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**Climate Change—Challenge and Opportunity**  
**Combined Viticulture & Enology Session**

**Extreme Heat: Managing Grapevine Response**

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A survey of 92 vineyards, representing 10 winegrowing regions in southeastern Australia, soon after they were exposed to a severe heat-wave, revealed that there was variation in the level of reported heat-related impact. This variation was observed between regions, within regions, and within vineyards. Notably the estimates of losses were not always related to the amount of heat above a certain threshold but more so to the management practices employed in the lead-up and during the event. Agricultural practitioners have a suite of management tools available to them that will enable them to cope within the range of typical climate variability. When an industry occupies a diverse range of climate regimes, as is the case with the Australian wine industry, these management tools will vary, though some overlap will occur. The success of the management techniques employed across the industry through this severe climate event were assessed and quantified. Applicable and achievable recommendations for managing severe heat events have resulted from this assessment. Quantification of the effectiveness of watering options, canopy structure, and vineyard design in response to the extreme heat has led to identification of both better and also less effective management strategies. Timeframes for the implementation of these options from vineyard planning phase through to daily management are suggested. We believe this method of capturing information from the diverse knowledge-base of managers within an industry is a very effective way to reveal potential adaptive capacity. Furthermore, the recommendations resulting from this bottom-up approach will be more readily accepted as the proof of success has already been tested in the field.

*Funding support:* Grape and Wine Research and Development Corporation in Australia. This study was undertaken as part of a postdoctoral fellowship addressing the Adaptive Capacity of the Australian Wine Industry to Climate Change. The fellowship is being undertaken by Dr. Leanne Webb.

**Impact of Management Practice and Environment on Carbohydrate Reserves and the Implications for Grape Production**

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The production and storage of carbohydrates in grapevines are influenced by vineyard management and climatic conditions. In cooler grapegrowing regions, assimilate production and storage after harvest are limited. However, predicted changes in climatic conditions will likely elevate carbohydrate production after harvest due to a longer and more effective photosynthetically active period. These altered environmental conditions are expected to influence carbohydrate reserves and seasonal dynamics with



## Climate Change—Challenge and Opportunity

### Combined Viticulture & Enology Session – CONTINUED

consequences for grape production. Winter carbohydrate reserves at budburst in the perennial structure are central to early root and shoot growth. The general pattern of seasonal reserve utilization is characterized by a decrease following budbreak, and then an increase that can begin any time between flowering and the later stages of ripening. Our work has shown that the amount of reserves stored prior to leaf-fall can be influenced by management practices and climatic conditions, and that these may alter vigor, yield, and grape composition in the following season. Recent modeling suggests future winegrape harvests in Australia will occur earlier, and it is likely that leaf-fall will occur later. We have extended this modeling to characterize the spatial pattern of heat accumulation during the post-harvest period in southern Australia for an indicator variety. Under warmer atmospheric conditions, viticultural practices in regions currently classified as cool climate will likely need to evolve in order to manage vines that accumulate carbohydrate reserves at significantly greater levels than they do presently.

*Funding support:* Grape and Wine Research and Development Corporation.

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## Winegrower Responses to Environmental Stresses: An Analysis of Potential Farm-Scale Adaptive Capacity to Climate Change

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The wine industry is increasingly recognized as highly vulnerable to climate change. However, winegrape production is highly influenced by the management decisions of growers, and their adaptive responses at the vineyard level have not been examined. We conducted 20 in-depth interviews with winegrowers and winemakers in the Sonoma and Napa regions of California's North Coast Wine Country to test several key hypotheses about responsiveness to environmental challenges. Analysis of the survey results supports three key hypotheses: (1) Growers tend to respond to vineyard stresses individually rather than collectively, except in the case of severe and new pests and diseases. (2) Responses may be reactive (as in the case of diseases such as *Botrytis*) or proactive (as in frost prevention). Proactive strategies may be very long-term, such as site selection for frost avoidance; medium-term, such as infrastructure investment; or short-term, such as irrigation decisions. Most proactive strategies undertaken to date are very short-term, in response to threats perceived as imminent (about to occur on the scale of hours to days). Maximizing the effectiveness of management responses often relies on accurate weather forecasts or predictions. (3) Growers tend to rely first and foremost on their own experience to guide their management decisions, which may be poor guidance under a climate regime not experienced in the past. We offer recommendations for improving adaptive capacity in the context of climate change, including enhancing the potential for proactive, collective responses.

