient storage. To test this objective, blueberry wine, ready for market, was packaged in each format and stored at 25°C for 240 days. Package performance was assessed for pH, titratable acidity, soluble solids, density, and alcohol, and no significant package-dependent differences were observed during storage ($p > 0.05$). Color stability varied by package: color intensity and hue measurements showed significant differences, with cans outperforming glass and PET. After 240 days, anthocyanin concentration was significantly higher ($p < 0.05$) in cans (49 mg/L) than in glass (44 mg/L) or PET (32 mg/L), indicating improved color retention. Free and total SO₂ varied with storage and differed by package at Day 240 ($p < 0.05$), with more free SO₂ retained in cans (40 mg/L) than in glass (25 mg/L) or PET (14 mg/L). Volatile organic compounds (VOCs) were summarized by class (alcohols, acids, aldehydes, esters, terpenes, and related compounds) and quantified as total VOC concentration (mg/L), providing an integrated indicator of aroma compound stability. Total VOCs differed by package ($p < 0.05$), with cans maintaining the highest concentrations compared to glass or PET. Overall, aluminum cans exhibited the smallest chemical deviations during ambient aging compared to PET and glass, which had more color, anthocyanin, SO₂, and VOC degradation; thus, aluminum cans are a viable alternative packaging material for carbonated blueberry wine.

Funding Support: Florida Department of Agriculture and Consumer Services

Enology – Enological Method Development Session (research reports)

Rapid Measurement of “Green” and “Moldy” Odorants in Grapes using Direct Analysis in Real Time Mass Spectrometry

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Reliable, rapid screening of underripe and mold associated off aromas is critical for informed harvest, sorting, and blending decisions in winemaking. The key contributors—*trans*-2-hexenol (“green, grassy”) and 1-octen-3-ol (“mushroom”)—are routinely quantified using headspace solid-phase microextraction-gas chromatography-mass spectrometry (HS-SPME-GC-MS), the standard method for confirming these quality limiting compounds. However, GC-MS cycle times of ~30 min/sample constrain throughput during harvest intake. To address this bottleneck, we developed a high speed workflow coupling solid phase mesh-enhanced sorption from headspace (SPMESH) extraction with direct analysis in real time tandem mass spectrometry (DART-MS/MS). Because alcohols ionize inefficiently under DART conditions, in situ derivatization with hindered nitrogenous bases was employed to enhance ionization efficiency. To mitigate matrix effects and accommodate the nonvolatile nature of these bases, we evaluated both pre incubation (in well) and post incubation (mist applied) derivatization strategies. In aqueous model systems, *trans*-2-hexenol produced strong responses and 1-octen-3-ol achieved limits of detection below sensory threshold, enabling differentiation at low concentrations. Saturated 1-hexanol remained less responsive, as expected. Among screened reagents, pyridine and quinoline yielded the best sensitivity, while stronger or higher mass bases increased chemical background and elevated detection limits. Overall, post incubation application of hindered nitrogenous bases before SPMESH-DART-MS/MS provided <1 min/sample screening for *trans*-2-hexenol and 1-octen-3-ol. This approach offers wineries and service laboratories a practical, high throughput complement to HS-SPME-GC-MS during crush and for routine quality control.

Funding Support: New York State Wine and Grape Foundation, E&J Gallo Winery

High-Throughput Tannin Fragmentation Fingerprinting Links Chemistry to Astringency

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Wine mouthfeel, especially astringency, is difficult to explain using conventional chemistry because phenolics are highly diverse and their sensory effects depend on molecular structure and interactions with the wine matrix and saliva. As a result, wines that appear similar by standard metrics (pH, titratable acidity, ethanol, and even total phenolics/tannin assays) can still elicit distinct sensory perceptions. To address these limitations, we related tannin fragmentation fingerprinting (TFF) data to sensory evaluation of California Cabernet Sauvignon wines. TFF is a family of liquid chromatography-tandem mass spectrometry methods that leverage electrospray in-source fragmentation to generate structurally informative fingerprints for condensed tannins (C-TFF), hydrolysable tannins (H-TFF), oxidation-derived adducts (O-TFF), and stilbenes (S-TFF). The wines were intentionally selected to be “chemically narrow” by traditional measures and analyzed using the TFF workflow to obtain structure-resolved phenolic profiles. TFF data sets were integrated with spectrophotometric assays (SPA) and basic composition, then related to a projective-mapping sensory configuration via multivariate analyses. In PLS2 models, basic chemistry showed low predictive value for both sensory dimensions, particularly Dim2 ($Q^2 = 0.029$). SPA (bulk phenolics) captured variance primarily associated with condensed tannins and their derivatives, yielding good prediction for Dim1 ($Q^2 = 0.664$) but poor prediction for Dim2 ($Q^2 = -0.588$). In contrast, TFF showed the strongest correspondence with the sensory map, providing robust prediction for Dim1 ($Q^2 = 0.711$) and acceptable prediction for Dim2 ($Q^2 = 0.368$). Loading patterns indicated that O-TFF and C-TFF features dominated Dim1, while H-TFF and S-TFF features contributed more strongly to Dim2. Overall, pairing TFF with projective mapping sensitively linked phenolic structure to astringency-related mouthfeel within a chemically narrow wine set, highlighting TFF as a stronger, more structure-informed framework than basic chemistry or bulk assays for connecting composition to perception.

Funding Support: United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) Hatch Program, including project no. PEN04792 (accession no. 7002577) and project no. PEN04761 (accession no. 1025695) and the American Vineyard Foundation (AVF) 2025-2954

Viticulture – Professional Development for Viticulturists Session (research reports)

Influence of Trellis System on Yield and Fruit Quality of Bunch Grapes in South Mississippi

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Trellis system selection is an important pre-planting decision in vineyard establishment, influencing vine productivity and fruit composition. While high wire bilateral cordon (HWBC) systems are widely used, vertical shoot-positioning (VSP) may offer advantages for certain southern-adapted cultivars. This study evaluated the effects of HWBC and VSP trellis systems on yield and fruit quality attributes of six interspecific hybrid bunch grape cultivars (Ambulo blanc, Black Spanish, Lomanto, Mamont noir, MidSouth, and Victoria Red) grown at the Mississippi Agricultural and Forestry Experiment Station, South Mississippi Branch, in Poplarville, Mississippi. Fruit were harvested in 2024 and 2025 and measurements included

yield per hectare and per vine, cluster and berry weights, clusters per vine, berries per cluster, total soluble solids (TSS), titratable acidity (TA), and juice pH. Significant cultivar $\times$ trellis interactions were observed for all yield components, while fruit quality differed significantly among cultivars. Black Spanish, Lomanto, and MidSouth produced higher yields on HWBC, with Black Spanish and Victoria Red exhibiting greater cluster weights under this system. Berry weight was higher on HWBC for Ambulo blanc, but higher on VSP for MidSouth. More clusters per vine were observed for Lomanto, Mamont noir, and MidSouth on HWBC, and Black Spanish had more berries per cluster on HWBC. Across cultivars, Black Spanish, Victoria Red, and Ambulo blanc had the highest TSS. Black Spanish had higher TA compared to all but MidSouth, while Victoria Red and Ambulo blanc had the highest juice pH. These results indicate that trellis type had no apparent effect on fruit quality, but HWBC may be better suited for maximizing yield in these cultivars.

Funding Support: This publication is a contribution of the Mississippi Agricultural and Forestry Experiment Station. This material is based upon work that is supported by the the National Institute of Food and Agriculture, Hatch project under accession number 440157. Additional funding was provided by the U.S Department of Agriculture, Agricultural Research Service, number 59-6062-6-003.

Bulletins Live and Mitigation: Updates for the Wine and Grape Industry Regarding Pesticide and Antimicrobial Label Changes

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Over the past several years, the Environmental Protection Agency (EPA) has been revitalizing efforts to update all pesticide labels to reflect growing concerns about human risks of pesticide exposure and environmental risks under the Endangered Species Act. In 2024, the Herbicide Strategy was finalized and in 2025, the Insecticide Strategy was released in its final iteration. The finalized Fungicide Strategy is expected by 2027. These Strategies are the first major changes to pesticide labeling since the introduction of the Worker Protection Standards. It is prudent for Extension staff, growers, and winery managers to understand what these changes entail and to familiarize themselves with the vocabulary and tools needed to demonstrate compliance with these new use requirements. The best way to demonstrate compliance is through a thorough understanding and documentation of on-farm strategies to mitigate application risks to handlers, applicators, the environment, and our communities using EPA online tools. This presentation is focused on the requirements of the new labels, including accessing and using the Bulletins Live! 2 and the Mitigation Menu websites, and provides an overview of the “points” system now in place and specific examples of products that are commonly used in grape production, which will fall under these new requirements now or in the near future. The new drift and runoff calculators and site-specific risk mapping will be covered. Tips and strategies for supporting tech-adverse populations and working with state agencies on compliance criteria will be discussed, as will new guidance on wastewater outflow for operations using antimicrobial products (e.g., wineries).

Funding Support: This research has been conducted as a literature review of EPA guidelines, tools, webinars and strategies, including interviews with compliance staff at the state level. No specific funding was provided to support these efforts.

Optimizing Educational Resources and Outreach Programs to Mitigate Fungicide Resistance in Vineyards

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Variable knowledge of fungicide mitigation practices among vineyard staff indicates a need for concerted educational efforts targeting all sectors of the grape industry. Addressing social-behavioral barriers to the dissemination of knowledge of pest and disease management can support the adoption of evidence-based practices. Surveys and interviews (2018 to 2025) with winegrape industry professionals in California and Washington uncovered barriers to practice adoption, utilization of knowledge resources, and educational gaps. These findings and the resulting models of industry communication networks were used to develop and evaluate novel outreach activities for pest and disease management that promote communication and collaboration skills, optimize educational resources, and engage social networks. They suggest an approach to increasing adoption of fungicide resistance mitigation by empowering key industry educators with the resources to build, sustain, and engage local peer networks that support knowledge dissemination and practice implementation; tailor educational resources to the purpose and audience; and develop interpersonal skills that facilitate communication and collaboration on industry-wide issues. Concerted efforts that approach knowledge dissemination from this framework can further the adoption of evidence-based practices for pest and disease management, while simultaneously nurturing an outreach and educational strategy that is crucial to a resilient agricultural industry.

Funding Support: American Vineyard Foundation (#2023-2746 and #2024-2746) and Specialty Crop Research Initiative Award No. 2024-51181-43184 titled "Pathogen Monitoring and Disease Management Within a Vineyard FRAMEwork" from the U.S. Department of Agriculture's National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and should not be construed to represent any official USDA or U.S. Government determination or policy.

Enology and Viticulture Research Report Posters

Comparative Study of Commercially Available Malolactic Bacteria in Wine

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Over the past several decades, numerous commercial *Oenococcus oeni* starter cultures have been introduced to the wine market in formats including frozen and freeze-dried preparations. These products are commonly differentiated by claims related to viable cell counts, robustness under wine conditions, and speed of malolactic fermentation. The goal of this study was to evaluate whether commercially available malolactic bacteria perform equivalently across wine conditions, and to highlight how winemakers may benefit from more deliberate culture selection based on specific wine parameters. Fifteen malolactic bacteria products from five manufacturers were evaluated. Cultures were plated on appropriate growth media to determine viable cell counts immediately upon rehydration or thawing. Cultures were then inoculated into Pinot noir and Chardonnay wines standardized to pH 3.3 and 15% abv. Wines were monitored over a 42-day period, with periodic measurement of viable cell counts, malic acid, and lactic acid concentrations. All products exhibited high initial viable cell counts, exceeding 1×10^{11} cfu/mL when assessed on growth media directly out of the package. However, notable differences emerged following inoculation into wine. Under wine conditions, several cultures demonstrated greater adaptability and sustained viability, consistently maintaining populations at or above 1×10^6 cfu/mL, a threshold generally associated with reliable and timely malolactic fermentation. In contrast, other products showed pronounced declines in viable cell counts during the trial. Fermentation kinetics also differed among products, with some cultures completing malic acid conversion more rapidly in both Pinot noir and Chardonnay, reaching 0.4 g/L malic acid up to 3 wk earlier than others. These results indicate that while initial cell counts were broadly comparable across commercial cultures, performance under wine conditions varied substantially. Culture robustness and viability are critical factors influencing malolactic fermentation outcomes, underscoring the importance of aligning bacterial selection with specific wine chemistry and production goals.

Funding Support: Novonesis North America

P2 from Withdrawn Folder: Immobilization of *Oenococcus oeni* as a Strategy to Optimize Malolactic Fermentation in Wine Under Unfavorable Conditions

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During malolactic fermentation (MLF), lactic acid bacteria, mainly *Oenococcus oeni*, convert malic acid into lactic acid, reducing acidity and improving wine flavor and microbiological stability. Adverse factors such as low pH, high ethanol content, and the presence of sulfites or other antimicrobial additives may inhibit this process, affecting final product quality. This study aimed to use immobilized cells of *O. oeni* X₂L as a strategy to improve MLF under unfavorable winemaking conditions. Cells were immobilized in alginate and chitosan beads cross-linked with sodium tripolyphosphate (TPP), and the most stable composition was selected (3% alginate, 2% CaCl₂, 1% chitosan, and 2% TPP). Alcoholic fermentation was carried out using a culture of *Saccharomyces cerevisiae* Lalvin

EC 1118 in Torrontes grape juice supplemented with a synergistic antimicrobial mixture of lapachol (L) and sodium metabisulfite (MBS) (9.8 + 156.3 µg/mL), reported as an inhibitor of *Aspergillus niger* and *Aspergillus carbonarius* growth, as well as the production of mycotoxins (mainly ochratoxin A). The resulting wine (Brix = 5.2, reducing sugars = 4 g/L, pH = 3.8, ethanol = 12%, and free SO₂ = 32 mg/L) was inoculated with free and immobilized *O. oeni* X₂L cells, then malolactic activity was evaluated by measuring the rate of malic acid consumption over time (0, 24, 48, 72, 96, and 120 hr incubation). Immobilized cells exhibited a malic acid consumption rate approximately two-fold higher than that of free cells, completing the MLF (residual malic acid <0.1 g/L), whereas free cells did not complete the process in the presence of the L+MBS mixture. These results suggest that immobilization enabled an efficient exchange between cells and medium and protected them from the inhibitory effects of L+MBS, thus improving MLF efficiency and providing an effective alternative for unfavorable winemaking conditions.

Funding Support: Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)

Effect of Entry Proof on the Extraction Kinetics of Volatile Compounds in Charred Oak Casks

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Distilled spirits are primarily aged in oak casks/barrels at varying ethanol concentrations. The decision of entry proof ultimately has both financial and chemical implications. At higher entry proof, fewer barrels are required for aging, but this affects the extraction of aroma and flavor compounds from the wood. This study explores the effects of ethanol concentration/entry proof on the kinetics of volatile compound extraction from traditional charred casks. Medium-convection, toasted char 3 (200 L) casks were used for the aging process at all entry points. Freshly distilled bourbon from a single distillation run was used as the base spirit, then watered back to the target alcohol-by-volume specific gravity. This was done at Iron City Distillery (Creighton, PA). Entry proofs were 125, 115, 105, 95, and 85 proof for 90 days. The short extraction was to evaluate the initial rapid extraction of oak phenols, which occurs during spirit maturation. Samples were collected throughout the extraction period and analyzed by headspace solid-phase microextraction gas chromatography-mass spectrometry (HS-SPME-GC/MS) for furfurals, guaiacols, and lactones. A modified first-order Lagergren extraction model was applied to each volatile compound at each entry proof, using a differential evolution parameter estimation routine. The model's outcome evaluates how entry proof affects the extraction kinetics of spirits. To confirm the mathematical determination of barrel specifications, an independent method was developed. Additionally, the extraction rates (k values) support a multivariate kinetic model for comparing and predicting the effect of ethanol on the extraction of volatile compounds.

Funding Support: Scotts Lab

Spectrofluorometric Fingerprinting with Machine Learning to Triage Smoke Taint Risk in Wine

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Wildfires are becoming more frequent and severe on the United States West Coast, increasing vineyard smoke exposure and the risk of smoke taint in wines. The 2020 wildfires triggered a sharp increase in submitted samples, exposing limitations in throughput and the need for rapid triage. Because mass spectrometry workflows require substantial preparation and instrument time,

turnaround slowed dramatically, resulting in ~1 mo of backlog testing. Producers were left to make harvest decisions with delayed or incomplete analytical guidance. We assess absorbance-transmission excitation-emission matrix (A-TEEM) spectroscopy with supervised machine learning as a rapid screening tool for smoke taint risk in wine. This study analyzes wine samples from multiple Northern California vineyards, spanning several varieties and vintages. A-TEEM fingerprints were collected from control and experimentally smoke-exposed wines. A higher emphasis will be placed on recall to minimize false negatives, reducing the chance that a smoke-tainted sample is incorrectly classified as no risk. Preliminary results show that PARAFAC-based deconvolution enhances A-TEEM feature quality for classification, and random forest and a single-layer neural network provide the strongest overall performance ($n = 396$). Wines classified as elevated taint risk will be prioritized for gas chromatography-mass spectrometry confirmation, easing capacity constraints and supporting timely decisions during wildfire events.

Funding Support: CDFA 2021 Multi-State Specialty Crop Program

Genomic Architecture of Coevolved Resistance and Virulence in the Wild North American *Vitis*-Downy Mildew Pathosystem

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Grape (*Vitis* spp.) production is increasingly threatened by downy mildew (DM), caused by the oomycete *Plasmopara viticola*. While North American wild *Vitis* species are the primary sources of resistance (Rpv) loci, the rapid evolution of *P. viticola* virulence threatens the durability of resistance in current hybrid cultivars. The Blue Ridge Mountains (BRM) represent a biodiversity hotspot where heterogeneous topography and microclimate have likely promoted far richer allelic diversity for biotic stress adaptation. This study tests the hypothesis that sympatric wild *Vitis* populations and *P. viticola* isolates in the BRM harbor significant genome-wide polymorphism, specifically within host immune receptors and pathogen effectors shaped by long-term coevolutionary dynamics. To investigate the hypothesis, leaves from ~650 wild grapevines (representing *Vitis aestivalis*, *Vitis labrusca*, *Vitis riparia*, and *Vitis vulpina*) and 125 *P. viticola* field isolates were collected across diverse ecological niches and elevation gradients (230 to 1400 m) in the National Forests of Tennessee, Virginia, and West Virginia. Host samples are being sequenced using whole-genome sequencing and mapped to a *Vitis* super-pangenome graph to accurately call single nucleotide and structural variations, avoiding the biases of single-reference mapping. Simultaneously, *P. viticola* genomes are being investigated to characterize effector repertoire evolution. By leveraging population genomics and graph-based computational algorithms, this research aims to reconstruct the eco-evolutionary history of the pathosystem and quantify the genetic diversity of the pathosystem's coevolutionary determinants. These results will provide actionable insights for germplasm curators and plant breeders, ensuring the efficient utilization and preservation of North American native *Vitis* reservoirs.