**Climate Change—Challenge and Opportunity*****Combined Viticulture & Enology Session* – CONTINUED****Climate Change in the Northeast United States and Implications for Grape and Wine Production****Alan N. Lakso**,\* Arthur T. DeGaetano, Jonathan Comstock, and David Wolfe\*Department of Horticultural Sciences, Cornell University, Geneva, NY 14456  
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In the last 30 years there has been significant warming in the northeastern United States. The associated decrease in extreme cold events has facilitated the development of the *Vitis vinifera* wine industry in New York. Climate change simulations predict significant warming to continue, especially in the winters. This will lead to more heat spells in the summer and increased warm periods in winter, punctuated by more typical winter cold outbreaks. Annual precipitation is expected to increase slightly, but expectations also call for more intensive rainfall episodes with more drought periods in between. Implications for grape and wine production are many. Longer and warmer growing seasons suggest riper wines and more long-season varieties. Increased CO<sub>2</sub> should also lead to increased yield potential. Warmer winters are expected to allow more cold-tender varieties to be grown; however, warm spells in the winter may lead to de-acclimation of the vines. This may be associated with continued cold injury, though occurring at warmer temperatures. Droughts and floods will likely emphasize the need for both irrigation and sites with excellent drainage. Winemaking will also require great flexibility in handling fruit from increasingly variable seasons.



**Water Management—Quantity and Quality**  
**Concurrent Viticulture Session**

**Monitoring Vine Transpiration Decline to Optimize the Timing of Irrigation**

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A decline in plant transpiration has been widely observed to occur when the fraction of transpirable soil water (FTSW) decreases below approximately 0.4. Thus, monitoring of transpiration decline could indicate when soil moisture deficit becomes too severe for the plant. However, vapor pressure deficit (VPD), soil hydraulic conductivity and dry root signaling to stomata are likely to affect the threshold where water supply is limiting transpiration. Thus, when light regime is not limiting, we investigated the stability of transpiration decline for different VPD and soil moisture levels to evaluate the potential of this approach for commercial applications. Using sap flow sensors, we measured vine transpiration in commercial vineyards and investigated the effects of contrasting VPD and various irrigation strategies (high vs. low volumes applied at different frequency) on transpiration decline. We found that in the absence of soil moisture deficit plant transpiration remains constant regardless of VPD for values greater than 2 kPa. When soil moisture deficit is more pronounced, VPD seems to have no effect on transpiration rate. We suggest that soil moisture deficit and VPD may have independent effects on transpiration. Regardless of irrigation, the FTSW threshold for the decline in transpiration with drying soil appears to be stable and to show little sensitivity to changes in VPD. Consequently, monitoring transpiration decline is a promising approach to determine when to trigger an irrigation.

**Effect of Deficit Irrigation and Kaolin-based Foliar Reflectant Particle Film on Aroma of cv. Merlot (*Vitis vinifera* L.)**

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Water deficit during development of red-skinned winegrapes enhances berry composition for wine production but increases the risk of fruit exposure to deleterious levels of heat and/or solar radiation. Foliar application of a kaolin-based particle film has been shown in many crops to alleviate stress symptoms, but its influence on wine composition is unknown. In this study we investigated whether foliar application of a kaolin-based particle-film may affect wine volatile aroma compounds and wine sensory attributes of the cultivar Merlot grown under differing levels of water deficit. Merlot vines were grown in the high desert region of southwestern Idaho and irrigated to meet 100, 70, or 35% of estimated crop evapotranspiration (ET<sub>c</sub>) from fruitset through harvest or 35% ET<sub>c</sub> until berry color change and then 70% ET<sub>c</sub> until harvest. Free volatile composition in the grapes was analyzed using stir bar sorptive extraction (SBSE)-GC-MS technique, and the precursors were isolated and hydrolyzed by enzyme under mild acidic conditions followed by SBSE-GC-MS analysis. Wines were analyzed

**Water Management—Quantity and Quality**  
**Concurrent Viticulture Session – CONTINUED**

over three consecutive growing seasons. The results demonstrated that despite vintage differences in volatile composition, in each of three years of this study, deficit irrigation during berry development had a consistent effect on wine volatile composition. The amounts of  $\beta$ -damascenone, citronellol, nerol, geraniol and their precursors were higher in deficit irrigated grapes and the wines. Deficit irrigation increased linalool glycoside in the grapes but not in the wine. Deficit irrigation had no impact on the concentration of  $\beta$ -ionone. Particle film did not affect wine volatile composition regardless of irrigation level.

**Evaluation of Deficit Irrigation Impacts on Vine Productivity over Five Years**

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This project evaluated the long-term effects of different in-season deficit irrigation levels on the productivity and quality of winegrapes on the Central Coast of California. The experiment was conducted from 2004 through 2008 in a Cabernet Sauvignon vineyard east of Paso Robles. This region is irrigated exclusively with groundwater, and there is concern that the expanding acreage of irrigated vineyards may contribute to depletion of the groundwater supply; hence the need for information on the long-term effects of reduced irrigation amounts. Treatments consisted of a grower standard control amount (approximately 65% of estimated crop evapotranspiration), and 50%, 75%, and 125% of the control amount; treatments were applied from fruit set to harvest each season. No significant differences in yields were seen during the first three years, but during the last two years the yields of the two drier treatments were significantly lower than the control. Berry size was consistently smaller in the two drier treatments throughout the study period. The number of fruit clusters per vine, only measured in the last two seasons, was not significantly different, while the average cluster weight was significantly lower in the two drier treatments. The juice soluble solids were consistently higher in the treatments receiving lower irrigation amounts, ranging from 0.1 to 2 Brix above the control amount; there were no differences in juice pH or titratable acidity.

*Funding support:* California Department of Water Resources and the J. Lohr Winery.



## Acid Management—Up or Down?

### Concurrent Enology Session

#### Malic Acid Reduction Using Encapsulated *Schizosaccharomyces pombe* in Double-Layered Alginate Beads

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Research efforts focusing on grapes and wines from the Midwest revealed that malic acid is the dominant organic acid in many varieties when grown in this region. In combination with generally high acidity often encountered in cold climate grapes, the Midwest wine industry faces some unique challenges. To address this issue, the Midwest Grape & Wine Industry Institute at Iowa State University has investigated several methods for acid reduction that lower especially the malic acid content. Application of encapsulated *Schizosaccharomyces pombe* in double-layered alginate beads, commercially available as ProMalic yeast, has shown a significant reduction in the malic acid concentration. Specifically, ProMalic yeast was hydrated according to the manufacturer's recommendations and placed in Frontenac must prior to inoculation with EC1118 (Prise de Mousse) yeast. During primary fermentation the ProMalic yeast was hydrated daily in plain sugar water. This step was vital, as previous trials without the daily hydration resulted in only minor reduction of malic acid. The organic acid profile was monitored daily using HPLC. Compared to control batches, the malic acid concentration in batches treated with ProMalic decreased significantly without an increase in lactic acid.

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#### Tools for Managing Malolactic Fermentation in Acidic Wines

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Malolactic fermentation (MLF) is a natural process for reducing acidity in wine. This research investigated the activity of lactic acid bacteria (LAB), mainly *Oenococcus oeni* species. MLF is carried out in all red wines but is also very effective in white or rosé wines, when necessary. However, high acidity levels, low pH (below 3.3), and/or high L-malic acid content (above 5 g/L) put major stress on LAB, which then have difficulty completing MLF. The first stage in managing MLF in overly acidic wines consisted of selecting a strain of LAB that was highly resistant to acidity. The selection process used genetic tools based on recent findings concerning diversity among *O. oeni* strains. One strain particularly resistant to low pH was developed using these methods. Other qualities of the strain are also very important as, in addition to pH, these wines are highly toxic to bacteria due to very high concentrations of medium-chain fatty acids such as octanoic and decanoic acids. Once the most efficient strain had been selected, it was necessary to develop a protocol for its use. This presentation reviews the innovative stages in *Oenococcus oeni* strain selection, giving details of the genetic tools used, then reporting on the inhibition of LAB by octanoic and decanoic acids, and, finally, presenting the protocol developed for managing MLF in particularly acidic wines.