Funding Support: Startup funds of Co-evolution lab (PI- Dr. Gautam Shirsekar) as a part of his hiring as assistant professor at the University of Tennessee, Knoxville.

Physiological Means to Lessen Virus Load in Leafroll-Infected Grapevines to Restore Infected Vineyards

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The two most significant viruses affecting grapevine productivity worldwide are the leafroll virus and the red blotch virus. As there is currently no cure for these viral diseases, a constructive approach

involves roguing infected vines and replacing them with certified, virus-tested stocks. This process is labor-intensive and costly, highlighting the need for a more economic strategy to manage the infection. Recognizing the pivotal role of phloem in virus infection, this study aimed to explore a method for reducing virus load and improving vine health by girdling the phloem in canes from leafroll-infected vines at different phenological stages. Phloem girdling was thoughtfully performed on canes during veraison, focusing on different regions between the proximal and distal clusters. In response to girdling, the vines demonstrated a remarkable ability to form a callus that bridged the girdled area. Additionally, the entire lamina of the leaves above the girdled section turned red due to anthocyanin accumulation, an outcome triggered by sugars being confined within the leaf. This reddening was notably distinct from the typical response in leafroll-infected vines, which exhibit reddening throughout the lamina while leaving the areas near the major and minor veins green. Importantly, the study found that the girdled canes had lower concentrations compared to the ungirdled canes. There were also minimal variations in primary metabolites such as sugars, acids, and nitrogenous compounds, as well as in secondary metabolites, including flavanols (tannins), flavonols, and anthocyanins, all essential for quality winemaking. Overall, this study provides valuable insights and demonstrates that girdling the phloem over multiple growing seasons can be an effective strategy for reducing virus load in infected vines, thereby enhancing vine health in a constructive manner.

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

Acid from Bubbles Not from a Bag: Glucose Oxidase Treatment for High pH Juice

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Making wine from high pH juice poses significant issues for microbial stability and balanced taste of the final product. The standard industry practice of adding large amounts of exogenous tartaric acid can be expensive and can have mixed efficacy without knowing the buffering capacity of the juice. Recent research has shown promising results using the enzymes glucose oxidase and catalase to increase acidity of high pH juice, but these results were demonstrated on a research scale. An extension-based trial at a commercial scale could increase adoption of this practice and potentially improve wine quality. Glucose oxidase and catalase were used to treat high pH juice from red wine grapes grown in a southern New Mexico vineyard. Two commercial wineries treated their must with glucose oxidase, catalase, and oxygen for 24 hr in 300-L tanks while continuing their standard practices in larger tanks. Titratable acidity (TA), pH, gluconic, and tartaric acid levels were analyzed using UV-vis spectrophotometry, titration, and pH meters for all lots until fermentation was complete. In comparison to the standard winery practice of adding exogenous tartaric acid, the enzyme treatment was an improvement for both increasing TA and lowering pH. Acidity differences between the standard practice and experiment lots peaked at 24 hr at the end of the oxygen treatment, after which acidity was slowly lost. Two weeks following treatment, the experimental lots had lost nearly half of their gains but remained an improvement over standard practices. Further research is needed to explain the eroding acidity gains observed in this trial. Both wineries expressed interest in using glucose oxidase and catalase on their juice in future harvests.

Funding Support: Self-funded through re-occurring NMSU viticulture and enology index.

Evaluating Verjus as an Acidification Tool for San Joaquin Valley Cabernet Sauvignon

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As climate change accelerates acid loss and color instability in grapes grown under warm-climate conditions, winemakers are seeking sustainable acidification strategies beyond conventional methods. Verjus, a green juice from unripe grapes, offers potential as a low-impact tool based on previous studies, but its optimal harvest timing for red wine applications in California's San Joaquin Valley remains undefined. This study evaluated the effects of Verjus additions on cv. Cabernet Sauvignon wine composition and color under warm-climate conditions. Four treatments were applied at crush: control (no addition), tartaric acid (36 g/L, 7.5% w/w), and Verjus harvested at 4 (V4, titratable acidity [TA] = 32 g/L) and 8 ws (V8, TA = 36 g/L) post-full bloom, also added at 7.5% w/w. All fermentations were conducted in triplicate under controlled conditions. At bottling, Verjus-treated wines showed a 4 to 6% reduction in pH ($p < 0.05$), though this was less than the 11% reduction achieved by tartaric acid. Only the V8 treatment resulted in a significant TA increase (6.9 g/L, 11% higher than the control). Verjus addition also reduced ethanol concentration, which may help mitigate high alcohol levels under warm-climate conditions. No significant differences were observed in tannins, anthocyanins, or polymeric pigments. However, all acidification treatments significantly shifted color hue toward the reddish spectrum, with no effect on color intensity. These results suggest that Verjus, particularly from earlier developmental stages, can effectively acidify red wines while preserving key chemical attributes and enhancing visual quality. Because Verjus can be produced from unripe berries removed during routine cluster thinning, this approach also offers an opportunity to recycle vineyard byproducts into a value-added acidification tool. Ongoing sensory evaluation and volatile aroma analysis will provide deeper insight into consumer acceptability and further support the practical use of Verjus in sustainable red wine production.

Funding Support: California State University Agricultural Research Institute (ARI), grant number 351380.

Wine Quality Impacts of a Thyme-Based Vineyard Spray Program

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The wine industry is under increasing demand to adopt more sustainable and environmentally friendly practices, including reducing reliance on synthetic agrochemicals. Plant-derived biofungicides represent a promising alternative but their effect on grape and wine quality remains underexplored. This study evaluated whether a thyme-based biofungicide, applied as part of a vineyard spray program, influences the chemical composition and sensory profile of wine. A randomized complete block design with three field replicates was used to apply five spray treatments (Conventional, Sulfur, Fun-Thyme, Fun-Thyme + Sulfur, and Hybrid) to cv. French Colombard vines. Grapes from each replicate were harvested separately and vinified in triplicate under controlled conditions (13°C). Berry composition, including Brix, pH, titratable acidity [TA], berry size, and weight, showed no significant differences among treatments, nor were there differences in sunburn or infection rates at harvest. Bottled wines showed no significant differences in pH, TA, alcohol, or organic acids across treatments, indicating that the thyme-based product did not adversely affect fermentation or core composition. Sensory triangle testing was conducted in three sessions, each corresponding to a unique vineyard replicate, using 34 untrained panelists (55 total evaluations). Wines from the thyme-based treatment were consistently distinguishable from sulfur-only wines, while comparisons with Conventional, FS, and Hybrid treatments did not yield reproducible sensory differences. These results suggest that the thyme-based biofungicide can be integrated into vineyard management without compromising fruit quality or altering wine sensory properties, supporting its potential role in sustainable viticulture. Further analysis of volatile aroma compounds and descriptive sensory profiling is underway to deepen understanding of aroma impacts across vintages.

Funding Support: AgroSpheres, INC. and Wilbur-Ellis Corporate

Effect of Exogenous Tetralone Absciscic Acid Applications on the Hormone and Metabolite Profile of Merlot Buds

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Many winegrape cultivars are vulnerable to freeze injury, leading to vine damage and crop loss. Cold hardiness is influenced by genotype, environment, and viticultural practices. Absciscic acid (ABA), a key phytohormone involved in dormancy and stress responses, has been shown to promote cold acclimation. However, its rapid degradation in plant tissues limits ABA's use as a plant growth regulator. To improve persistence, ABA analogues such as tetralone ABA have been developed to resist enzymatic degradation. Tetralone ABA contains a tetralone ring that prevents cyclization after oxidation of the 8'methyl group, extending molecule activity. Previous work identified tetralone ABA as a promoter of cold hardiness. This study examined its effects on dormancy, cold hardiness, and metabolite and hormone profiles in multiple *Vitis* genotypes. Tetralone ABA was applied to canopies at two rates (0.5, 1.0 g/L) postharvest to Marquette, Merlot, and Riesling grapevines and compared to SABA and untreated controls. Bud water content and cold hardiness were monitored throughout dormancy. Bud tissue samples were prepared and hormone profiling was conducted using liquid chromatography-selective reaction monitoring (LC-SRM) analyses to quantify tetralone ABA and ABA catabolites. Buds were also analyzed using UPLC-qTOF-MS equipped with a BEH C18 column for analysis of semipolar metabolites to assess broader metabolic responses through untargeted metabolomics. Some increases in hardiness were observed late in dormancy with tetralone ABA treatments but were not consistent across cultivars or rates of application. In Merlot, phaseic acid and dihydrophaseic acid levels differed significantly on occasions, coinciding with increased bud water content. Tetralone ABA catabolites were low through most of dormancy and inconsistently detected. Metabolomics results revealed several features of interest elevated by tetralone ABA, including p-coumaroyl flavonoid glycosides, flavonoid dimers, and monoterpene glycosides; many associated with phenylpropanoid pathway activity. These findings indicate metabolic shifts that warrant further investigation.

Funding Support: Canadian Grapevine Certification Network, Ontario Grape and Wine Research Inc., Agriculture and Agri-Food Canada Sustainable CAP

Effect of Temperature on Development of Grapevine Scale Insects (*Parthenolecanium persicae*) in Greenhouses

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Changes in storms, fires, and temperature are all explained by relatively fast change in overall climate associated with human activity and use of fossil fuels. Climate change may influence insect growth and development and these changes can lead to greater damage to grapevines. I have studied how increasing temperature affects development of the grapevine scale insect, *Parthenolecanium persicae*, to determine whether the life cycle can change from a univoltine (one life cycle per year) to a multivoltine (more than one cycle per year) species. Insects were raised on 72 Chardonnay grapevine rootlings (clone 76 Bernard 3309C) allowed to grow for 1.5 mo (25°C day:15°C night). The plants were then moved into high temperature (35°C day:25°C night) and moderate temperature conditions (30°C day:20°C night) or left in control conditions (25°C day:15°C night) for 2 more wk. After plants were acclimated to their new conditions, five gravid female scales were placed on the plants at the end of November. At each temperature,

a full Latin square was designed, so that two of every four plants had scale insects introduced and the other two were controls. Scale insects moved onto the leaves and were allowed to develop on the plants. Insects were collected every month to determine growth patterns. In addition, plants were monitored for linear growth and leaf chlorophyll content over 3 mo. At the end of the experiment, plants were harvested, dry mass of roots and shoots measured, and grape mass determined. These measurements were then correlated with the rate of growth and density of scale insects on each plant to determine how temperature affected both scale insects and the plants themselves.

Funding Support: Wine Australia South Australian Research and Development Institute

Perennial Vegetation in Rocky Vineyard Soil Reduces Vine Growth, Increasing Berry Phenolics at the Expense of Yield

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Alleyway vegetation is used in vineyards to compete for water and nutrients, modifying vine growth and ultimately, wine quality. Vegetation can also benefit soil quality and ecological sustainability. Very rocky soils impede cultivation of vegetation (e.g., seeding, weed management), limiting these potential benefits. In northeastern Oregon, some vineyards are planted in Freewater, a very cobbly loam soil which contains 10 to 20% large cobbles in the rooting zone. A field experiment was established there in 2023 to compare the effects of perennial vegetation (*Lolium perenne*) with clean cultivation. Soil was collected in spring 2023 to 2025 for analysis of physical, chemical, and biological traits. Leaf temperature, water potential, stomatal conductance, and transpiration were measured during the summer in 2023 and 2024. Leaves were collected at veraison each year for nutrient analysis. Mature clusters were harvested for analysis of yield and berry chemistry. Vegetated plots had higher soil respiration, lower potentially mineralizable nitrogen, and a lower nitrogen mineralization rate than cultivated plots. Canopies were 20 to 29% smaller in vegetated plots, despite similar leaf nitrogen in both treatments. Vine yield, cluster mass, and berry mass were 25, 22, and 17% lower, respectively, in vegetated plots; cluster and berry number were unaffected. Juice chemistry was largely unaffected, but juice nitrogen was lower for vegetated plots. Berry quercetin and anthocyanin concentrations were higher in vegetated plots, likely in response to smaller canopies and increased sun exposure. In this study, vines responded rapidly to reduced soil nitrogen availability imposed by the perennial vegetation. The homeostasis of vine fertility and nitrogen status was maintained by balanced reductions of canopy and fruit size. Thus, perennial vegetation confers similar effects in very rocky soils as elsewhere, aiding canopy management and improving quality attributes like berry phenolic content.

Funding Support: USDA-NIFA (Western SARE) Oregon Wine Research Institute ETS Laboratories

Detection and Abundance of Plant-Parasitic Nematodes in Oregon Vineyards Vary by Region, Nematode Genus, and Soil Type

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Grapevines host several plant-parasitic nematodes (PPNs) that cause damage to roots and can transmit viruses like grapevine fanleaf virus. PPN populations vary with the soil type, land-use history, cultural practices, and plant material of a vineyard. The status of PPNs in Oregon vineyards was most recently assessed

in 1994 and 1995. As such, the present survey intends to improve management by identifying the up-to-date distribution and abundance of PPNs in vineyards across Oregon's winegrape growing regions and determine which site characteristics are associated with PPNs. Beginning in fall 2023, soil samples were collected from 43 vineyard blocks in the Willamette, Umpqua, Rogue, and Columbia growing regions. These blocks were sampled again in spring 2024. In fall 2024 and spring 2025, 45 new vineyard blocks were sampled. *Paratylenchus* spp., *Mesocriconema* spp., and *Pratylenchus* spp. were identified in more than 40% of samples; *Xiphinema* spp. and *Helicotylenchus* spp. were identified in more than 30% of samples; *Tylenchorhynchus* spp. and *Meloidogyne* spp. were identified in more than 10% of samples; and *Hemicycliophora* spp. were identified in fewer than 10% of samples. PPNs were detected most frequently in the Columbia and Rogue regions. Detection in different soil types varied by genus, but PPNs were identified most often in samples from sites with sandy loam (50%) and loam (38%) soils. PPN counts were inversely related to soil clay content. PPN counts were generally low and only 4.7, 3.5, 2.9, and 0.6% of samples were above economic thresholds for *Xiphinema* spp., *Pratylenchus* spp., *Meloidogyne* spp., and *Mesocriconema* spp., respectively. In fall 2025, 43 new blocks were sampled; these blocks will be sampled again in spring 2026. The results of this survey not only specify which PPN genera are most common but also indicate which regions and soil types are most likely to host PPNs.

Funding Sources: Northwest Center for Small Fruits Research

Smoke-Derived Volatile Phenols in Cabernet Sauvignon Wines Respond to Controlled, Variable-Rate Smoke Exposure

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Wildfire smoke exposure poses a significant threat to the United States wine industry. Exposed grapes can absorb smoke-derived phenols, producing unpleasant (e.g., ashy) aromas and flavors in wine. The relationship between the degree of smoke exposure (i.e., smoke concentration) and smoke-derived phenols in grapes and wine is not well understood, making it difficult to predict the risk of smoke events to wine quality. This study addresses this relationship by evaluating smoke-derived phenols in grapes and wine subjected to variable, experimentally controlled smoke levels. In 2025, mature grape clusters from 10 varieties were smoked for 90 min in greenhouse film-covered chambers by heating a mixture of straw (triticale) and wood pellets (oak and Douglas fir) in a smoker. Smoke levels of 0, 18000, 36000, 54000, 72000, and 90000 $\mu\text{g}/\text{m}^3$ PM_{2.5} were targeted by monitoring an aerosol meter and manually adjusting a valve downstream from the smoker. Following exposure, grapes were frozen for later analysis and vinification. Wines were made in duplicate by incubating 1 kg crushed berries in 0.7-L fermentation jars at 32°C for 1 wk. Volatile phenols (VPs) in Cabernet Sauvignon wines were analyzed by a commercial laboratory; the remaining samples will be analyzed in spring 2026. Smoke treatments increased concentrations of guaiacol, 4-methylguaiacol, *m*-cresol, *o*-cresol, phenol, syringol, and 4-methylsyringol in Cabernet Sauvignon wines. No *p*-cresol was detected in the wines. VPs were not significantly different above 54000 $\mu\text{g}/\text{m}^3$, suggesting that exposure risk is not linearly related to smoke level at extremely high PM_{2.5}. The effect of smoke level on wine VPs is likely limited by the absorption rate of these compounds in grapes and confirms that duration is also important for determining smoke exposure risk to wine quality. With additional analyses, this study will enable improved prediction of smoke exposure risk by smoke level across multiple varieties.

Funding Sources: USDA-NIFA-SCRI project award no. 2021-51181-35862

Short-Term Effects of Compost and Tillage on Vine Yield and Soil Health of Chardonnay Vineyards in California and Oregon

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With increasing pressure to implement more sustainable agricultural systems, regenerative practices have gained momentum within the wine industry. Regenerative practices like cover cropping, compost application, and no-till have been shown to enhance soil health, with potential to benefit productivity in the long run and compete with conventional markets. However, there is limited research evaluating how these practices perform across different viticultural regions, where variations in climate and soil properties may influence the outcome. This study aims to improve understanding of how these practices influence vine performance and soil health in Chardonnay vineyards across distinct regions, namely, Polk, Oregon and Sonoma, California. This 3-yr study evaluated the short-term effects of four treatments in two Chardonnay (*Vitis vinifera*) vineyard sites with rootstock 101-14. Both regions implemented a field experiment with randomized complete block design, three replicates per treatment. For each treatment, a plot was assigned consisting of four adjacent vine rows, 60 vines each, and three tractor rows between. All treatments had cover crop mix seeded every year. Soil samples were taken annually during budbreak from tractor and vine row 30-cm deep using an auger. Samples were analyzed for soil health indicators. Leaf blades were collected and dried from 10 identified vines per treatment, then sent for macro- and micro-nutrient analysis. Vine yield was assessed during harvest. Pruning weights were collected in the dormant seasons and vine vigor was estimated using the Ravaz index. Juice chemistry and phenolic compounds were evaluated from subsampled clusters and analyzed at a commercial laboratory. Our preliminary findings indicate that vine yield is affected by both soil management and year, showing strong year-by-treatment interaction. There is a noticeable difference in treatments with conventional management versus NC treatments. This data is essential to support the use of regenerative practices in viticulture and to provide growers with regionally relevant expectations and improved decision-making guidance.