**Grape Ripening—Dealing with Variation**  
*Concurrent Viticulture Session***Variation between Berries, Bunches, and Vines in Pinot noir Vineyards: Effects on Grape and Wine Composition**

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Experiments with Pinot noir clones 114 and G5V15 from cool climate Tasmanian vineyards investigated effects of natural variation in berry size and *Botrytis* infection on grape and wine composition (using ultra-microvinification), and of aspect of berries on the bunch (facing canopy exterior or interior). The onset of fruit coloring was studied in relationship to time of flowering, and to grape and wine composition using single bunch ferments for 76 clusters. At the vine level, cluster thinning during veraison was compared with no thinning, and also the effect of thinning or retaining clusters with mostly green berries and thinning or retaining clusters with colored berries. This experiment was carried out over two years and allowed comparison of the effects of fruit thinning and fruit selection. The effect of natural vine to vine variation was studied using aerial infrared images identifying vigor. The effect of vine vigor on canopy attributes, yield, fruit, and wine composition was studied over three years. Aerial plant vigor maps were well correlated to vine pruning weight, canopy density, chlorophyll content, and improved leaf retention. There was not a consistent relationship between the image and yield and fruit sugar concentration, although titratable acidity and pH tended to increase with vigor, as did yeast assimilable nitrogen. Vine to vine variation was also assessed by comparing vines affected with and symptomatic for leafroll virus strain GLRaV-9. Results show that variation exists at all levels, berry, cluster and vine, and the implications of this variation in commercial vineyards to vineyard management for wine quality will be discussed.

*Funding support:* Tamar Ridge Estates, Tasmanian Institute of Agricultural Research, Tasmanian Department of Economic Development, Australian Ausindustry ICIP, Australian Grape and Wine Research and Development Corporation, and Australian Postgraduate Award.

**Model to Predict the Demand for Bentonite in Wine Based on Ambient Data and Weather Anomalies**

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Excessive amounts of protein in wine may lead to haze formation during winemaking. Fining with bentonite prior to bottling reduces that risk by removing proteins. It is still an open question, why different vintages differ significantly in their general demands for bentonite and how one can predict the required amount. We evaluated climate-related factors, enological treatments, and ripening parameters to create a model that



## Grape Ripening—Dealing with Variation

### Concurrent Viticulture Session – CONTINUED

would enable a prediction of average bentonite demand. Most of the haze proteins were identified to be pathogen related as a response to stress exerted on the vine. Hence, a feasible correlation between environmental factors such as sunshine hours, solar radiation, precipitation, and water balance was created to explain and predict the amount of bentonite needed. More than 800 wines were analyzed to calculate the average demand from 2001 to 2008. In years with lower demand the number of unusual weather events was higher, so it was concluded that weather anomalies reduce the need for bentonite. The term weather anomaly is defined as a significant variation from the long-term average. The year 2004 is missing in the model because grapevines were physiologically over-compensating for the extremely hot and dry vintage 2003. The coefficient of determination reveals that weather anomalies could explain 87% variation in bentonite demand during eight vintages in German wine from the Palatinate region. One possible explanation could be that climate-related stress factors led to an accumulation of tannins in the berry, which may have triggered precipitation of proteins and diminished the haze forming proteins in the latter wine.

## Estimating Grape Yield: Seasonal Changes in Berry Growth and Maturation as Related to Cropping Levels over Two Seasons in Michigan

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Growing grapes in Michigan, or in any cool climate region, requires several tools to evaluate both yield and ripening potential. Needed are: 1) methods to assess the growing season's capability to ripen a specific crop amount, 2) acceptable methods to estimate the crop level in the vineyard, and 3) repeatable, quantified methods to adjust the vine's crop to appropriate levels. Of these, yield estimation is the most challenging task because it is influenced by seasonal and vineyard variability, particularly as these affect berry growth. Berry development consists of two sigmoidal growth periods separated by a lag phase and each stage is differentially influenced by several factors (e.g., temperature, yield levels). The main objective of this work was to monitor berry growth and chemistry of the juice each week after fruit set. Concord (*Vitis labruscana* Bailey), Riesling, and Cabernet franc (*V. vinifera* L.) grapes were employed, and cumulative heat units were used as an indicator of the halfway point in berry weight in two different seasons and under a range of different yield levels. Yield levels influenced the ripening profiles and berry growth of the different cultivars. However, when growth analyses were conducted on the basis of percent of berry growth as function of final berry weight (100%), differences among yield levels disappeared, leaving only cultivar and seasonal influences. Moreover, when berry development was analyzed in relation to seasonal growing degree day accumulation, developmental curves and phenological stages followed the same pattern for each cultivar under the different experimental conditions.

**Innovation—From Mechanization to Automation**  
*Concurrent Viticulture Session***Development of a Self-Propelled Autonomous Transport and Propulsion Device for Working Assistance in Steep Slope Vineyards**

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In Germany, steep slope vineyard cultivation is continuously declining. Due to the immense workload and the exhausting and dangerous working conditions, thousands of hectares have been abandoned in the last few years. With adequate innovative mechanization, the labor time could be significantly reduced, thus reducing risk of accidents, increasing work safety, and achieving economical competitiveness. Therefore, a multifunctional transport and propulsion device for working assistance in steep slope vineyards is under construction. Utilizing optical and satellite-based steering devices, navigation in the vineyards is carried out automatically, and thus no driver is necessary. The use of newly developed propulsion devices, combined with modern compound materials and an innovative chassis concept, with proper ground conditions, permits driving grades up to 70%.

*Funding support:* Federal Agency for Agriculture and Food, FRG.

**Spatial Variability of Soil Composition, Soil Texture, and Soil and Vine Water Status in Cabernet franc Vineyards**

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The purpose of this study was to determine spatial variability with respect to soil composition, soil texture, and soil and vine water status in ten Cabernet franc vineyards in the Niagara Peninsula of Ontario. It was hypothesized that water status zones could be identified within vineyard blocks, and that this spatial variation would be consistent and stable temporally. Soil texture, soil chemical composition, soil moisture and leaf water potential ( $\Psi$ ), as an indicator of vine water status, were determined and compared within the ten research vineyard blocks from 2005 to 2007. Soil samples were collected from every fourth vine and were analyzed for pH, organic matter, P, K, Mg, Ca, texture, CEC, and base saturation using standard procedures. In each vineyard block, water status zones were identified on GIS-generated maps using leaf  $\Psi$  and soil moisture measurements. The inverse distance weighting interpolation algorithm was used to construct the grid files. Spatial correlation analyses demonstrated that soil moisture zones were consistent in one vineyard from 2005 to 2006, while from 2006 to 2007, consistency was observed in six blocks. Leaf  $\Psi$  zones were temporally consistent in three vineyards from 2005 to 2007. Spatial correlation analyses between soil texture and soil chemicals, including percent organic matter, cation exchange capacity, soil pH and base saturation, K, P, Ca, and Mg demonstrated site-specific relationships.

**Innovation—From Mechanization to Automation*****Concurrent Viticulture Session – CONTINUED*****NDVI Imaging as a Tool for Characterizing Fruit and Wine Variability on Two Mechanically Harvested Merlot Vineyards in California**

**Martin P. Mendez-Costabel**,\* Luis A. Sanchez, Nick Dokoozlian, and Pedro C. Towers  
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NDVI images were generated at veraison for two mature, mechanically harvested Merlot vineyard blocks of the same age, trellis, rootstock, and management practices grown in the North Coast of California. Mean NDVI values per row were calculated, and each vineyard divided into three major vigor classes according to their average NDVI value per row. Five clusters were randomly selected in 20 different locations within each row and combined into 54-kg wine lots. Additionally, the composition of 20 randomly selected clusters per row was determined at harvest. Wines were bottled three months after completion of fermentation, and wine composition evaluated two months later. The results indicate that the fruit and wine quality components analyzed in the study did not show a clear relation with NDVI values. Fruit color and fruit moisture were negatively correlated to NDVI, while both fruit aroma precursors and Brix levels were higher in rows with high NDVI values. Wine color, total phenols, polymeric tannins, and potassium were negatively correlated to NDVI values. Differences in fruit and wine composition were greater between blocks than within blocks. The results suggest that using the average NDVI values per row within a specific mechanically harvested vineyard block is not accurate for separating fruit quality differences.