Funding Support: Foundation for Food & Agriculture Research (FFAR)

Effects of Agrivoltaic Practices on Overwintering and Cultivation of *Vitis vinifera* Riesling in Iowa

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Low-temperature injury is one of the limiting factors of grapevine cultivation in regions like the Northern Midwest, where winter temperatures are highly variable. Historically, *Vitis vinifera* cultivars have been unreliable in these regions, as buds face damage with temperatures below freezing and whole vines eventually collapse from years of cold damage. This has led to interspecific cultivars with improved hardiness being grown in cold regions. However, these cultivars have some undesirable qualities and while improvement research is ongoing, another possible solution would be cultivating *V. vinifera* in protected areas. Agrivoltaics is the practice of integrating solar energy production and agriculture on the same land. Previous studies showed that solar panels create a unique microclimate that can boost productivity of other perennial crops during the growing season. In 2024, *V. vinifera* Riesling was planted under 5 ft rotating solar panels and in an open field to assess the effect of agrivoltaic practices on overwintering and physiology of *V. vinifera* in Iowa. Since planting, environmental parameters of light intensity and air temperature have been monitored to quantify microclimatic changes. Additionally, plant physiological responses, including phenology and dormant bud necrosis, have been

monitored. During the 2024 to 2025 winter season (December to February), the open field experienced 19 days with temperatures below -20°C, with a maximum low of -27.70°C. In contrast, the area under solar panels experienced 15 days with temperatures below -20°C with a maximum low of -26.26°C. During the 2025 growing season, all open-field vines did not survive the winter and had to be replanted, while all protected vines had minimal dieback and produced vegetation in the growing season. First year results indicate that the protected environment had a positive effect on Reisling bud survival during critical temperatures. Monitoring is continuing during the 2025 to 2026 winter season and preliminary results indicate a similar trend.

Funding Support: DOE-SETO-FARMS

Preliminary Characterization of New Mexico Vineyard Soils and Assessment of Nutrient Availability Constraints

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The New Mexico State University viticulture program initiated a research and extension effort to characterize the soils, irrigation water, and nutritional status of New Mexico vineyards. Preliminary results from seven commercial vineyards in southern and central NM have provided insight into soil variability, irrigation water quality, and nutrient availability constraints in the context of viticulture in arid regions. Soil samples (0 to 30 cm deep), irrigation water, and vine tissue samples (petioles or blades) were collected and analyzed by third party laboratories. Measurements include soil pH, soil electrical conductivity (EC), organic matter, exchangeable cations, and nutrient concentrations. Irrigation water EC, total dissolved solids, sodium adsorption ratio (SAR), and bicarbonate were tested. Blade and petiole nutrient status were also analyzed. Most sampled vineyards had high values for total soluble salts and exchangeable sodium. The irrigation water results from selected vineyards showed high bicarbonate concentrations and high SAR values, consistent with a risk of soil salinity and soil sodicity. To evaluate the effect of these constraints in vine response, the program will assess how soil and water quality relate to vine tissue and fruit composition. The available tissue analyses from selected sites showed micronutrient patterns consistent with reduced iron availability under alkaline soil conditions, with iron concentrations in petioles as low as 22 to 23 ppm. Visual symptoms of iron chlorosis were documented in the affected blocks. High sodium concentrations (0.6 to 0.9 %) were also detected in petioles at some locations. Because data analysis and sampling are still ongoing, these results will change over time as additional data is collected. The program will continue sampling in 2026 to refine the characterization of NM vineyards and provide a baseline for future research on irrigation management to enhance vineyard sustainability in water-limited regions at risk of salinity and sodicity.

Funding Support: New Mexico State University, viticulture program, ACES college. New Mexico Wine Association

Acid Management Strategies in Fortified Tempranillo Wines from Warm Climates in California

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Fortified Tempranillo wines from the Central Coast of California were produced under two treatments during alcoholic fermentation (AF): a control with a 3 g/L tartaric acid addition, and fermentation with the lactic acid-producing yeast *Lachancea thermotolerans* (Omega strain). No significant differences were found in oxidation-reduction potentials during AF between control and *Lachancea* ferments (10 and 15 mV, respectively). Postfortification, finished

wines of control and *Lachancea* had comparable alcohol by volume (ABV) of 19.06 and 19.17%, respectively, and residual sugars of 66.5 g/L in the control and 73.9 g/L in *Lachancea*. Control wines had a lower pH (3.89) than *Lachancea* wines (3.96); however, *Lachancea* produced more lactic acid (2.37 g/L versus 0.23 g/L in the control), resulting in higher titratable acidity (TA) (7.70 g/L versus 7.00 g/L in the control). *Lachancea* wines contained 8% more total tannins and higher odor activity values (OAVs) for ethyl butyrate and ethyl hexanoate (46.3 and 14.4% higher than the control, respectively), while control wines had a higher OAV for isoamyl acetate (43.3% higher than *Lachancea*). *L. thermotolerans* appears to be a viable strategy to increase the acidity of fortified wines. Two additional postfortification treatments were executed using the control wine: ion exchange (IE) treatment followed by blending at a 25% proportion, and 100% IE wine. The 100% IE wine had little effect on alcohol (18.32%), reduced pH to 2.06, and increased TA to 10.80 g/L. Blending at a 25% proportion resulted in wines with an ABV of 18.58%, reduced pH to 3.58, and increased TA to 7.78 g/L. Further chemical analysis is underway.

Funding Support: Richard Lauchland (Duas Terras Vineyard) and Treasury Wine Estates (St. Helena, CA) are thanked for their donation of fruit and logistical support, respectively.

Acid Management in Warm-Climate Tempranillo Wines

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Tempranillo wines from the Central Coast of California were produced using three acid management strategies in addition to a control: addition of 0.9 g/L fumaric acid (FA) before alcoholic fermentation to inhibit malolactic fermentation (MLF), fermentation with lactic acid-producing *Lachancea thermotolerans* (Omega strain), and ion exchange (IE) treatment of juice followed by blending at a 30% proportion before alcoholic fermentation. All treatments were co-inoculated with malolactic bacteria on Day 2 of alcoholic fermentation, with the exception of FA. FA wines showed higher tannins (12.6%) and total phenolics (12.1%) than the control. FA was the least effective at reducing pH, decreasing it by 0.07 units and increasing titratable acidity (TA) to 6.98 g/L compared to 6.04 g/L in the control. Inhibition of MLF with FA resulted in wines with the least lactic acid (0.21 g/L versus 0.55 g/L in the control), most malic acid (2.16 g/L versus 1.21 g/L), and least acetic acid (0.03 g/L versus 0.18 g/L). *Lachancea* produced the most lactic acid (3.76 g/L) and was most effective at increasing TA (9.22 g/L). *Lachancea* wines exhibited the highest odor activity value for isoamyl acetate and FA wines for ethyl butyrate (271 and 37.6% higher than the control, respectively). The 30% IE juice wines had 18.5% less anthocyanins, 27.8% less total polymeric pigments, 8.6% less tannins, and 13.6% less total phenolics than the control. These wines also had the lowest pH, reduced by 0.42 units, the lowest potassium (14.9% less than the control) and the most tartaric acid (2.93 g/L versus 2.64 g/L). Sensory analysis is underway.

Funding Support: Richard Lauchland (Duas Terras Vineyard) is thanked for their donation of fruit.

Alternatives to Sulfur Dioxide: How Efficient Are They?

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In response to consumer demand for reduced chemical inputs, winemakers are exploring strategies to lower sulfite additions while maintaining wine quality. Producing high-quality wines with reduced SO₂ remains challenging because of the increased risk of microbial spoilage and oxidation. Consequently, alternatives such as chitosan and enological tannins are gaining interest for their

potential protective effects. Previous work showed no significant differences in phenolic concentration, hue, or color intensity in La Crescent wines when low free SO₂ levels (30 mg/L) were added at bottling, suggesting that minimal SO₂ may be sufficient to preserve color and quality during aging. The present study evaluated the effect of chitosan and enological tannins applied during winemaking on the quality of Frontenac and La Crescent wines, compared with wines produced using conventional SO₂ additions. Chemical parameters including free and total SO₂, color, and phenolic content, were assessed. In addition, levels of dissolved oxygen in wines at 7 and 11 cm from the neck were followed for 5 mo. La Crescent wines produced without SO₂ exhibited seven times more dissolved oxygen at bottling, lower phenolic concentrations, and reduced color intensity compared with wines made with SO₂. In contrast, Frontenac wines showed similar color intensity across treatments despite higher monomeric anthocyanin concentrations in wines produced with SO₂. The concentration of acetaldehyde, along with bacterial and yeast populations, will be evaluated after 5 mo of aging to further assess wine stability. These findings suggest that the effectiveness of SO₂ alternatives may be cultivar-dependent, highlighting the need for tailored sulfite-reduction strategies to maintain wine quality and stability.

Funding Support: USDA-AMS Iowa Specialty Crop Block Grant Program (SCBGP) through USDA grant 25SCBPIA1299

Valorization of Grape Pomace as a Clean-Label Additive in Pre-cooked Pork Sausages

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Grape pomace (GP), the primary solid by-product of winemaking, represents 20 to 25% of total grape solid mass. Although commonly composted, used as animal feed, or discarded (which may create environmental challenges), GP contains valuable bioactive components, including phenolics, fibers, and proteins. These compounds exhibit antioxidant and antimicrobial activities, making GP a promising clean-label ingredient for food applications, including processed meats. Therefore, this study investigated how Marquette (red) and La Crescent (white) winegrape pomace influence microbial stability and oxidative changes in pre-cooked pork sausages during an 84-day storage period. GP from both grape cultivars was dried using air-drying or vacuum-drying, ground, then analyzed for phenolic profiles, proteins and fiber content, and aerobic (APC) and psychrotrophic (PSY) microbial counts. Thereafter, GP was incorporated into pork sausages at 1% or 2%, with or without added antimicrobial or synthetic antioxidant. Sausages were encased, cooked, cooled, and stored under illuminated, refrigerated conditions to simulate retail display. Color, texture, lipid oxidation, and microbial counts were monitored over time for 84 days. La Crescent pomace contained higher phenolic and protein contents than Marquette pomace across both drying methods. Sausages with higher pomace concentrations showed increased initial counts for APC and PSY, but these decreased during storage, suggesting potential antimicrobial effects. Sausages containing 1% red pomace were significantly softer after 84 days than on day 0, but the texture was not significantly different between treatments. The sausages containing red pomace were significantly darker than the control. Proposed antioxidant effects appeared more apparent in color parameters than in lipid oxidation, as the biomarker for oxidative stress in sausages was not significantly different between treatments. Future work will focus on optimizing pomace particle size for selected treatments in preparation for sensory evaluation of GP-enhanced sausage formulations.

Funding Support: USDA NIFA NCR-SARE

Leveraging Volatile Sensing for Rapid Detection of Smoke-Derived Signatures in Grapes and Wines

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Smoke-exposed grapes accumulate volatile organic compounds (VOCs) and their glycoconjugate precursors that can be released during fermentation and impart unpleasant, smoky, and ashy flavors to wines, complicating harvest decisions and potentially compromising wine quality. Current diagnostic methods rely on gas chromatography-mass spectrometry/liquid chromatography-mass spectrometry (GC-MS/LC-MS) analyses and small-scale fermentations that are time-consuming and costly. As smoke events continue to affect the California wine industry, there is a growing need for rapid, cost-effective methods to assess smoke impact risk in grapes and wine. This study explores the use of a novel, commercially available signature analysis machine (SAM) that leverages differential sensing and data models to classify samples rapidly based on VOC signatures. Using wines across various cultivars from the 2020 and 2021 vintages, the SAM was able to differentiate smoke-affected wines from non-affected wines with classification driven by smoke exposure rather than variety or vintage. GC-MS and LC-MS chemical analyses were performed as validation for all samples to quantify smoke-derived volatile phenols and their glycoconjugates, respectively. Use of SAM for the detection of smoke impact is currently being extended to grape samples collected from Napa Valley appellations affected by the Pickett Fire in 2025. Results suggest that rapid VOC fingerprinting may enable detection and classification of smoke-derived signatures. Continued integration of VOC signals with chemical and sensory data to construct a library of validated smoke exposure signatures may enable rapid screening of grape samples and risk assessment. Similar approaches are also being explored for the detection of fresh mushroom aroma (FMA) in France, supporting the broader applicability of this strategy to vineyard-derived sensory risks.

Funding Support: Research was jointly funded through USDA-ARS, UC Davis, Moët Hennessy, and Analog Devices.

Impact of *Lachancea thermotolerans* Yeast Strains on Acids and Sugars during Chambourcin Wine Fermentation

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There is increased interest in using non-*Saccharomyces* yeasts such as *Lachancea thermotolerans* (LT) to enhance complexity and resolve challenges with low acidity in wines. Thus, the effect of different LT strains on acids and sugars of musts/wines during fermentation at 21°C for 15 days and at bottling were evaluated. In 2024, 263 kg of Arkansas-grown Chambourcin (*Vitis* hybrid) grapes were hand-harvested, randomized into batches, crushed, and destemmed. Seven inoculation treatments in duplicate were conducted using *Saccharomyces cerevisiae* (SC) and three LT strains including a commercial strain (Laktia™) and two experimental strains (LT1 and LT2), receiving sequential SC inoculations after 24 or 48 hr. All treatments were co-inoculated with malolactic bacteria 24 hr after inoculation with SC. At harvest, grapes had 20.29% total sugars, pH 3.52, 0.88% titratable acidity (TA), 0.77 to 0.85% malic acid, 0.02 lactic acid, and 1.06% total organic acids. All treatments completed alcoholic fermentation by day 10, when SC wines had the highest pH (3.71) compared to all other treatments. At day 10, SC wines had 0.71% TA, but wines fermented with LT had 0.84 to 1.06%. From days 7 to 14, LT1-SC-48 hr wines had higher lactic acid (0.38 to 0.40%) compared to SC and Laktia wines (0.16 to 0.26%), regardless of timing of sequential inoculation. At bottling, all wines produced with LT had lower pH (3.48 to 3.59) compared to SC

wines (3.69), except for Laktia-SC-24 hr and LT2-SC-24 hr wines. TA was highest in the LT1-SC-48 hr wines (0.93%). LT1-SC-48 hr wines had the highest lactic acid (0.40%) compared to all other wines (0.22 to 0.34%). LT strains in mixed inoculation with SC produced Chambourcin wines with lower pH and higher TA and lactic acid, offering a fermentation approach to enhance acidity, stabilize microbial balance, and address winemaking challenges in warm-climate regions.

Funding Support: Lallemand Oenology

Preliminary Results with Agrivoltaics in Western Colorado

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The transition from fossil fuels to renewable energy has increased competition for land between energy production and agriculture. Agrivoltaics (AV; also known as vitivoltaics in vineyards), which means producing energy and crop production on the same land, offers a potential solution by integrating solar panels with grapevines. In Western Colorado's semiarid climate, grapevines face increasing challenges from high temperatures and extreme weather events. Installing solar panels above grapevines may help reduce these stresses while also producing renewable energy. This study evaluates an AV system installed over mature Chardonnay grapevines at the Western Colorado Research Center. The experimental design compares vines grown under opaque or semitransparent solar panels with a control treatment without panels. Environmental conditions including solar radiation, air temperature, humidity, and wind speed were monitored alongside bud cold hardiness. Energy production and potential economic benefits were also assessed. Preliminary results indicate that temperatures beneath the solar panels were consistently warmer with increases of up to 3°C compared to the Control. A killing frost occurred in the Control on 29 Oct, while it occurred 1 mo later with AV. Bud cold hardiness measurements showed that buds under the solar panels were slower to acclimate but reached similar levels compared to the Control by mid-winter. Delayed acclimation may increase the risk of cold injuries during fall. In contrast, warmer temperatures under the panels reduce that risk. Long-term data will be needed to resolve which of those contrasting effects is more important. We will share additional data on early vine development and microclimatic conditions. These early findings suggest that AV may improve vine resilience to temperature extremes while providing additional economic benefits through renewable energy production.

Funding Support: Colorado Wine Industry Development Board, Colorado Department of Agriculture; Agrivoltaics research and demonstration grant, U.S. Department of Agriculture; specialty crop block grant, Dave and Mary wood Fund, McCary Family Fund, Anne Wenzel and David Miller, The AES Corporation, Western Colorado Community Foundation Core Fund and Giving Circle, CSU Energy Fund.

Effect of Vine Spacing and Boron Application on Yield, Fruit Chemistry, and Vine Nutrition of Muscadine Cultivar Paulk

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Muscadines (*Vitis rotundifolia*) are relatively pest- and disease-resistant grape species native to the southeastern United States. The region's soil is often deficient in boron (B) and mineral nutrient application is often overlooked. Furthermore, limited research has explored planting densities for commercial muscadine production. In late summer 2024, leaf blade and petiole analysis of the muscadine cultivar Paulk reported B deficiency. This study evaluated the effect of four B application strategies (spring soil

application; prebloom foliar application; fall foliar application after harvest, all at 0.22 kg/ha; and an untreated control) and three vine spacings (3, 4.6, and 6 m) on vine productivity, primary fruit chemistry, and tissue nutrient composition of 6-yr-old B deficient Paulk vines. B application strategies and vine spacings had no effect on yield per ha, berry weight, berry diameter, or primary fruit chemistry (total soluble solids, titratable acidity, and pH). Previous trials on the vines reported higher yield per ha at closer spacing, indicating size advantage for the vines diminishes as the vines age. Vine spacing did have a significant effect on yield per vine, with vines spaced at 6 m producing 6 kg and 15 kg more fruit than those spaced at 4.6 m and 3 m, respectively. B treatments differed in leaf blade ($p < 0.001$) and petiole ($p < 0.001$) B concentration at bloom and leaf blade B concentration at veraison ($p < 0.001$). All vines, treated or untreated, had B tissue concentration within or above the sufficiency range (15 to 25 ppm), contrary to 2024, where all tissues were deficient. Pruning weights are being collected to understand how these treatments influence the balance between vegetative growth and yield. In conclusion, B application may not improve yield and quality within a season, but it can improve the tissue B concentrations. Closer spacings may benefit growers in initial years; however, the benefit may not continue as the vines mature.