## Monday Oral Presentations (Submitted Abstracts)

## ICCS TECHNICAL ABSTRACTS CONTINUED

**Soil Management—Integrating Nutrition, Biodiversity, Carbon Sequestration, Salinity, and More: Concurrent Viticulture Session****Low N Supply, But Not Low P or K Supply, Alters Pinot noir Growth, Yield, and Berry Aroma Profiles**

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To understand how nutrients influence the growth, physiology, and berry quality attributes of Pinot noir, supplies of nitrogen (N), phosphorus (P), and potassium (K) to vines grown in a sand-culture vineyard were each independently manipulated from 2006-2008. Vines received complete nutrition during their first three establishment years (2003-2005). Low N supply reduced vine N status, low P supply reduced vine P status, and low K supply reduced vine K status as intended (based on leaf blade and petiole tests). However, only N treatments impacted the growth or yield of vines, and the influence of N increased over time. Early season shoot lengths, photosynthesis, yield, and berry weights were all reduced by low N supply in 2008, but not prior to this time, while dormant season pruning weights and juice YAN were lower in 2007 and 2008. Berry sugars were higher in low N vines in 2008, but pH and TA were not altered by N supply. Low N supply also increased the concentration of numerous terpene alcohols (primarily bound forms) in berries in 2008, independent of N effects on berry size or maturity. An increased concentration of norisoprenoids in berries from low N vines was attributed to N effects on berry size. Berry aroma profiles were not altered by low P or K supply. Our findings suggest that enhancing the concentrations of certain berry aroma compounds by reducing N supply to vines may not be possible without sacrificing overall vine productivity or reducing juice YAN below acceptable levels.

*Funding support:* USDA-ARS and Northwest Center for Small Fruits Research.

**Conservation Tillage of Cover Crops for Carbon Sequestration and Diminished Greenhouse Gas Emissions**

Michael Wolff,\* David Smart, and Danielle Pierce

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Following passage of the California Global Warming Solutions Act of 2006, it is important to constrain baseline greenhouse gas emissions from vineyards and examine mitigation options. Three vineyard floor treatments in a Napa vineyard were sustained for 6 years under (1) an annually seeded, no-till barley cover crop, (2) an annually seeded, incorporated and tilled barley cover crop, and (3) incorporated and tilled resident vegetation. The experiment was laid out in a completely randomized block design in a Cabernet Sauvignon vineyard on *Vitis riparia* x *V. rupestris* cv. 101-14 rootstock. We found that emission of CO<sub>2</sub> was lowest in treatment (2) last year. The results suggest that twice-yearly tillage reduces the C sequestration benefits of seeding a barley cover crop. (We are awaiting soil C test results to show us whether this interpretation is correct. Results will be in by the time of the conference.) While a permanent cover crop may be preferable for C sequestration, vine water stress increased



**Soil Management—Integrating Nutrition, Biodiversity, Carbon Sequestration, Salinity, and More: Concurrent Viticulture Session – CONTINUED**

in treatment (1), resulting in declining pruning weights and yields. Thus, we need to ascertain the frequency with which cover-cropped rows should be tilled, in order to maximize both soil C sequestration and vineyard productivity. We have studied the quantitative, spatial, and temporal distribution of N<sub>2</sub>O greenhouse gas emissions (300x more warming than CO<sub>2</sub> per unit) following nitrate fertilizations. First-round results show greater emissions in treatment (2). Natural emissions have also been found following precipitation, requiring further study of possible dependence on cover crop and tillage treatment.

*Funding support:* American Vineyard Foundation, California Competitive Grant Program for Research in Viticulture and Enology, and the Viticulture Consortium West.

**Do Bait Lamina Strips Capture Meaningful Changes in Soil Biological Activity after the Application of Composts and Manures in Established Vineyards?**

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Vineyards established on heavy clay loam soils struggle with compaction and poor soil aeration. The conventional advice is to supplement organic matter either in the form of cover crops grown and incorporated in situ, or the addition of various manures, composts, and other suitable organic wastes. The question arises whether subsequent changes in vine vigor and productivity are related to conventional mineral changes in the soil solution or complex biological changes in the soil flora/fauna due to changes in soil texture, aeration, and water holding capacity. Bait lamina strips were chosen as a simple index of biological activity, to supplement the usual soil/tissue/fruit analyses and vine yield components. Five manure/compost/waste materials (composted turkey litter, fresh broiler litter, spent mushroom compost, composted yard and municipal household waste, and N-Viro stabilized sewage sludge) were applied to an established vineyard with rates estimated at 34 kg/ha total N. Tissue, soil, and fruit analyses showed very minor but predictable changes in N, P, and K after three seasons while there were significantly increased bait lamina feeding patterns with all composts compared to controls. However, these strips offer only a very small snapshot of soil health and results are highly variable. Alternative sampling methods will be proposed.