Funding Support: UGA foundation

Dose-Response Effects of Ethanol on Oral Sensations: Baseline Data for Non-Alcoholic Wine Formulation

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Traditional wines rely heavily on ethanol-induced activation of the Transient Receptor Potential Vanilloid 1 (TRPV1) receptor to produce heating and other mouthfeel sensations that are absent in non-alcoholic (NA) wines. Understanding how a wine matrix influences TRPV1-activated alcohol perceptions may help identify compounds that can replace ethanol's sensory effects in NA wine. This study aims to generate dose-response curves for ethanol and potential TRPV1-activated ingredients (e.g., capsaicin, gingerols, piperine) in water and de-alcoholized wine for heating/tingling, sourness, sweetness, bitterness, and astringency. In a pilot sensory panel, 13 untrained panelists evaluated nine water-based and nine NA wine-based samples, with ethanol concentrations of 0, 4.2, 5.25, 6.56, 8.19, 10.24, 12.8, 16, and 20%. Samples were served in randomized order among participants, using a swish-and-spit protocol. Attribute intensities were recorded in Compusense using the Generalized Labeled Magnitude Scale (gLMS). There were large individual differences in perceived sensory intensities across all samples. A two-way analysis of variance revealed significant interactions between ethanol concentration and solution type. Participants perceived a sensory difference at concentrations as low as 5.25% in water, but not until 8.19% in NA wine. Besides sweetness, other attributes changed with increasing concentration. The average intensity of 5.25% ethanol in water was moderate for heating/tingling and astringency, and weak for sourness. In NA wine, increasing ethanol concentration increased astringency and decreased sourness and sweetness, demonstrating ethanol's role in altering multiple sensory attributes. At the highest concentration (20%), the wine matrix suppressed heating/tingling by ~42% compared to water. Data collection on capsaicin and gingerols is ongoing using the same protocol. We will then expand data collection to 30 participants. Knowledge of the sensory perception of ethanol and potential substitutions, and their effects on wine sensory attributes, will help guide the formulation of no- or low-alcoholic wines that are acceptable to consumers.

Funding Support: Ha Nguyen: Nguyen Research Funds at UC Davis Viticulture & Enology

Exploring Photosynthetic Traits as Potential Mechanisms of Physiological Tolerance to Spotted Lanternfly Sap-Feeding

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The spotted lanternfly (*Lycorma delicatula*, SLF), a sap-feeding planthopper, has emerged as a major invasive insect pest in North America. Grape producers in Mid-Atlantic states have reported negative effects on yield and vine health following exposure to adult SLFs. Similarly, recent research has highlighted the potential repercussions of prolonged exposure on fruit ripening, transpiration, and vine carbon storage. However, the responses of photosynthetic traits remain underexplored, despite potential implications for vine carbon balance. To examine the effects of prolonged adult SLF sap-feeding on photosynthesis, young, non-bearing container-grown Chambourcin (*Vitis* interspecific hybrid) and Vidal blanc (*Vitis* interspecific hybrid) vines were randomly assigned to one of two infestation densities (0 or 20 SLFs/shoot). After 25 days of continuous infestation, simulating an uncontrolled infestation scenario, chlorophyll fluorescence and A-Ci response curves were conducted. Key photosynthetic metrics were determined, including maximum quantum yield of photosystem II and rates of maximum carbon assimilation, electron transport, carboxylation, and dark respiration. Vine canopies were harvested to quantify total leaf area. Leaf, petiole, and stem tissues were collected to assess the partitioning of dry biomass, nitrogen content, and nonstructural carbohydrate content. Based on previous research, we hypothesized that infested vines would have lower overall photosynthetic capacity relative to non-infested controls, leading to lower stem nonstructural carbohydrates. In contrast, infested Chambourcin vines had greater maximum quantum yield than non-infested vines, and infested vines of both varieties had comparatively elevated rates of maximum assimilation, electron transport, and carboxylation. These data indicate that vines may upregulate biochemical photosynthetic processes as a potential tolerance mechanism to sap-feeding, and ongoing analysis of nitrogen and carbohydrate content will determine if such responses can help offset resource removal by SLFs. This work highlights the need to further examine whether photosynthetic responses vary by vine genotype and under different infestation scenarios.

Funding Support: Virginia Tech College of Agriculture and Life Sciences, Virginia Wine Board

Climate-Driven Shifts in Budbreak and Cold Hardiness of Grapevines across Contrasting Environments

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Climate change is shifting the grapevine phenological calendar, resulting in earlier dormancy release and an increased risk of frost injury across diverse viticultural regions. This study examined how climate-driven temperature variability influences bud physiology, deacclimation behavior, and cold hardiness in grapevines grown under contrasting environments. A total of 312 F₁ hybrids derived from a cross between *Vitis riparia* as a cold-hardy parent and *Vitis vinifera* Fresno Seedless were evaluated for budbreak phenology and cold hardiness across two locations representing distinct climatic conditions: Parlier, California, and Fargo, North Dakota. Bud cold hardiness was assessed using differential thermal analysis, and genotypes were classified into five cold-hardiness groups based on relative lethal temperature thresholds. Budbreak timing and developmental progression were quantified using the global BBCH scale to characterize deacclimation behavior under contrasting environmental cues. Results demonstrated that low-temperature exotherm distributions shifted substantially between locations and developmental stages. Late-winter samples from Fargo exhibited greater absolute cold hardiness but increased phenotypic variance, whereas Parlier samples showed earlier loss of cold tolerance

and reduced variation in budbreak. Bud developmental timing covaried with low-temperature exotherm structure, with earlier BBCH progression associated with reduced cold tolerance, a relationship that was repeatable across environments. The findings of this study indicate that frost risk under climate variability is driven by genotype-specific deacclimation responses, identifying deacclimation dynamics as a measurable and selectable trait for regionally adapted grape breeding.

Funding Support: VitisGen 3, USDA Specialty Crop Research Initiative

Soil Hydraulic Responses to Combined Regenerative Management Practices in a Commercial Sonoma Vineyard

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Regenerative practices such as reduced tillage, organic amendments, and managed grazing are promoted in vineyards for their potential to support soil health and water resilience. Yet, their effects on soil water dynamics in commercial settings remain under-documented. To address this gap, we are monitoring soil hydrology in a field experiment in Sonoma County, CA, comparing a conventional alternate-tillage system with cover cropping to two combined regenerative treatments that integrate compost and sheep grazing but differ in tillage (no-till versus alternate tillage). Since spring 2023, soil moisture and temperature sensors installed at 30, 60, and 90 cm in both vine and tractor rows have been logging hourly data. Continuous sensor monitoring focuses on three primary treatments: the conventional system, the regenerative no-till system, and the regenerative alternate-till system. In parallel, seasonal infiltration tests have been conducted using mini-disk infiltrometers across treatments, and cumulative infiltration has been modeled using the Philip equation to estimate infiltration parameters. Preliminary results show that treatment-level differences in infiltration have been small, with most variation occurring between years rather than among management practices. Continuous soil moisture and temperature records exhibit expected seasonal patterns, with only modest and inconsistent separation among treatments. In some periods, regenerative treatments show slightly higher mid-profile moisture, though these differences remain subtle relative to temporal variability. Ongoing work centers on event-based analyses (heatwaves and major rainfall) and the integration of weather station data, evapotranspiration estimates, and soil physical properties, such as aggregate stability. These integrations and analyses will help refine the interpretation of whether stacked regenerative practices provide measurable hydrologic benefits relevant to irrigation planning and climate adaptation.

Funding Support: Foundation for Food & Agriculture Research (FFAR) and the California Department of Food and Agriculture (CDFA)

Innovative Volatile Organic Gas Sensing Machine Predicts Fresh Mushroom Aroma (FMA) Wine Taint in Must

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Fresh mushroom aroma (FMA) is an undesirable off-flavor in wine, characterized by a button mushroom-like aroma. Reported in several French wine regions around 2000, FMA is associated with specific fungal consortia present on grapes. The defect is

typically detected only at the end of alcoholic fermentation by sensory analysis. Early identification of FMA-risked musts would prevent economic losses associated with producing tainted wines and further prevent spoilage of wines via blending. Here, we report for the first time a technological approach enabling detection of FMA risk directly from grape must. The signature analysis machine (SAM) is a tabletop electronic nose designed to analyze complex mixtures of volatile organic compounds (VOCs). VOC detection is achieved using a high-dimensional array of highly orthogonal sensors integrated into a vial cap, generating a distinctive multidimensional "signature" for each sample. Following supervised training on labeled data sets, SAM learns characteristic signatures associated with predefined classes and can subsequently classify unknown samples, with performance improving as additional data are acquired. SAM was trained using 26 FMA-tainted and eight non-tainted Pinot meunier musts, as well as eight non-tainted Pinot noir musts. Sensory evaluations and chemical analyses of the wines produced from these musts were used for validation. The model achieved 99% specificity and greater than 90% sensitivity in detecting FMA taint directly from the original musts. Moreover, preliminary results indicate that SAM can predict the severity of FMA as later rated by trained sensory panels, weeks after fermentation, based solely on analysis of the initial must. These results demonstrate the potential of electronic-nose technology for early prediction of FMA in musts. Similar approaches are also being explored for smoke-taint detection in California, supporting the broader applicability of this strategy to vineyard-derived sensory risks.

Funding Support: This project was conducted in collaboration with Analog Devices, Inc (ADI), which provided early access to its VOC sensing machine as well as technical support related to data analytics and experimental design

Characterizing the Effects of Canopy Size on the Severity of Late-Season Dehydration in Sonoma County Cabernet Sauvignon

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In recent years, extreme temperature fluctuations near grape harvest have made accurate yield prediction increasingly difficult. Late-season dehydration, a process that occurs after maximum berry weight is attained and concurrently with mesocarp cell vitality loss, plays a crucial role in concentrating sugars to achieve desired wine styles and defines this stage of uncertainty. Its extent depends largely on the vapor pressure deficit (VPD) around the berry, vine water stress, and time from onset to harvest. Recent studies have focused on methods to mitigate late-season dehydration, particularly in warmer years, yet to our knowledge, no research has examined the extent and drivers of differences within the same vineyard. In 2024, we conducted a yield variability trial comparing high- and low-vigor canopies that revealed a wide range of dehydration-related cluster weight change from veraison to harvest between +34% and -22%. Building on these preliminary observations, in 2025, five Cabernet Sauvignon vineyards in northern Sonoma County were classified as high- or low-vigor plots based on a histogram analysis of normalized difference vegetation index from mid-July 2024 Sentinel 2 satellite imagery, ensuring maximum canopy differences without manipulation. Fruit zone microclimate was monitored continuously from veraison until harvest, while berry weights were collected weekly. Destructive cluster weights were collected at veraison, maximum weight, and commercial harvest. A relatively cool season paired with several rain events in the late season reduced dehydration, and few significant differences were observed. However, statistically significant differences in fruit zone microclimate were found between vigor classes. An analysis of daily differences in fruit zone VPD showed that these rarely exceeded 1.0 kPa until ambient temperatures exceeded 35°C. This suggests that in future years, an accumulation of temperatures above 35°C in the

late season may result in more significant differences in the rate and degree of dehydration.

Funding Support: GALLO

Budgeting Nutrient Removal in Vineyards in Dry Climates

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Efficient nutrient management is critical for sustaining grapevine productivity and fruit quality. This study evaluated annual nutrient removal in irrigated vineyards of arid eastern Washington (<200 mm precipitation) over a 3-yr period (2021 to 2023). Vine tissue samples were collected from Chardonnay, Sauvignon blanc, Syrah, and Concord to quantify potential nutrient losses through harvested fruit, abscised leaves, and, for winegrapes, pruned canes. Results showed that Concord exhibited greater annual nutrient removal compared to winegrapes, with potassium and nitrogen representing the largest macronutrient losses. Fruit harvest accounted for the majority of nutrient export, which was strongly influenced by crop yield. Additional potential losses occurred via leaf abscission and cane pruning, with higher biomass (i.e., greater canopy size) amplifying the removal of macronutrients such as nitrogen and calcium. Early fall frost events disrupted foliar nutrient remobilization, resulting in elevated retention of nutrients such as nitrogen and phosphorus in senescent leaves. These findings highlight the necessity of comprehensive vineyard nutrient budgets that integrate all pathways of nutrient loss. By accounting for fruit, leaf, and cane contributions, this work provides actionable insights for optimizing fertilization strategies, enhancing nutrient use efficiency, and supporting long-term vineyard sustainability in dry-climate production systems.

Funding Support: • USDA-NIFA Specialty Crop Research Initiative • WA State Grape & Wine Research Program • WA State Concord Grape Research Council • WSDA Specialty Crop Block Grant Program

Performance of Fungus-Resistant Grape Varieties in the Niagara Peninsula in Ontario, Canada

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Fungus-resistant grape varieties may advance sustainable viticulture in Ontario, Canada by reducing fungicide inputs while maintaining productivity and wine quality. This project evaluates suitability and climate resilience of fungus-resistant grape varieties in the Niagara Peninsula in Ontario, using an integrated approach that includes seasonal development, winter risk, vine performance, fruit composition, and winemaking outcomes. These results provide preliminary evidence for a broader program to inform new plantings at the Brock University research farm and multisite evaluation. Across two seasons, bud cold hardiness and field phenology metrics, including budbreak and bloom timing, were monitored to assess winter injury risk and alignment with the local growing season for Soreli, Sauvignon Rytos, Cabernet volos, and Merlot kanthus. During the 2024 to 2025 dormant season, varieties showed distinct cold hardiness dynamics; Cabernet volos the best cold tolerance (low temperature exotherm of -24.9°C), and all varieties remained strongly freeze-tolerant (below -17°C) by the end of sampling, indicating substantial protection from early spring frost. Grapevine performance indicators, including yield components and vine balance measures, were collected to benchmark production consistency. At harvest, berry composition was measured to benchmark ripening relative to regional targets. Cabernet volos was harvested at 11.4% potential alcohol compared with 13.7% for Cabernet franc from the same vineyard, highlighting variety-dependent differences in sugar accumulation under shared

site conditions. To connect vineyard performance with practical wine outcomes, Soreli and Cabernet volos were fermented over two years using locally isolated Ontario yeast strains, *Saccharomyces uvarum* CN1 in the first year and *S. uvarum* CS6 in the second year, alongside commercial *Saccharomyces cerevisiae* controls. Fermentations completed to dryness, wines were chemically characterized, and samples are suitable for future sensory evaluation. Collectively, these results establish baseline metrics of resilience and regional suitability to guide broader validation.

Funding Support: Ontario Research Fund- Research Excellence

Transcriptome and Metabolite Profiling Reveals Correlation of Smoke Taint Accumulation with the Phenylpropanoid Pathway

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Wildfire smoke exposure has continued to be a threat for the wine industry, causing smoke-tainted wines, reminiscent of medicinal, smoky smell and ashy aftertaste. Grape berries exposed to smoke can uptake smoke-derived volatile phenols (VPs) and metabolize them into glycosylated derivatives (Gly-VPs), which later can be released during fermentation and upon consumption. The biosynthetic pathway of Gly-VPs is ill defined, albeit studies have identified several smoke-responsive glycotransferases that contribute to their accumulation. The identified glycotransferases function in the phenylpropanoid pathway and are responsible for biosynthesis of other secondary metabolites. Therefore, this study aims to investigate the correlation of Gly-VPs accumulation with monomeric phenolics biosynthesis in Cabernet Sauvignon berries following simulated smoke exposure. Plant growth regulators that are reported to regulate the phenylpropanoid pathway were applied to amplify the potential correlation and to provide insights on possible mitigation practice in the vineyard under smoke exposure risk. Absciscic acid (ABA) and methyl jasmonate (MeJA) were applied to the fruit zone of the vine 1 wk postveraison and 1 wk prior to the simulated smoke exposure. Grapes were sampled 1 and 5 days post-smoke exposure and at harvest (33 days postexposure). There was a positive correlation between the concentration of Gly-VPs and monomeric phenolics in grapes collected at harvest, regardless of the ABA/MeJA application. The ABA-treated grapes had significant higher amounts of Gly-VPs than the control without ABA treatment at 5 days postexposure. The stimulating effect of ABA on Gly-VPs accumulation diminished for some of the measured Gly-VPs at harvest. The results suggested that either the application of ABA might promote further metabolism of the measured Gly-VPs into new metabolites or it affected the rate of the glycosylation process rather than the amount. The effect of MeJA on Gly-VPs accumulation was arbitrary. More analyses including transcriptome profiling will be performed to elucidate the observations.

Funding Support: USDA

Vine Nitrogen Dynamics: Rootstocks Alter Pinot noir Growth and Productivity More than Yeast Assimilable Nitrogen

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Nitrogen (N) is one of the most important macronutrients in grapevines that affects vine growth, productivity, and fermentation kinetics. Tissue N and yeast assimilable N (YAN) are indicators of vine and must N status used by grapegrowers and winemakers and can be influenced by rootstock. The most common rootstocks planted in Oregon are 3309C, 101-14, and Riparia Gloire, all vigor-reducing rootstocks that may limit N uptake and must N. A mature trial (27-

to 28-yr-old) of Pinot noir grafted to eight rootstocks (1103P, 101-14, 3309C, 420A, 44-53, 5BB, Riparia Gloire, and Schwarzmann) and own-rooted vines was evaluated over 2 yr (2024 and 2025) to understand N dynamics under the non-fertilized, non-irrigated management common in Oregon's Willamette Valley. There were differences by rootstock for vegetative growth, yield, vine and must N, and N utilization efficiency. Vines on 5BB, 420A, and 1103P were consistently high performers. These rootstocks had nearly two-fold vegetative growth and yield compared to vines on 3309C, 44-53, Riparia Gloire, and Schwarzmann (low performers). Vines on 5BB consistently had the highest N concentration in leaf blades at veraison. However, N utilization efficiency (yield/plant N) was consistently highest in the three high-performer rootstocks (1103P, 5BB and 420A). However, only 5BB had higher must YAN than all other rootstocks and own-rooted vines. While rootstock influenced vegetative and reproductive growth, the ratio of vine size-to-crop weight was also affected by rootstock. The high-performer vines on 5BB, 420A, and 1103P were balanced (yield: pruning wt: 7 to 9) while lower-performing vines on Riparia Gloire, 44-53, and Schwarzmann produced a higher proportion of yield relative to smaller canopies (yield: pruning wt: 12 to 15) and had lower N utilization efficiency. While rootstock can have a major impact on vine growth, yield, and N utilization efficiency, there is similar must N accumulation for Pinot noir.

Funding Support: Oregon Wine Board, Oregon Wine Research Institute

Quantitative Analysis of Grapevine Red Blotch Associated Virus in the Napa Valley

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A study was conducted to measure the grapevine red blotch virus (GRBV) titer and distribution within individual vines and to assess the effect on fruit chemistry. DNA from basal leaf petiole samples was extracted and quantitative PCR was used to measure the number of GRBV copies per milligram of plant tissue. Initial screenings were performed in eight different vineyards based on visual symptoms postveraison. Vines from each vineyard were categorized based on viral titer and placed into groups of non-detect, low-, medium- and high-titer. Three vines per category from each vineyard were included in the study. Six canes across each vine were sampled and the basal leaf petioles were tested for virus titer. Clusters were collected from selected shoots 1 to 3 days before commercial harvest and fruit from each vine was composited for standard chemistry and phenolic analysis. The GRBV viral load in petiole samples ranged from <5 viral copies/mg (non-detect) to 110,000,000 viral copies/mg. Viral load in individual canes across the vine can be highly variable. Overall, there was a correlation between viral load and effect on fruit chemistry. GRBV concentrations of >300,000 copies/mg were associated with reduced total soluble solids and anthocyanins. In addition, malic acid and titratable acidity increased, along with an associated reduction in pH. Findings show that GRBV can be present at low levels, having minimal or no effect on fruit chemistry. Individual varieties and vineyards may have a varying response to viral load. Additional work is needed to gain a better understanding of viral load effect on fruit chemistry, as well as making rogueing decisions.

Funding Support: ETS Laboratories

A Targeted LC-MS/MS Method for Quantifying Amino Acids in Cold-Hardy Grape Juice and Wine

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Cold-hardy grape cultivars differ from *Vitis vinifera* by producing a chemically complex fermentation matrix with elevated protein

content, diverse free amino acid pools, and compositional shifts during fermentation. Traditional nitrogen metrics such as yeast assimilable nitrogen (YAN) lack the resolution to capture amino acid-specific dynamics that directly influence yeast metabolism, fermentation kinetics, and aroma formation. To address this analytical limitation, a targeted liquid chromatography tandem mass spectrometry (LC-MS/MS) method was developed to enable high-resolution, quantitative profiling of individual amino acids in grape juice and fermented wine. The method was designed to operate across chemically diverse matrices, accounting for high organic-acid content, ethanol, and matrix effects typical of fermentations of high-protein, cold-hardy cultivars. Direct sample preparation using only centrifugation was optimized for rapid throughput while preserving amino acid integrity. Chromatographic separation was performed by reversed-phase liquid chromatography, followed by tandem mass spectrometric detection with multiple reaction monitoring of amino acid-specific transitions. Stable retention times, compound-specific ion ratios, and deuterated internal standards were used to ensure analytical confidence, reproducibility, and accuracy for targeted analytes. Method performance was evaluated for linearity, sensitivity, repeatability, and matrix effects in both juice and wine. The resulting method enables simultaneous quantification of free amino acids across fermentation stages, providing a detailed nitrogen speciation profile that conventional assays cannot capture. When paired with complementary acid profiling by high-performance liquid chromatography and volatile analysis by headspace solid-phase microextraction gas chromatography-mass spectrometry, this LC-MS/MS method enables interrogation of nitrogen utilization and metabolic outcomes with molecular specificity. This analytical framework lays the groundwork for mechanistic investigation of nitrogen behavior in fermentation systems and supports data-driven modeling of yeast nutrient utilization. More broadly, the method provides a transferable tool for fermentation research in which amino acid composition rather than bulk nitrogen concentration governs biological and sensory outcomes.

Funding Support: USDA - Specialty crop block grant program

Continuous Cold Stabilization Via Rapid Selective Crystallization

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Conventional cold stabilization of white wines involves chilling and holding wines below 32°F for periods ranging from 1 day to several weeks, with the option of potassium bitartrate seeding. This approach is energy- and time-intensive and can result in yield losses of up to 1.5%. Alternative technologies have had limited adoption due to inconsistent performance, additive use, negative effect on organoleptic properties, pH modification, high capital costs, or difficulty integrating into operations. Our research objective was to develop a reliable, additive-free, and commercially viable cold stabilization method that reduces energy consumption while preserving wine quality. amaea specializes in developing novel molecular filtration media for selective, continuous, rapid, and scalable wine treatment applications in packed, expanded, and fluidized beds. Fluidized beds are known for their efficient mass and energy transfer properties. We hypothesized that applying particle engineering techniques to functionalize and modify potassium bitartrate crystal morphology to improve flow and micromeritic properties would optimize the crystals' performance in a fluidized bed and enable it to be regenerated and reused. This would enable consistent, energy-efficient cold stabilization at commercial scale. The engineered medium was incorporated into a continuous filtration-based system integrating a fluidized bed and controlled heat transfer set up. The system achieved rapid, continuous cold stabilization at processing rates of up to 1000 L/hr using a single 100 kg crystal column. The degree of cold stabilization achieved is adjustable by altering input temperature and flow rate, allowing

wineries to achieve cold stabilization to their required specification. Compared with conventional refrigeration-based cold stabilization, energy consumption can be reduced by up to 85%, while achieving potassium bitartrate stability without measurable effects on wine sensory or pH. These findings demonstrate that selective crystallization using an engineered functionalized potassium bitartrate medium enables an efficient and scalable alternative to traditional practices.

Funding Support: amaea Limited

USDA Releases Loose-clustered Vignoles Clone That Reduces Late Season Fruit Rots

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Vignoles is an aromatic, white-fruited winegrape variety valued by growers and wineries in the eastern United States. Vignoles is grown in diverse locations in New York, Missouri, Indiana, Ohio, Pennsylvania, Illinois, Nebraska, and Michigan. Consumers recognize and value the variety for its special wine quality. However, Vignoles production is limited by its extremely compact clusters that increase its propensity to Botrytis cinerea bunch rot and sour rot, frequently leading to significant crop losses and decrease in quality. In 2007, the USDA grape genetics research unit used mutation breeding to screen and produce 'loose-clustered' clones that would offer slightly reduced fertility, less compact clusters, and reduced severity of cluster rots. Selections were evaluated at two field locations from 2016 to 2020. Compared to standard Vignoles, they reduced cluster rot severity by ~30 to 94% and reduced cluster weight by 25 to 33% over five growing seasons. The USDA Grape Genetics Research Unit has released a single selection called "Vignoles 2" that offers a two- to four-fold reduction in yield and quality losses due to disease. For growers, this will often offset the 25% reduction in cluster weight, resulting in higher yields of sound, high quality fruit.

Funding Support: the USDA Grape Germplasm Resources unit of the Agricultural Research Service, and by the Cornell Federal Formula Funds Grants Program, administered by Cornell AgriTech.

Adult Spotted Lanternfly Infestations on Cabernet franc

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The spotted lanternfly (*Lycorma delicatula*, SLF) is an invasive sap-feeding planthopper that has emerged as a significant threat to winegrape production in Virginia and the eastern United States. While grape producers primarily apply insecticides to control adult SLF populations, more information is needed to optimize standard practices and develop targeted density-specific management strategies. For this study, 21 6-yr-old Cabernet franc (*Vitis vinifera*) vines grafted onto 420-A rootstocks (*Vitis berlandieri* × *Vitis riparia*) were caged with exclusion netting at the Alston H. Smith Jr. Agricultural Research and Extension Center in Winchester, VA. Vines were randomly assigned to different infestation density treatments (0, 5 adult SLF per shoot, and 10 adult SLF per shoot) and different infestation timings (at veraison, 3 wk after veraison, or both times). Vines were infested at each time point for a week before SLFs were removed. At harvest, yield parameters (yield/vine, cluster weight) were quantified and berry samples were collected to assess the effects on berry weight and juice chemistry parameters (total soluble solids, pH, titratable acidity, yeast assimilable nitrogen). Buds were collected in winter to assess effects on cold tolerance. The first year of data suggests that the density and timing of adult SLF infestations had no significant effect on measured Cabernet franc fruit chemistry parameters, yield parameters, or bud cold

hardiness. Additionally, preliminary results seem to indicate that experimental vines tolerated the imposed infestation length and densities without incurring effects on measured traits. Data will be collected in the spring to evaluate effects on fruit from sequential harvests. Additional analyses looking at fruit total phenolics and volatile composition will be critical to understand holistic effects on grapevine and fruit chemistry. Finally, these treatments will be implemented for a second year to evaluate the effect of consecutive feeding events across seasons.

Funding Support: Virginia Wine Board, Virginia Agricultural Council, Virginia Tech College of Agriculture and Life Sciences

2,4-D Detected Within Texas AVA Grapevine Rooted Cuttings Negatively Influences Cutting Root Growth and Development

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Growers within the Texas High Plains and Hill Country American Viticulture Areas (AVA) produce nearly 100% of all Texas *Vitis vinifera* L. grapes. In addition, these areas are major agricultural regions and formulations of auxin-based herbicides (dicamba and 2,4-D) are applied to many crops within these regions. Close proximity to cropland and pastures and climatic factors found within each AVA have made vineyards particularly vulnerable to auxin-based herbicide injury. Because grapevines are highly sensitive to synthetic auxin herbicides, grapegrowers are concerned about the effect these herbicides may have on current vine growth and productivity, and long-term sustainability. Therefore, to determine whether auxin-based herbicide residues remain in vine tissues for an extended period of time, on two occasions in winter 2023 dormant canes were gathered from the Texas High Plains and Hill Country AVA, and rooted cuttings of five grape cultivars (Cabernet Sauvignon, Malbec, Mourvèdre, Roussanne, Tempranillo) were gathered from each AVA. For each experiment, cuttings were rooted in a growth chamber and moved to a greenhouse once cuttings rooted. Foliage and root tissues from rooted cuttings were evaluated for the presence of 2,4-D and dicamba. Results indicate dicamba residues were not detected in foliage or root tissues. However, 2,4-D residue was detected in foliage and root tissues across each cultivar and each location. Furthermore, for each cultivar and location, greater concentrations of 2,4-D were found in leaf tissues when compared to root tissues. In addition, Pearson correlation and linear regression analysis indicated that cutting 2,4-D leaf and root concentration negatively affected root dry weight and longest root of each cutting. These findings suggest 2,4-D residues remain in vines for an extended time period and may reduce future root growth, potentially affecting future vine growth, productivity, and sustainability.

Funding Support: Texas Department of Agriculture

Field Performance of a 'Chambourcin' × 'Cabernet Sauvignon' Hybrid Population for Cold-Hardy Winegrape Production

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Vitis interspecific hybrid Chambourcin is a French-American hybrid grape valued for its cold hardiness, disease resistance, and wine quality in the Midwestern United States, while *Vitis vinifera* Cabernet Sauvignon is not well adapted to this climate but is widely recognized for its superior enological characteristics. This study evaluated the field performance, phenology, and fruit composition of a Chambourcin × Cabernet Sauvignon hybrid

population under Missouri growing conditions to identify selections with improved climatic adaptation and production potential. A mapping population of 273 F1 hybrid vines maintained at the Missouri State University Fruit Experiment Station was evaluated during the 2025 growing season. Of these, 173 surviving vines were assessed for field performance. Assessments were conducted to document vine growth, phenological development, winter injury, and disease incidence. Fruit was sampled at commercial maturity for analysis of soluble solids, titratable acidity, pH, and juice color, and basic berry and cluster characteristics were documented. Variation was observed among progeny in budbreak timing, ripening progression, winter survival, and susceptibility to common fungal diseases. Several selections exhibited improved cold tolerance and reduced disease pressure. Fruit composition among top-performing individuals demonstrated balanced sugar and acid profiles, consistent ripening patterns, and favorable harvest windows suitable for wine production. These results indicate that select Chambourcin × Cabernet Sauvignon hybrids possess strong potential for sustainable grape production in Missouri and similar regions. Data generated during this initial evaluation phase establish a foundation for continued selection and subsequent enological assessment. This population represents a promising resource for developing regionally adapted cultivars that reduce production risk and chemical inputs while maintaining high fruit quality.

Funding Support: U.S. Department of Agriculture, Agricultural Marketing Service

Mythbusting Sulfur Phytotoxicity in Grapes: The Role of Adjuvant and Environmental Conditions on Sulfur Phytotoxicity

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Sulfur assists in powdery mildew disease management and aids in fungicide resistance mitigation. Unfortunately, many grapegrowers limit use of sulfur during mid-summer due to concerns about temperature-related phytotoxicity. Currently there is a lack of data-backed information on when sulfur may induce damage on winegrapes (*Vitis vinifera*). Available information is often anecdotal and disregards environmental conditions, product formulations, and tank mixtures. This study used field, potted, and growth-chamber trials with *V. vinifera* Chardonnay to evaluate factors including sulfur formulation, adjuvants, and their interaction under different temperatures and relative humidities (RH). Both brand name and generic sulfur were used at a concentration of 19.15 g/L. Adjuvants evaluated were Complex, Embrace, JMS, Nufilm-P, Oroboost, and Silwet. In the field and potted study, sprays were conducted on days that were forecast to exceed 29.4°C. In growth chamber studies, four environmental combinations were used: 38°C + 80% RH, 38°C + 45% RH, 27°C + 80% RH, and 27°C + 45% RH. Phytotoxicity was limited in all treatments, even when field and potted vine treatments occurred between 30.6 and 40°C for both the name brand sulfur control (0.4% foliar severity) and the generic sulfur control (4.2% foliar severity). The growth chamber study showed that temperature was the largest influence on phytotoxicity expression, but RH also increased incidence and severity. Leaf age affected phytotoxicity, with younger tissue typically having higher severity (16%) than older tissue (0.01%). The use of certain adjuvants increased the severity of phytotoxicity significantly in the field, potted, and growth-chamber studies. This data suggests that the risk of mid-summer phytotoxicity is less driven by sulfur itself, but more by acute environmental conditions like high RH and interactions with other chemicals that may be in the spray tank.

Funding Support: Washington State Grape and Wine Research Program, Washington State University, Auction of Washington Wines, Washington State wine grape growers and wineries through the Washington state wine commission, Northwest Center for Small Fruits Research

Integrating UV-C and Canopy Management for Grape Powdery Mildew Control

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The germicidal use of UV-C light (254 nm) is a method of grape powdery mildew (*Erysiphe necator*) suppression in grapevines (*Vitis vinifera*). However, UV-C applications cannot be adjusted like traditional sprays to account for changes in canopy volume, so information is needed on how canopy management influences the effectiveness of UV-C light applications. From 2023 to 2025, we conducted a study on the effectiveness of hybrid management programs (fungicides + UV-C), coupled with canopy management techniques, on powdery mildew control. The study included a fungicide program plus UV-C (200 J/m²) once or twice a week during the powdery mildew “critical window” (start of bloom to 4 wk post full-bloom), an unsprayed control, and a full-season fungicide control. Within each management regime, we compared the influence of canopy management strategies, including prebloom shoot thinning, shoot thinning + early fruit zone leaf removal, and a “do nothing” control. Disease control on clusters at the end of the season was equivalent whether a full-season fungicide program was used, or whether a modified fungicide + UV-C program (either 1x weekly, or 2x weekly) was used ($p = 0.65$, 0.95 , and 0.26 , respectively, for 2023, 2024, and 2025). Canopy management influenced cluster disease in 2023 ($p = 0.020$) and 2024 ($p = 0.0016$) and in 2025 ($p = 0.058$), with the early shoot thinning + prebloom fruit zone leaf removal having the lowest cluster disease severity. Yield and fruit quality differences were linked to defective disease managed, not canopy management, and were driven by high disease severity in the untreated control. This trial shows that UV-C can be integrated into conventional disease management programs, replacing sprayed fungicide treatments during bloom, while still maintaining disease control on clusters.

Funding Support: Washington State Grape and Wine Research Program, Washington State University, Auction of Washington Wines Washington state wine grape growers and wineries through the Washington state wine commission, Northwest Center for Small Fruits Research

Culture in the Cellar and Beyond: Leadership That Strengthens Teams in Viticulture and Enology

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In viticulture and enology, technical expertise and quality processes are essential, but they are not sufficient on their own. The teams that bring grape to glass, year after year, depend on leadership that fosters trust, cohesion, and a culture of shared purpose. In this keynote, Dr. Bernie Mullin introduces a practical leadership framework designed to help wine industry professionals strengthen internal culture and team performance while maintaining the craft and quality that define their work. Drawing on case examples from high-stakes environments, Dr. Mullin shows how trust—the willingness of team members to rely on one another, speak up, and engage openly—serves as the foundation for resilient operations. Leaders will learn how to cultivate psychological safety, align team goals with mission, and enhance collaboration between vineyard crews, cellar teams, winemakers, marketing staff, and leadership. The session will address persistent challenges in the wine industry, such as seasonal workforce dynamics, burnout in harvest seasons, and disconnects between technical teams and organizational strategy. Attendees will leave with actionable strategies to embed trust and purpose into culture and daily work; improve retention and engagement across roles and seasons; and align organizational culture with quality, sustainability, and innovation objectives. By investing in people and leadership, wineries and vineyards can turn culture from a soft ideal into a measurable competitive advantage, elevating both team performance and the excellence of their wine.