**Microbiology—Good, Bad, or Ugly**  
*Concurrent Enology Session***Aroma Differences between Wild and Inoculated Ferments in Sauvignon blanc Wines****Kirsten M. Creasy\***\*Centre for Viticulture and Oenology, Lincoln University, Lincoln 7647, New Zealand  
(creasyk@lincoln.ac.nz)

There has been much research evaluating different aspects of wild ferments versus cultured ferments and it is generally accepted that wild ferments can make more complex wines. However, little of this work has used gas chromatography-olfactometry (GCO) to assess and group specific aromas. Two wines were fermented from the same Sauvignon blanc juice: one with a cultured yeast specific for the variety and the other with wild yeast. The wild yeast was collected by sterilizing a portion of the juice and leaving it in the vineyard to start to ferment. The wines were fermented under the same conditions but in separate sites to prevent yeast cross contamination. Once the wines were bottled, they were analyzed using GCO. The panelists assessing the wines recorded aroma descriptors and aroma intensity over a 60 minute run time. These descriptors were placed into specific aroma groups based on the Wine Aroma Wheel. The results showed a significant difference between the two wines. The cultured yeast ferment was dominated by only two aroma groupings (chemical and fruity), whereas the wild ferment was spread mainly over five groupings (earthy, vegetative, fruity, floral, and chemical). In addition, the number of descriptor responses was greater in the wild ferment than the inoculated ferment (a rate of 1.6:1). These results support the notions that wines made with wild yeasts display greater aroma complexity and that GCO is an effective tool to assess wine aromas.

**Effects of Yeast Strains and Vinification Techniques on Acetaldehyde Kinetics in Wine****Erhu Li and Ramón Mira de Orduña\***

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During fermentations, the concentration of acetaldehyde, which is of relevance to wine aroma, red wine color, and microbiological stability, is determined by yeast metabolism. While it is known that SO<sub>2</sub> addition leads to increased yeast acetaldehyde formation, the actual dose effect and strain variations are not well studied. This research evaluated the ability of 26 yeast strains, including *Saccharomyces* and non-*Saccharomyces* strains and commercial starters to form and degrade acetaldehyde in a model medium and during grape must vinifications. The effect of pH, temperature, and nutrient addition was considered as well as yeast response to SO<sub>2</sub> additions at different fermentation


**Microbiology—Good, Bad, or Ugly**
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stages. Specifically, the effect of using SO<sub>2</sub> to stop alcoholic fermentation with the aim of achieving wines with residual sugar was compared with cooling. Acetaldehyde kinetics and final concentrations were highly genus-, species- and strain-dependent. Peak acetaldehyde values varied from 2.19 to 189.39 mg l<sup>-1</sup> and acetaldehyde yield ranged from 0.25 to 39.31 mg per g of glucose in the model system. *Sch. pombe* showed the highest acetaldehyde yield and peak values in the model must and actual must fermentations. All other non-*Saccharomyces* species produced less acetaldehyde than the *S. cerevisiae* strains. Buffer pH, initial glucose concentrations, and SO<sub>2</sub> addition had noticeable effects on acetaldehyde production, but not fermentation temperature. Stopping alcoholic fermentation with SO<sub>2</sub> led to greatly increased acetaldehyde levels compared with cooling. This research provides new information on acetaldehyde control, especially with regards to SO<sub>2</sub> utilization and the characteristics of increasingly popular non-*Saccharomyces* strains in cool-climate winemaking.

*Funding support:* China Scholarship Council (State Scholarship Fund No. 2008630061 for Erhu Li).