Funding Support: Dr. Bernie Mullin

AI-Integrated Spectroscopy for Early Detection of Grapevine Powdery Mildew

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Powdery mildew (*Erysiphe necator*) remains one of the most economically significant diseases in viticulture, necessitating repeated preventive fungicide applications. In Michigan vineyards, management is largely calendar-based because infection is typically detected only after visible symptom development. This reactive strategy increases production costs, elevates resistance risk, and contributes to unnecessary chemical inputs. This study evaluates the feasibility of integrating high-resolution Vis/near-infrared spectroscopy with machine learning for early, non-destructive detection of powdery mildew at the leaf level. Year 1 objectives were to (i) establish a controlled infection system, (ii) generate high-resolution spectral data sets (350 to 1800 nm) from healthy and infected grapevine leaves, (iii) identify diagnostic wavelength regions, and (iv) initiate development of an AI-based classification framework. Dormant canes of Pinot noir, Chardonnay, Riesling, and Pinot blanc were propagated under controlled greenhouse and growth chamber conditions. Plants were inoculated with morphologically confirmed powdery mildew spores and monitored through symptom development. Leaf reflectance was collected using ASD, SVC, and Avantes spectrometers with standardized probe positioning. Spectral preprocessing included Savitzky-Golay smoothing, derivative analysis, chlorophyll index calculation (MCARI), and dimensionality reduction. Infected leaves exhibited consistent spectral alterations across cultivars, including increased reflectance in the visible range (400 to 700 nm), a shallower chlorophyll absorption feature near 670 to 690 nm, blue-shifted red-edge transitions (700 to 750 nm), and reduced water absorption depth near 970 nm. First-derivative analysis enhanced separability by revealing diminished chlorophyll-related peaks and reduced near-infrared scattering associated with mesophyll disruption. Diagnostic regions consistently identified across cultivars included 550 to 600 nm, 650 to 700 nm, 700 to 800 nm, and ~970 nm. Preliminary implementation of PCA, support vector machine, and random forest classifiers demonstrated spectral separability between healthy and infected leaves. These results establish a robust foundation for scaling AI-integrated spectroscopy from leaf-level detection to canopy-level monitoring and precision disease management in vineyards.

Funding Support: The Michigan Department of Agriculture & Rural Development (MDARD) and Michigan State University Project GREEN

New Yeast Strain Promoting Aromatic Complexity and Stability in Cool-Climate Fermentations

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The purpose of this research was to identify a new strain of *Saccharomyces cerevisiae* capable of producing complex, aromatically stable wines suitable for extended aging. This work was carried out at the Center of Excellence for Research in Microbiology (CERM), a partnership between Enartis and Italiana Biotecnologie which focuses on the research and development of yeasts, yeast derivatives, and bacteria for enological applications. Strains were evaluated through fermentations of red and white cool-climate grape varieties, with temperature and nutrition as additional variables, after which chemical and sensory analysis of the resultant wines revealed significant differences in their volatile profiles and aromatic properties. Recently developed at the CERM, the new yeast strain EnartisFerm Q GRACE was found to produce relatively high levels of 3-ethoxypropanol compared to

other commercially available strains of *S. cerevisiae*. Contributing ripe fruit or pastry-like notes, 3-ethoxypropanol is a higher alcohol that remains stable in wine over time, thereby preserving aromatic complexity during aging. EnartisFerm Q GRACE was also found to produce roughly equal concentrations of ethyl and acetate esters, resulting in wines with more balanced fruity and floral character.

Funding Support: N/A

Fermentation Temperature as a Tool to Limit *Hanseniaspora uvarum* Proliferation in Spontaneous Wine Fermentations

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Hanseniaspora uvarum is frequently observed as the dominant non-*Saccharomyces* yeast during the early stages of spontaneous grape juice fermentations, with important consequences for wine quality and fermentation performance. Recent studies indicate that *H. uvarum* exhibits a faster growth rate than *Saccharomyces cerevisiae*, enabling it to rapidly dominate microbial populations at fermentation onset. Although spontaneous fermentations are often associated with enhanced wine complexity, excessive proliferation of *H. uvarum*, and the associated production of acetic acid and ethyl acetate, poses a significant risk to fermentation reliability and wine quality. Previous work suggests that *H. uvarum* has a lower optimal growth temperature than *S. cerevisiae*. In this study, we investigated the effect of fermentation temperature on the growth dynamics and competitive interactions between these two species using flow cytometry. High-resolution cell monitoring revealed that relatively small changes in fermentation temperature strongly influenced early population dynamics. Higher fermentation temperatures favored *S. cerevisiae*, allowing it to achieve higher cell densities early in fermentation and resulting in faster and complete alcoholic fermentations. In contrast, lower temperatures promoted *H. uvarum* growth and led to slower fermentations. The effect of temperature was further evaluated in a spontaneous Chardonnay fermentation, with microbial populations monitored using DNA metabarcoding. Elevated fermentation temperatures shifted population dynamics toward increased relative abundance of *S. cerevisiae* and accelerated fermentation progression. Conversely, lower temperatures resulted in sustained dominance of *H. uvarum* and extended alcoholic fermentation by ~14 days. These results demonstrate that modest adjustments in fermentation temperature represent a practical strategy to modulate microbial competition and reduce risks associated with excessive *H. uvarum* proliferation in spontaneous wine fermentations.

Funding Support: Wine Australia

Genetic and Phenotypic Profiling of SO₂ Tolerance in *Brettanomyces* Winery Isolates

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Brettanomyces bruxellensis is a key spoilage organism of wine and displays substantial strain variation in tolerance to sulfur dioxide (SO₂), the principal antimicrobial used for its control. To elucidate the genetic determinants underlying SO₂ tolerance in winery-associated populations, we phenotypically assessed 26 isolates from Australian wineries and generated long-read genome assemblies. The isolates exhibited broad variation in SO₂ tolerance, which was strongly associated with phylogenetic lineage and ploidy level. Haplotype-resolved analysis of SSU1, encoding a sulfite efflux pump implicated in SO₂ resistance, revealed nine distinct haplotypes, including the previously reported high-tolerance H1 variant. Strains with elevated SO₂ tolerance contained multiple copies of the H1 haplotype, often linked to retrotransposon insertions and structural rearrangements at the SSU1 locus. Comparisons with laboratory-

evolved strains further supported a role for retrotransposons in promoting SSU1 copy number expansion. Collectively, these results indicate that transposon-driven structural variation is a key mechanism contributing to adaptive SO₂ tolerance in winery *B. bruxellensis* populations.

Funding Support: Wine Australia

Reductive Versus Oxidative Winemaking Effects on the Chemical Composition and Sensory Profile of Vermentino Wines

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Vermentino grapes (pH 3.41, Brix 22.5, titratable acidity 5.5 g/L) were pressed and split into three treatments, namely Control, N₂ (reductive) handling, and Air (oxidative) handling. Control juice received 50 ppm SO₂ and CO₂ blanketing, N₂ was bubbled with nitrogen for 2 hr at 1000 mL/L/hr, and Air underwent hyperoxygenation for 2 hr at 1000 mL/L/hr. Control and N₂ were inoculated with VL3 (Laffort). Meanwhile, Air was further split into two treatments: AirVL3, which was inoculated with VL3; and AirMon, which was inoculated with Lalvin M (Montrachet strain, Lallemant). Further, during fermentation N₂ and AirMon received glutathione. Oxidation-reduction potentials (ORP; Ag/AgCl reference electrode) during juice processing stayed at 125 mV for Control and 50 mV for N₂, demonstrating that an addition of SO₂ was sufficient to maintain a low pre-fermentation ORP. The addition of ascorbic acid on N₂ only made a marginal difference in ORP when SO₂ was present. Air, which received no SO₂, averaged 313 mV prior to hyperoxygenation and a peak of 420 mV and dissolved oxygen (DO) of 4.6 mg/L during hyperoxygenation. Passive hyperoxygenation led to an increase of almost 200 mV in ORP over the Control. Average phenolics were 141 mg/L for Control, 120 mg/L for N₂, and 20 mg/L for AirVL3 and AirMon. Total ester odor activity values were highest for Control, and 15, 23, and 37% lower than Control for N₂, AirVL3, and AirMon, respectively. Overall, the extremely reductive environment of the juice and fermentation stage for Control and N₂ led to wines that were objectionable due to their H₂S levels. Comparatively, hyperoxygenation in conjunction with yeast choices can achieve reductive (AirMon) versus oxidative (AirVL3) style wines.

Funding Support: Richard Lauchland (Duas Terras Vineyard) and Treasury Wine Estates (St. Helena, California) are thanked for their donation of fruit and logistical support, respectively.

Reductive Versus Oxidative Juice Handling During Fermentation of Rosé Wines

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Carignan (pH 3.64, 25.6 Brix, titratable acidity [TA] 5.7 g/L) and Grenache grapes (pH 3.35, 22.9 Brix, TA 5.55 g/L) were harvested and each varietal was whole cluster-pressed for rosé winemaking. Carignan juice was separated into Reductive (40 ppm SO₂) and HyOx (550 mL/L/hr air for 2 hr). Grenache juice was separated into Reductive (40 ppm SO₂) and HyOx (125 mL/L/hr air for 2 hr). Each treatment was then split during fermentation by sparging regimen: N₂ or O₂. The treatments for each varietal were ReductN₂, ReductO₂, HyOxN₂, and HyOxO₂. Oxidation-reduction potential (ORP) for Carignan showed an average of 114 mV (Ag/AgCl reference electrode) for Reductive and reached a stable 342 mV for HyOx, with a corresponding peak in dissolved oxygen (DO) of

4.9 mg/L. In contrast, Grenache Reductive averaged 100 mV and HyOx averaged 181 mV with a peak at 210 mV. DO for HyOx was inconsistent during sparging, reaching 3.7 mg/L and as low as 0.086 mg/L, demonstrating a lack of saturation. Phenolics for Carignan ReductN₂ and ReductO₂ were 87 and 82 mg/L, respectively, while hyperoxygenation reduced phenolics by 69 and 64% for HyOxN₂ and HyOxO₂. Phenolics for Grenache ReductN₂ and ReductO₂ were 233 and 227 mg/L, respectively, while hyperoxygenation reduced phenolics by 22 and 21% for HyOxN₂ and HyOxO₂. For both varietals, the OAVs with the largest impact in order of contribution were ethyl *n*-octanoate, ethyl hexanoate, isoamyl acetate, and ethyl butyrate. There were no significant differences across treatments for Carignan for these volatiles. Grenache similarly had no significant differences except for ethyl *n*-octanoate, with OAVs of 440, 350, 438, and 340 for ReductN₂, ReductO₂, HyOxN₂, and HyOxO₂, respectively, demonstrating an interaction between varietal and treatment. Sensory analysis is underway.

Funding Support: Richard Lauchland (Duas Terras Vineyard), Erin Amaral (Pacific Coast Farming), and Rancho Arroyo Grande Vineyard are thanked for their donation of fruit. And Treasury Wine Estates (St. Helena, California) are thanked for their logistical support.

Targeting Reductive and Oxidative Wine Styles Using Hyperoxygenation, NTUs, and Redox Potential in Loureiro Wines

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Loureiro grapes (pH 3.17, 18.5 Brix, titratable acidity 7.07 g/L) were pressed and the juice divided into Reductive (50 ppm SO₂, 160 mg/L ascorbic acid, and 500 mL/L/hr N₂ sparging for 2 hr) and HyOx (250 mL/L/hr air sparging for 2 hr, and no SO₂). Juice was further split into low (30) nephelometer turbidity units (NTUs) and high (600 to 700) NTUs, giving four treatments: RedHiNTU, RedLoNTU, HOHiNTU, and HOLoNTU. The oxidation-reduction potential (ORP) of HyOx juice peaked at 420 mV with a dissolved oxygen (DO) peak of 2.45 mg/L during hyperoxygenation; Reductive ORP averaged 58 mV. Fermentation finished in 4 days for all treatments, with average ORPs of -86 mV (RedHiNTU), -88 mV (RedLoNTU), -34 mV (HOHiNTU), and -38 mV (HOLoNTU). Phenolics were below 10 mg/L for HyOx treatments, contrasting with 61 and 54 mg/L for RedHiNTU and RedLoNTU, respectively. The largest volatile contributors for all treatments were as follows, with RedLoNTU having the highest concentrations of each: isoamyl acetate (5738 mg/L), ethyl *n*-octanoate (1514 mg/L), ethyl hexanoate (1223 mg/L), ethyl butyrate (550 mg/L), and linalool (400 mg/L), demonstrating a strong varietal effect. Compared to the same compounds in RedLoNTU, compounds in RedHiNTU were 9, 31, 26, 15, and 31% lower; compounds in HOHiNTU were 12, 6, 13, 32, and 7% lower than RedLoNTU; and compounds in HOLoNTU were 15, 4, 15, 16, and 13% lower than RedLoNTU. NTU levels thus had a large effect on aroma when done in conjunction with reductive winemaking and very little effect with oxidative winemaking. Overall, handling juice reductively or oxidatively in combination with two different NTU levels can alter the sensory profiles of white wines, while maintaining their varietal characteristics. Sensory analysis is underway.

Funding Support: Scott Williams (Coastal Vineyard Care) and Treasury Wine Estates (St. Helena, California) are thanked for their donation of fruit and logistical support, respectively.

Evaluating Foliar-Applied Functional Compounds to Mitigate Heat and Water Stress in Cabernet Sauvignon Grapevines

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Climate change-driven heat and water stress have increasingly threatened grapevine physiology, fruit composition, and yield in warm-climate viticultural regions such as California's Central Valley. This study evaluated the effectiveness of foliar-applied functional compounds as sustainable strategies to mitigate heat and water stress in Cabernet Sauvignon grapevines while maintaining photosynthetic efficiency and fruit quality. Over two growing seasons, field trials were conducted to evaluate three categories of compounds: particle film (diatomaceous earth and calcium carbonate), film-forming biopolymers (di-1-*p*-menthene (pinolene), starch, xanthan gum), and plant growth regulators (abscisic acid, ethephon, salicylic acid). Treatments were applied at bunch closure and veraison for particle films and biopolymers, and at veraison for plant growth regulators within a randomized complete block design. Vine water status, gas exchange, and fruit composition were measured throughout the season, while yield components were assessed at harvest. Across seasons, several treatments improved vine water status and intrinsic water use efficiency, with particle films and select biopolymers moderating vine water status and improving gas exchange under high temperatures, while maintaining fruit composition and ripening dynamics. Calcium carbonate and diatomaceous earth reduced stress indicators while maintaining fruit ripening dynamics. Starch and xanthan gum demonstrated potential as a biodegradable alternative to conventional film-forming biopolymers. Among the compounds evaluated, some plant growth regulators improved ripening behavior, while others reduced transpiration. Overall, results indicate that foliar-applied functional compounds differ substantially in their physiological tradeoffs, while particle films and film forming biopolymers offer a promising and sustainable strategy to improve resilience in warm viticultural regions.

Funding Support: ARI USDA NIFA-NextGen

Grapevine CYP734A13 and CYP734A15 Are Both Brassinosteroid-Inactivating Cytochrome P450 Enzymes

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Grapevines (*Vitis vinifera*) are cultivated worldwide, with fruit used for fresh consumption, wine, juice, and raisin production. As a group of plant growth-promoting hormones, brassinosteroids (BRs) play extensive roles in multiple aspects of grapevine/environment interactions. BRs can enhance plant biomass accumulation, disease resistance, and tolerance to abiotic stress. Plant BR homeostasis can be modulated by a conserved cytochrome P450 family, CYP734A, that specifically inactivate BRs. However, grapevine CYP734As have not been functionally characterized to date. Here, we cloned CYP734A13 and CYP734A15 from the popular table/raisin grape cultivar Thompson Seedless and demonstrated its BR-inactivating activity via ectopic expression in *Arabidopsis thaliana*. Overexpression of either CYP734A13 or CYP734A15 causes BR-deficient dwarfism in *Arabidopsis*, which can be rescued by exogenous application of brassinolide (BL), the most biologically active BR found in plants. The BR biosynthetic inhibitor brassinazole (BRZ) can abolish *Arabidopsis* seedling hypocotyl growth difference between CYP734A13/15 overexpression lines and mock plants harboring the empty vector. CYP734A13/15 overexpression also abolishes *Arabidopsis* seedling photomorphogenic phenotypes in high-fluence-rate white light conditions. Our findings collectively indicate that both CYP734A13 and CYP734A15 are valid brassinosteroid-inactivating P450

enzymes that can be potential genome editing targets for elevating endogenous BR levels in grapevine.

Funding Support: USDA-ARS appropriated project

Natural Background Concentrations of Volatile Phenols and Their Glycoconjugates in California Grapes and Wine

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Increased frequency and severity of wildfires have led to substantial economic losses for the California grape and wine industry through vineyard smoke exposure. When grapevines are exposed to wildfire smoke, grapes can accumulate elevated levels of several volatile phenols and their glycoconjugates, which may later be released during fermentation, potentially leading to smoke-tainted wines. While elevated levels of these compounds serve as markers for smoke exposure, low levels of these compounds are naturally present in grapes and wines. Characterizing these natural background levels is essential to assess smoke exposure risk accurately in California vineyards. In this study, six smoke-associated volatile phenols and seven of their glycoconjugates were analyzed using gas and liquid chromatography, respectively, to determine background levels in grapes and wine. Samples from a total of 10 cultivars were collected across several California AVAs over three vintages to generate a data set describing the natural levels of smoke-associated compounds expected in California vineyards. Results indicate that compound concentrations are significantly influenced by grape variety, growing region, and vintage, for multiple compounds analyzed. These results indicate the natural variability in grapes, which is driven by differences in grape metabolism and environmental conditions, supporting the need for cultivar- and region-specific baselines for interpreting analytical data during wildfire events. Collectively, this data set provides California grapegrowers with a reference framework to assess smoke exposure risk and support informed vineyard and winemaking management decisions following periods of suspected wildfire smoke exposure.

Funding Support: The American Vineyard Foundation, Specialty Crop Research Initiative Grant # 2021-51181-35862/project accession # 1027470 from the USDA National Institute of Food and Agriculture.

Threats Posed to Mechanically-Harvested Grapes as Spotted Lanternfly Expands Range in the United States and Mitigation Strategies

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In Southeast Pennsylvanian spotted lanternfly (SLF) infested vineyards, grapes are predominantly harvested by hand and pressed in small batches, providing multiple points of contact to remove SLF from the harvested crop. However, almost all 32,000 acres grown in the Erie region are mechanically harvested, eliminating the possibility of hand-removing SLF before processing. Juice/wine industry processors use the Standards for Grades of Grapes for Processing and Freezing (USDA 1997) for tolerance on quality. Using current standards, a 22-ton load of grapes would be rejected if one or two adults were present in the core sample of 1000 g. The Penn State and Cornell lanternfly research team worked to identify potential risks created in the highly mechanized grape production industry of the Lake Erie region prior to SLF arrival and establishment. Risks identified were whether mechanical harvesters would "harvest" SLF present on the vines with the grapes, thus contaminating the harvested crop, whether harvested SLF would impart taint/toxicity to the juice/wine, what mitigation strategies

are available to avoid potential contamination, and whether SLF can be prevented from re-infesting vineyards if a preventative insecticide application is made just prior to mechanical harvest. Vineyards in the Lake Erie region may become infested with SLF as soon as 2026, and no mitigation plans are in place to deal with SLF contamination during mechanical harvest to help the industry. Additional insecticide applications are required before and after harvest to control the populations and mitigate vine damage from excessive, extended feeding on sap by the SLF adults. Increased costs associated with mitigating SLF in mechanically harvested grapes could easily exceed profit margins along with the threat of declined loads. Learn about the pilot mechanization study, taint/toxicity work, and harvest window techniques investigated by the Penn State/Cornell SLF team as SLF expands its range.

Funding Support: Pennsylvania Department of Agriculture Ag Resource Center Funding, The New York Wine and Grape Foundation, The Lake Erie Regional Grape Program, and Penn State Extension.

Effect of Foliar Fertilization on Polyphenols against Abiotic Stress

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Climate warming increasingly alters grapevine ecophysiology and berry secondary metabolism, leading to imbalances in phenolic composition that threaten wine stability and sensory quality, particularly in warm and dry viticultural areas. Among flavonols, excessive quercetin accumulation in grape skins has emerged as a critical challenge for red wine making, prompting development of agronomic strategies capable of mitigating heat-induced effects without compromising technological maturity. This study evaluated the effect of a foliar biostimulant (Oenoterris Expression, Sofralab) on vine physiological responses and quercetin accumulation in *Vitis vinifera* L. cv. Sangiovese under warm climatic conditions. Field trials were conducted in Tuscany over two consecutive growing seasons (2024 to 2025), comparing untreated control vines and treated vines receiving two foliar applications per season (5 + 5 L/ha) at pea-size berry and bunch closure stages. Treatments were applied over ~0.5 ha, with monitoring performed on a representative sample of at least 100 vines. Vine ecophysiological performance was assessed through measurements of leaf gas exchange (net photosynthesis and transpiration) using a portable photosynthesis system (CIRAS-3) and midday leaf water potential was determined with a Scholander pressure chamber. Grape technological maturity and phenolic composition were monitored from veraison to harvest, with targeted quantification of quercetin derivatives and polyphenol extractability by high-performance liquid chromatography; all analyses were performed in triplicate. In 2024, phenolic sampling was conducted at harvest while in 2025, sampling encompassed four key phenological stages. Foliar application induced a rapid and transient modulation of vine gas exchange, while leaf water potential remained unaffected, indicating an improved water-use strategy rather than the induction of water stress. Technological ripeness parameters at harvest were not significantly altered. In contrast, treated vines consistently exhibited lower absolute quercetin concentrations at comparable maturity levels across both seasons, suggesting a selective regulation of secondary metabolism in response to foliar biostimulation. Overall, these findings demonstrate that targeted foliar application of Oenoterris can decouple heat stress from excessive quercetin accumulation, supporting a reasoned agroecological approach for producing phenologically balanced red wines under climate warming scenarios.

Funding Support: SAS SOFRALAB

Custom Oligonucleotide Panels for Targeted Detection of Grapevine Viruses using High-Throughput Sequencing

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Viral diseases pose a major threat to global grapevine production, causing substantial economic losses and limiting international trade. Determining the phytosanitary status of grapevine planting material is therefore essential for domestic certification programs and safe international movement of vines. In this study, we developed and assessed a targeted high-throughput sequencing (HTS) approach using a custom oligoprobe panel to improve detection of grapevine-infecting viruses that are relevant to Canadian viticulture. Custom Ampliseq DNA oligoprobe panels were designed to detect 24 RNA and six DNA viruses known to infect grapevines by targeting both structural and non-structural genes as regions of interest. Petiole samples from seven virus-infected grapevines maintained at the phytotron facility at Brock University were used in this study. The methodology comprises an oligoprobe-based and non-oligoprobe-based approach with either total RNA (totRNA) or double-stranded RNA (dsRNA) as the source of library preparation. The HTS approaches were labelled as oligoprobe-total RNA (OM-TR), oligoprobe-double-stranded RNA (OM-DR), non-oligoprobe-total RNA (NOM-TR), and non-oligoprobe-double-stranded RNA (NOM-DR). Among these, the OM-DR workflow performed best, yielding greater viral diversity and higher viral read intensity, thereby substantially increasing the sensitivity of virus detection. Using Virtool, we detected 10 viruses across seven infected grapevine samples, including Grapevine leafroll-associated virus (GLRaV)-1, -2, -3, Grapevine rupestris stem pitting-associated virus (GRSPaV), Grapevine Pinot gris virus (GPGV), Grapevine virus H (GVH), Grapevine virus E (GVE), Grapevine red blotch virus (GRBV), Grapevine rupestris vein feathering virus (GRVFV), and Grapevine enamovirus 1 (GEV-1). The oligoprobe-based targeted HTS strategy showed strong promise as a robust, sensitive, and scalable diagnostic tool for grapevine viruses, supporting quarantine measures and domestic certification of grapevine propagative material in Canada.

Funding Support: Genome British Columbia and Genome Canada through the project (code 189GRP), entitled "CLEan plAnt extractioN sEquencing Diagnostics (CLEANSED) for Clean Grapevines in Canada."

Effect of Prefermentation Manipulations on the Balance of Terpenic Gewürztraminer

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Prefermentation treatments conducted on Gewürztraminer from Monterey County, CA were established to produce varying levels of acidity to evaluate volatile aroma development and sensory features related to wine balance. Gewürztraminer underwent a control treatment and a 22.7% waterback addition, chaptalization, and 30% ion exchange of its juice at pressing. Across all volatiles at pressing, the control and chaptalized treatments resulted in the highest concentrations of terpenes and esters. Specifically, chaptalization enhanced the following esters and higher alcohols associated with fruit and floral notes: isoamyl acetate, ethyl decanoate, and 2-phenylethyl, while the control treatment preserved floral terpene β -citronellol. Ion exchange and waterback treatments produced the lowest concentration of the same volatiles; however, the ion exchange treatment produced the highest amount of linalool while specifically lowering isoamyl acetate, ethyl decanoate, and geraniol. The waterback treatment tended to mute all aromas. Similar patterns to volatile production emerged in odor activity values (OAVs) across treatments. In addition to prefermentative

treatments, a portion of juice was collected and either ion exchanged or frozen to conduct süssreserve, a postfermentative treatment used to introduce residual sugar. While chemical differences were apparent across acidity, alcohol, and aroma production, further treatments including süssreserve, de-alcoholization, and CO₂ additions and sensory analysis are underway to evaluate the role of acidity, residual sugar, and ethanol content on perceived wine balance.

Funding Support: Scott Williams (Coastal Vineyard Care), Stephan L'Aseo (L'Aventure Winery, Paso Robles, CA), and Treasury Wine Estates (St. Helena, CA) are thanked for their donation of fruit and logistical support, respectively.

Effect of Prefermentation Manipulations on the Balance of Red Wines

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Selected prefermentative treatments were conducted on red varieties from the Central Coast of California, with the aim of manipulating targeted wine components (alcohol, tannin content, and titratable acidity [TA]) and assessing their role in wine balance. Treatments for Graciano included a 12% waterback addition, chaptalized, and control; while Marselan included a 10.6% waterback addition, 50% stem addition/5% saignée, and 30% ion exchange juice addition to must. Graciano exhibited no effects on pH or TA at pressing; while Marselan ion exchange treatments resulted in a 5% lower pH and 14% higher TA (compared to the control). Marselan 50% stem addition/5% saignée treatment produced pH values 5.6% lower than the control. In Graciano wines, waterback consistently suppressed compounds associated with floral and fruit aromas: geraniol, ethyl decanoate, and linalool were 20 to 29% less relative to the control, while 2-phenylethyl acetate was 67% lower. Chaptalization suppressed geraniol and linalool while enhancing isoamyl acetate and ethyl hexanoate. In contrast, waterback in Marselan enhanced isoamyl acetate and hexyl acetate. Stem addition treatments promoted compounds such as β -citronellol, geraniol, methyl salicylate, ethyl cinnamate, and β -ionone. The contrasting effects of prefermentative treatments on acidity and aromas highlights varietal differences between Graciano and Marselan. As such, waterback treatments respond differently across varieties. Treatments involving ion exchanging juice effectively increase acidity, while potentially compromising aroma complexity. While chemical differences were apparent across treatments, further postfermentative treatments and sensory analysis are underway to evaluate the role of acidity, residual sugar, and ethanol content on perceived wine balance.

Funding Support: Scott Williams (Coastal Vineyard Care), Stephan L'Aseo (L'Aventure Winery, Paso Robles, CA), and Treasury Wine Estates (St. Helena, CA) are thanked for their donation of fruit and logistical support, respectively.

Spatio-temporal Analysis of Historic Heatwaves and Production: Effects on California Grape Varieties

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The challenge of growing winegrapes under warmer and drier conditions has intensified in recent decades. While controlled-environment heat treatments have elucidated the physiological response of grapevines, including effects on growth, yield, and fruit composition, quantification of heatwave effects at the commercial scale is more challenging due to the wide range of in-season interventions that growers can deploy as mitigation practices. However, the efficacy of these cultural practices is

inconsistent and their implementation is constrained by factors such as additional cost or infrastructure requirements and logistical challenges. In previous work, we linked seasonal weather patterns uncovered by clustering analysis to vineyard productivity attributes of Cabernet Sauvignon in Napa Valley. That single-region and variety study provided statistical evidence of how pre- and postveraison heatwaves drive significant shifts in harvest date and adversely affect yield and fruit composition. Here we present a cross-regional (Central Coast, North Coast, North Valley, South Valley) and multi-varietal analysis for winegrapes grown across California. The observational data set comprises 28,402 vineyard-year records from 2858 geolocated vineyards, 24 grape cultivars, and 15 vintages (2010 to 2024). Daily meteorological data were extracted for vineyard coordinates from the PRISM database and aggregated to derive seasonal descriptors. Growing seasons were classified into vintage-types using hierarchical clustering analysis, and vintage-type effects on yield and harvest date were assessed across regions and varieties. Intersecting weather classifications with production metrics revealed different degrees of impact based on specific combinations of region and variety, as well as the alignment of heat events with phenological stages. The results of this integrated, spatiotemporal analysis allowed the identification of high-risk region $\times$ variety scenarios in California that are most susceptible to heat stress. This approach provides a reproducible framework for targeted efforts in the experimentation of adaptive interventions aimed at mitigating the effects of intensifying heat events.

Funding Support: GALLO

Assessing Carbon Storage Potential of Regeneratively Managed Vineyard Soils

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Soil carbon storage is widely recognized as essential to both reducing atmospheric CO₂ levels and improving soil health. To optimize soil carbon storage, it is important to understand both its potential and limitations. This study focuses on two key carbon pools: particulate organic carbon (POC), which is quick to decompose, and mineral-associated organic carbon (MAOC), which is stable and remains in the soil long-term. Both pools play critical roles in carbon stabilization. While POC content is influenced by multiple factors beyond soil texture, MAOC is almost entirely dependent on the presence of fine particles, which suggests a saturation point for carbon storage. This research aims to identify these MAOC saturation points in regeneratively managed soils by sampling vineyards across California. Soil fractionation techniques are used to isolate POC and MAOC, and carbon content is measured using an elemental analyzer. By determining the MAOC saturation threshold, we can better predict a soil's capacity for long-term carbon storage based on properties like soil texture and management practices. Preliminary data show an exponential increase in POC and a logarithmic increase in MAOC with increasing SOC, suggesting that carbon saturation may be occurring in high SOC vineyards within the data set and that soils with a high fine fraction content and large carbon deficit offer the greatest potential for long-term carbon storage. Together, these results provide a way for growers to match regenerative practices to site-specific capacity, enabling more efficient, targeted, and durable long-term carbon storage in vineyard systems.

Funding Support: Foundation for Food and Agriculture Research

Consumer Sensory and Affective Responses to Wildfire-Affected Wine: Influence of Preference, Region, and Labeling

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Wildfire smoke can give wine smoky, burnt, and ashy flavors that often hide positive attributes and reduce liking. While the chemical and sensory effects of smoke exposure are well known, less is understood about how consumers respond to these wines, especially in regions with different levels of wildfire experience. This study compared consumer perceptions of smoke-affected wines in Oregon, where wildfire smoke is common, and Ohio, where exposure is limited. Consumers in both states evaluated five wine blends with different levels of smoke impact and rated liking, emotional responses, and sensory characteristics. As smoke impact increased, smoky and ashy attributes became more intense, with the 100% smoke-affected blend showing the strongest effects. Although consumers in Oregon and Ohio differed in wildfire familiarity, prior experience with smoke-affected wines, and wine consumption habits, overall liking, and emotional responses were similar across regions. Instead, two equally sized consumer groups emerged based on their response to smoky flavors. One group showed higher liking for smoke-affected wines than the other, along with clear differences in emotional and sensory ratings. Consumers also evaluated wine labels to examine how smoke-related information influenced expectations, predicted sensory properties, emotional responses, and purchase intent. Overall, the results suggest that individual preference for smoky flavors plays a larger role in consumer response to smoke-affected wines than regional background, while regional experience may still shape expectations when smoke-related information is presented.

Funding Support: USDA-Agricultural Research Service (ARS) project # 2072-21000-057-00D

Characterizing Airborne Fungal and Bacterial Microbiomes in 'Chardonnay' Vineyards across the United States

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Airborne microbes play an important role in vineyards. They move between plants, act as inoculum for disease, and contribute to the overall microbial environment surrounding the vines. Although vineyard soils and phyllosphere communities have been studied extensively, little is known about what is present in the air. This project aims to characterize airborne fungal and bacterial communities across major United States grapegrowing regions using culture-independent amplicon sequencing. Air samples were collected using a vacuum-based method from three Chardonnay (*Vitis vinifera*) vineyards across five different states within the U.S. This geographic diversity provides an opportunity to examine how airborne microbial communities vary across different growing regions. All air samples were collected before harvest in the first year of this study to build a preliminary data set. Total DNA was extracted from the air samples and is currently being processed for amplicon sequencing targeting the bacterial 16S rRNA gene and fungal ITS region to capture the microbiome diversity of the air samples. The microbial community composition is expected to differ across states, influenced by climate, management practices, and local environmental factors. The main goals of this work are to identify dominant taxa across vineyards, distinguish core versus regionspecific microbiomes, compare alpha and beta diversity among states, detect known grapevine pathogens and potential beneficial microbes, and examine whether bacterial and fungal communities show similar biogeographic patterns. This first year of data will support a follow-up multiyear study to track how airborne microbiomes shift across seasons and grape growth

stages. Ultimately, understanding these patterns may help improve disease forecasting and guide regionspecific disease management strategies in viticulture.

Funding Support: United States Department of Agriculture – National Institute for Food and Agriculture – Specialty Crop Research Initiative Award No. 2024-51181-43184 titled “Pathogen Monitoring and Disease Management Within a Vineyard FRAMEwork.”

Integrating Extension and Research to Develop *Vitis* × *Muscadinia* Hybrids with Improved Disease Resistance and Quality

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Muscadinia grapes are resistant to many pathogens that affect *Vitis* (bunch grapes), the backbone of the United States grape industry. However, breeding *Vitis* (V) with *Muscadinia* (M) is complicated due to the difference in chromosome numbers. Our team of 31 U.S. grape research/extension experts in genetics, breeding, pathology, quality, marketing, and production will lead a project entitled “Through the Grapevine: Developing *Vitis* × *Muscadinia* Wide Hybrids for Enhanced Disease Resistance and Quality” (USDA NIFA SCRI #2024-51181-43236). In the first year of the project, the team delivered 34 presentations, hosted 13 virtual meetings, published four articles, two abstracts, and five fact sheets, held three webinars, released three muscadine cultivars, and created a project website to ensure collaboration within and among objectives. The Genetics, Breeding, and Pathology teams genotyped 1516 samples, processed 2429 black rot samples, 167 powdery mildew samples, and 86 downy mildew samples, developed 72 V × M hybrid populations, characterized flower sex and seedlessness loci, created a genetic linkage map, and developed a new chromosome painting tool. The Quality and Marketing teams assessed muscadine juice aroma/flavor with over 600 respondents in 10 U.S. states, evaluated aroma/flavor of 66 *Muscadinia* and V × M hybrid grape purees in consumer studies, evaluated appearance, texture, and flavor of 20 *Muscadinia* and V × M hybrid grapes in consumer studies, developed a consumer survey on product packaging, and created a moderator guide for grower focus groups. The Production team established eight replicated and seven demonstration trials, held 37 consulting appointments with grape/berry growers, evaluated 23 hybrid genotypes across eight states, provided 14 training courses, hosted seven field days, and developed a muscadine cultivar selection tool. Outreach in the first year targeted university personnel (researchers, staff, students, and extension), grapegrowers, wine producers, horticultural crop growers, and consumers.

Funding Support: USDA NIFA SCRI #2024-51181-43236

One-Shot Evolutionary Genomics of a Wild *Vitis*-Downy Mildew Pathosystem

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Host-pathogen coevolutionary studies require population-scale genomic data from both host and pathogen, yet obligate biotrophic pathogens present a major obstacle because they cannot be cultured outside living host tissue. Traditional single-spore isolation approaches are labor-intensive, limit sampling depth, and underestimate strain-level diversity present during natural infections. We tested the hypothesis that whole-genome sequencing of naturally infected grape tissue can provide a reliable, cost-effective alternative for simultaneous host and pathogen population genomic inference. We sampled wild and cultivated grape populations across Tennessee, along with non-infected greenhouse and growth chamber controls, and extracted

DNA using an in-house optimized protocol for wild plant tissues. Libraries were sequenced using paired-end Illumina technology, and sequencing depth was systematically subsampled to evaluate minimum coverage requirements. Host genotyping was performed using a pangenome-based framework, while pathogen genotyping relied on reference-based variant detection. Across sequencing depths, we assessed single-nucleotide polymorphism accuracy, phylogenetic stability, and population genetic inference, including population differentiation, genetic structure, and allelic diversity. We identify a sequencing depth threshold at which phylogenetic relationships and population genetic parameters stabilize for both host and pathogen, enabling reliable evolutionary inference without pathogen isolation. These results demonstrate that one-shot sequencing of infected tissue captures biologically meaningful host-pathogen genomic variation while substantially reducing labor, time, and cost. This approach is broadly applicable to fungal, oomycete, and other obligate biotrophic pathosystems and is particularly valuable for rapid surveillance of pathogen evolution, fungicide resistance, and resistance breakdown in both natural and agricultural systems.

Funding Support: Startup funds from the Co-Evolution Lab (PI Gautam Shirsekar), as he started as an associate professor at the University of Tennessee, Knoxville.

Classification of Interspecific Grape Cultivars Based on Polyphenol Composition using A-TEEM™ Spectroscopy

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Vitis vinifera cultivars prefer warmer, drier climates and are generally susceptible to frost and microbial infections. The eastern and central United States are typically not well suited for *vinifera* grape cultivation. In these regions, cold-hardy interspecific cultivars have been developed through breeding programs. Of significant interest for these conditions are two *Vitis aestivalis*-based cultivars, Norton and Cynthiana, which have long been assumed to be identical. Recent evaluation of historic records and genetics, however, suggest that the two cultivars may be different. In this study, we employed a simultaneous absorbance, transmittance, and fluorescence excitation-emission-matrix acquisition (A-TEEM™) spectroscopy, which rapidly scans grape and wine extracts to sensitively resolve and characterize their complex chemical compositions. A-TEEM™ spectroscopy has been shown to make accurate regional, cultivar and vintage classifications of *vinifera* grapes as well as to detect adulteration with diglucosidic anthocyanin extracts. We now investigated the capacity of A-TEEM™ spectroscopy to differentiate between Norton and Cynthiana grown commercially side by side under identical conditions over three vintages. We also included parallel analyses of two other interspecific hybrids, Merchette and Chambourcin, and one advanced breeder selection (10W14N). The primary A-TEEM™ analyses included scans focusing on the anthocyanin spectral absorbance and fluorescence emission region (400 to 700 nm), since hybrid grapes are most different from *V. vinifera* in their diglucoside-rich anthocyanin profile. The conclusion was that both principal component analysis (PCA) and hierarchical cluster analysis (HCA) resolved all the grape cultivars studied within a 99% confidence interval. While being different, it was also clear that Norton and Cynthiana grapes showed a close, clustered relationship with respect to their PCA coordinates and their HCA dendrogram's weighted variable distances. A-TEEM classification can be used for rapid, accurate identification of cold-hardy hybrid grapes, including the notoriously similar cultivars, Norton and Cynthiana.

Funding Support: No external funding

Malic Acid Modulation by *Saccharomyces cerevisiae*: Development of Novel Deacidifying Strains

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Malic acid is a major grape-derived organic acid that is differentially metabolized by *Saccharomyces cerevisiae* strains during alcoholic fermentation. Depending on the strain and conditions, typical winemaking starters consume up to ~30% of initial malic acid. Using QTL-assisted breeding, new *S. cerevisiae* strains with contrasting phenotypes were obtained: ACIDIC strains that preserve or produce malic acid (up to 3 g/L), and DEMAL strains that degrade up to 80% of the initial malic acid. Comprehensive phenotypic characterization highlighted distinct behavior between these two strain groups. DEMAL strains showed stable malic acid consumption across a range of fermentation conditions, while ACIDIC strains preserved malic acid in less ripe matrices, and produced it at higher pH and sugar levels. A novel deacidifying strain, DEMAL1, was selected for further evaluation in laboratory- and winery-scale trials. In Sauvignon blanc fermentations (initial malic acid 6.4 g/L), DEMAL1 decreased malic acid to 1.8 g/L, compared to ~4.2 g/L for conventional starter strains (n = 24). Winery trials confirmed its deacidifying capacity, with wines showing differentiated aromatic (thiols and esters) and sensory profiles. Application of DEMAL1 was further evaluated for managing excessive acidity in early-harvested grapes intended for lower-alcohol wines (~10% ABV). It also allowed faster malolactic fermentation and resulted in lower final lactic acid concentrations across wine styles. With malic acid consumption consistently exceeding 60%, DEMAL1 represents a distinctive biological tool to improve balance in grapes from cooler climates and vintages. It is also well suited to earlier-harvested fruit, NOLO wine programs, and can assist with challenging malolactic fermentations. Collectively, these results extend the natural capacity of *S. cerevisiae* to modulate wine acidity while providing practical and cost-effective tools for adjusting wine balance under diverse production conditions.

Funding Support: Laffort

Cabernet franc Polyphenols: A Popular Virginia Varietal with Highly Varied Phenolic Content

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Cabernet franc (*Vitis vinifera*) is the most planted grape in Virginia, accounting for 15% of grapegrowing acreage. Cabernet franc grapes grow well in Virginia and are often used to produce varietal wines in varied styles. However, data on the phenolic composition of this varietal are limited. Thus, the goal of this project was to quantify polyphenols in finished Virginia Cabernet franc wines from different vintages and regions across the Commonwealth. A total of 79 finished Cabernet franc wines from the 2019 to 2023 vintages were collected from 51 wineries representing the major growing regions of Virginia. Seven non-Virginia Cabernet franc wines were also included as comparators. Wines were analyzed for phenolics via summary metrics (total polyphenols, total tannins, and total monomeric and polymeric anthocyanins) and chemical fingerprinting (38 individual phenolics quantified via liquid chromatography-tandem mass spectrometry). Phenolic content varied widely across both vintage and region for total phenolic content (1145 to 3113 mg GAE/L; median 2066), condensed tannins (78 to 1715 mg ECE/L; median 593), monomeric anthocyanins (14 to 391 mg C3GE/L; median 111), and polymeric anthocyanins (53.4 to 78.2%; median 67.3%). There were no significant regional differences within Virginia nor between Virginia and non-Virginia samples. Virginia wines from the 2019 vintage contained significantly higher condensed tannins than other vintages tested, reflecting excellent growing conditions that year. When compared to non-Virginia samples, Virginia Cabernet franc wines had similar gallic

acid content but tended to be lower in catechins, quercetin, and myricetin. These data highlight the broad diversity in the phenolic content of finished Virginia Cabernet franc wines, particularly across different vintages. Future studies tracing Cabernet franc phenolics from grape to bottle are necessary to understand the genesis of these differences in the finished wines.

Funding Support: Virginia Wine Board

Preliminary Insights Assessing the Effects of Controlled Scaling a Non-Contact Method for Selective Extraction of Off-Flavor Molecules in Wine

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There are various off-flavors in wine, ranging from Brettanomyces, reduction, and smoke-taint, that decrease wine quality. Current mitigation treatment methods are harsh, non-specific, and have limited efficacy. Treatment methods like activated carbon fining or reverse osmosis remove desirable qualities in the wine with the off-flavors. Thus, a more selective treatment method is necessary. Of the various off-flavors in wine, reduction and smoke taint were chosen as the compounds of interest as they are from the same compound class – thiols. Reductive wines have H₂S and mercaptans, while smoke-tainted wines have thiophenols. Specific treatment of the wine is hypothesized to improve wine quality. A closed-loop, two-flask system was developed, where wine was placed in the first flask and a solution of a thiol-selective trapping compound, 5,5'-dithiobis(2-nitrobenzoic acid) (DTNB), was placed in the second flask. The system was purged with nitrogen gas, and a peristaltic pump was connected to cycle the volatiles from the wine through the system. Volatile thiols would react with DTNB in the separate flask, becoming nonvolatile, while the other volatile compounds continue to cycle through the system returning to the wine. This allows for the selective removal of thiols from the wine. This system was scaled up for treatment of a larger volume of wine for chemical and sensory analysis. The wines used in this study were a reductive Chardonnay and Pinot noir and a smoke-tainted Pinot noir. The chemical analysis involved a headspace gas chromatography tandem mass spectrometry method to measure the change in various volatile compounds generally found in wine after treatment. Sensory analysis was used to determine if panelists could differentiate the treated wine and their preference for the wines. Future work for this project includes implementing it at a winery scale and treating other off-flavor compound groups, like volatile phenols from *Brettanomyces*.

Funding Support: USDA National Institute of Food and Agriculture and USDA-Agricultural Research Service (ARS) project number 2072-21000-057-00D through the Plant Gene Expression Center.

Evaluation of Film Coatings as a Preventative Strategy for Smoke-Derived Phenol Uptake in Winegrapes

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A range of preventative techniques have been investigated to limit the uptake of volatile phenols in winegrapes, yet none have reached commercial use due to practical applications or insufficient conclusive data. One emerging strategy involves spray application of cellulose nanofiber (CNF) based films. This study evaluated the effectiveness of CNF films as a barrier between smoke-derived compounds and winegrapes. Film formulations consisted of CNF matrices blended with β -cyclodextrin, chitosan, or low methoxy phenol. These films were applied to Pinot noir grapes prior to smoke exposure in custom-designed cages. Following exposure, half of the grapes were washed to assess whether film removal would alter the levels of smoke-derived compounds in the

resulting wines. Grape and wine samples were analyzed for volatile phenols and phenol glycosides by gas chromatography-tandem mass spectrometry and liquid chromatography-tandem mass spectrometry, respectively. MANOVA and partial omega squared effect size analysis were used to evaluate treatment effects. Volatile phenol concentrations were significantly influenced by both film type and wash treatment, whereas phenol glycosides were only influenced by film type. Acetic acid and titratable acidity were also significantly affected by wash treatment. Despite these statistical differences, effect size values indicated that film and wash treatments had limited practical impact as a vineyard preventative strategy. High data variability, likely related to compromised film integrity under the imposed smoke conditions, further limited the ability to draw definitive conclusions. Overall, these findings indicate that CNF-based films warrant additional vineyard studies under representative wildfire smoke conditions.

Funding Support: the American Vineyard Foundation, Specialty Crop Research Initiative Grant # 2021-51181-35862/project accession # 1027470 from the USDA National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and should not be construed to represent any official USDA or U.S. Government determination or policy.

Phenological Stage Detection in Grapevines Using Time-Lapse Trail Cameras for Disease Management

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Effective spray guidelines for reducing fungicide resistance risk require precise, site-specific mapping of grapevine phenological stages. Accurate identification of growth stages enables optimized fungicide timing while minimizing unnecessary applications. This study aimed to map six critical phenological stages: six leaves separated, rachis elongation, ~50% bloom, fruit set, bunches beginning to hang, and bunch closure, in disease-susceptible *Vitis vinifera* and disease-sensitive hybrid varieties across major United States grapegrowing regions, including New York, California, Oregon, Washington, and Michigan. To capture continuous field observations, trail cameras capable of collecting both daytime and nighttime imagery were used. Cameras were mounted at two distinct viewing angles: one looking across the canopy, and another positioned to look within the canopy to closely capture cluster development. In total, 40 across-canopy view cameras were deployed, with one to three units installed per site depending on vineyard size and logistical considerations. An additional 30 inside-canopy-looking cameras were deployed, primarily in New York and California. Preliminary analysis was conducted using human visual assessment of the collected imagery to determine whether phenological stage is visible or not. Results indicated that early-season phenological development, particularly the six leaves separated stage (E-L 13), was highly detectable (86% of total sites with clear observations). Similarly, late-season stages spanning from bunches beginning to hang through bunch closure (E-L 29 to E-L 32) demonstrated strong visibility, with more than 70% of camera sites successfully capturing identifiable phenological progression. In contrast, mid-season reproductive stages, specifically ~50% bloom (EL-23) and fruit set (EL-27), were more difficult to observe. These stages were frequently obscured due to technical and environmental constraints, including limited camera resolution, canopy shading, sun angle interference, and variable lighting conditions. These findings highlight both the potential and limitations of trail-camera-based phenological monitoring and inform future improvements in imaging strategies for precision disease management.

Funding Support: the Specialty Crop Research Initiative Award No. 2024-51181-43184 titled "Pathogen Monitoring and Disease Management Within a Vineyard FRAMEwork" from the U.S. Department of Agriculture's National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s). They should not be construed to represent any official USDA or U.S. Government determination or policy.

Oxidation-Reduction Potential Monitoring during Alcoholic Fermentation of Rhône Varietals from California

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Grenache (GR), Syrah (SY), and Mourvèdre (MO) wines were produced separately using two prefermentative protocols: HOT (heating and air sparging) and COLD (cooling, nitrogen sparging, 50 mg/L SO₂, 100 mg/L glutathione [GSH], and 160 mg/L ascorbic acid), and two alcoholic fermentation protocols: OXI (1 hr air sparges twice per day) and RED (1 hr nitrogen sparges twice per day). The combined treatments were: HOT OXI, HOT RED, COLD OXI, and COLD RED. During alcoholic fermentation, oxidation-reduction potential values for GR, SY, and MO wines were 110, 105, and 58 mV for HOT OXI; -36, -25, and -94 mV for HOT RED; 60, 56, and 8 mV for COLD OXI; and -70, -81, and -116 mV for COLD RED, respectively. At pressing, all HOT RED and COLD RED varietal wines contained higher anthocyanins, tannins, total phenolics, and total color (420 nm + 520 nm + 620 nm absorbances) than their respective HOT OXI and COLD OXI treatments. Contrastingly, total polymeric pigment concentrations were highest in HOT OXI and COLD OXI wines across all varieties. GSH was highest in all COLD RED wines, but concentrations remained low, with 2.43, 0.87, and 1.19 mg/L in COLD RED GR, SY, and MO wines, respectively. Treatment effects on ester composition were minimal, whereas terpenoids were higher in HOT OXI and HOT RED wines across all varieties. Analysis of the contributions of variety, prefermentative treatment (HOT/COLD), and alcoholic fermentation treatment (OXI/RED) to wine phenolic and volatile composition showed that OXI and RED explained 67% of the variation in total phenolics, while variety accounted for 38% and 45% of the variation in total esters and terpenoids, respectively. The GR, SY, and MO wines will be blended factorially and subjected to sensory evaluation.

Funding Support: No external funding was used for this project. E. & J. Gallo Winery (Healdsburg, California) and Treasury Wine Estates (St. Helena, California) are thanked for their donation of fruit and logistical support, respectively.

Effects of Macro-Oxygenation and Oxidation-Reduction Potential Control on Syrah Wines

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Syrah grapes were subjected to three cap management protocols during alcoholic fermentation: punch-downs (PD), macro-oxygenation (MOX), and redox-controlled oxygen sparging (RedoxCon), while monitoring CO₂ production and release. PDs were executed twice per day; the MOX protocol delivered 10 mg/L/day for 1 day, 20 mg/L/day for 3 days, and 5 mg/L/day for 3 days; and RedoxCon was activated when the oxidation-reduction

potential reached -40 mV (Ag/AgCl). The average oxidation-reduction potentials (ORPs) of PD and MOX were -49 mV, while the average ORP of RedoxCon was 8 mV from inoculation to pressing. At pressing, PD and RedoxCon wines were below 0 Brix, while MOX wines were 2.4 Brix. Compared to RedoxCon, MOX wines released 0.5 g/L/hr more CO₂ from inoculation to pressing. At pressing, no differences were observed in pH or titratable acidity; however, ethanol (% v/v) in MOX wines was 0.95% v/v and 0.82% v/v lower than in PD and RedoxCon wines, respectively, and residual sugars were 570% and 90% higher in MOX wines than in PD and RedoxCon wines. No differences were found in wine color (AU 420+520+620 nm), CIELab coordinates, total phenolics, or tannins at pressing, although PD contained 11% more total anthocyanins than MOX, and RedoxCon contained 42% and 21% more polymeric pigments than PD and MOX, respectively. No overall differences were observed in GSH, GSSG, or GRP among treatments. Isoamyl acetate and phenylethanol were highest in PD wines, while ethyl hexanoate and ethyl octanoate were highest in MOX wines. MOX and RedoxCon during alcoholic fermentation produced Syrah wines comparable to PD wines in phenolic, color, and glutathione profiles; however, MOX wines had higher medium-chain ester levels and sluggish fermentations due to reduced mixing and oxygen dissolution.

Funding Support: No external funding was used for this project. E. & J. Gallo Winery (Healdsburg, California, USA) is thanked for their donation of fruit, and Treasury Wine Estates (St. Helena, California, USA) and Parsec (Florence, Italy) are thanked for their logistical support.

Early Detection of GLRaV-3 in a Table and Raisin Grape Germplasm Collection in Central California

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Caused by grapevine leafroll-associated virus 3 (GLRaV-3), grapevine leafroll disease (GLD) is one of the most devastating viral diseases in most grapegrowing regions worldwide. Unfortunately, due to a lack of understanding of the GLRaV-grapevine interaction, there are currently no applicable measures to cure GLRaV-3 infection. Most effective GLD control strategies include planting certified virus-free grapevines and removing virus-infected vines through roguing. Therefore, early detection of GLRaV-3 is critical for timely removal of infected plants in the vineyard. Here, we evaluated the efficiency and accuracy of GLRaV-3 early detection by RT-PCR, using a table and raisin grape germplasm collection in California's Central Valley. The results were verified by late detection using enzyme-linked immunosorbent assay (ELISA). We found that the efficacy of RT-PCR-based GLRaV-3 early detection highly depends on the genotypes. Some GLRaV-3-infected germplasm could be detected by RT-PCR at an early stage, while other lines either generated inconsistent results between individual plants or exhibited only negative outcomes; however, they were almost all later confirmed to be GLRaV-3 positive by ELISA. The inconsistency is probably due to slower virus propagation and disease development in these lines. We also found that despite the lower GLRaV-3 early detection rate, all positive RT-PCR results are accurate and can be used to guide timely vine removal to prevent GLRaV-3 spread. Early detection of GLRaV-3 across various varieties and breeding lines provides valuable germplasm-dependent guidance for table and raisin grape growers and researchers in Central California, enabling them to initiate disease management as early as April.

Funding Support: USDA-ARS appropriated projects