**Management of *Dekkera* (*Brettanomyces*) by SO<sub>2</sub> and Filtration**

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Winemakers use both SO<sub>2</sub> and filtration as means to control red wine spoilage associated with *Dekkera* (*Brettanomyces*). Responses of *Dekkera* to SO<sub>2</sub> include inducement of an altered physiological state (nonculturable) which, in turn, may yield physically smaller cells which would affect filtration efficiency. Two strains of *D. bruxellensis*, B1b and F3, were inoculated into previously sterile-filtered red wines (0.45 μm). Once populations reached 106 cfu/mL, half of the wines received 0.5 mg/L molecular SO<sub>2</sub>. After six days, each wine was filtered, in triplicate, through absolute membranes of different porosities. Culturability (plate counts using a nonselective medium), viability (epi-fluorescence microscopy and Vi-Cell analysis), and genetic detection (Scorpion probes analysis) were monitored immediately before and after filtration and during extended storage up to 200 days. While strain B1b was removed from wines by filtration through 1.2 μm, strain F3 was initially detected in filtered wines by Scorpion and eventually direct plating. Subsequent filtration of wines inoculated with F3 through 0.8 μm membranes resulted in removal of this strain. A minimal porosity of 0.8 μm is therefore recommended for removal of *Brettanomyces* from wines. Addition of SO<sub>2</sub> prior to filtration decreased the number of detectable cells in filtered wines.

*Funding support:* Wine Advisory Committee, Washington Wine Commission, and the WSU Agricultural Research Center.

**Fruit and Wine Aroma—Focusing on Objectivity  
Combined Viticulture & Enology Session****Managing Green Flavors after Harvest: Response of  
2-Alkyl-3-Methoxypyrazines to Various Wine Treatments**Gary Pickering,\* Amy Blake, George Soleas, and **Debra Inglis**

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2-Alkyl-3-methoxypyrazines (MPs) are important grape- and insect-derived flavor compounds in some juices and wines. Of particular interest to cool-climate winegrowing, they are largely responsible for the green, vegetative characters associated with wine made from grapes that have not achieved optimum ripeness. We review some recent research from our lab that has investigated the capacity for juice clarification, yeast, fining, oak treatment, wine packaging and wine storage conditions to moderate MP concentrations. We also present some previously unreported results. A preliminary study was conducted to examine the relative capacity of commonly used wine closures to mediate MP content in wine. A Chardonnay wine spiked with 40 ng/L each of 3-isobutyl-, 3-*sec*-butyl- (SBMP), and 3-isopropyl- 2-methoxypyrazines was soaked for 140 hrs with either agglomerate corks, natural corks, moulded synthetic closures or extruded synthetic closures at two levels of closure addition (5 units/L and 10 units/L). All closures significantly reduced MP concentrations in the wine, with the greatest decrease observed with synthetic closures (70%–89% reduction). SBMP was most affected by closure treatments. We conclude that there is capacity to significantly mediate the impact of MPs on wine quality postharvest.

*Funding support:* Natural Sciences and Engineering Research Council of Canada, Wine Council of Ontario, and Grape Growers of Ontario.

**Influence of Grape Ripeness on the Analytical and Sensory Properties of  
Styrian Sauvignon blanc****Erich Leitner\***

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Sauvignon blanc belongs to the top five planted grape cultivars worldwide and shows unique sensory properties which can range from “green” to “tropical” notes. Several compounds are responsible for the different styles and characteristics. 3-Isobutyl-3-methoxypyrazine (IBMP) is mainly responsible for the “green, bell pepper” note with a sensory threshold of 2 ng L<sup>-1</sup>. The concentration of IBMP is mainly influenced by fruit maturity and the climate of the wine growing area and decreases with increasing ripeness and warmer temperatures. Sulfur containing compounds are another group of components which can have a dramatic influence on the aroma properties of Sauvignon blanc at very low concentrations. One of the most potent aroma compounds in wines is 4-mercapto-4-methylpentan-2-one (4MMP) with a reported threshold of 0.8 ng L<sup>-1</sup>. Depending on the concentration, 4MMP can add box-tree or exotic passion fruit aroma to the wine. In contrast to IBMP, these substances cannot be found in the grapes or in the grape juice but are formed during fermentation from odorless precursors. So


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the influence of the used yeast can be of great importance to the formation of aroma active compounds. Although the Styrian wine area is one of the smallest (450 ha Sauvignon blanc) in comparison to other Sauvignon blanc producing regions, it belongs to the leading producing regions in the world. The aim of this study was to monitor the influence of the sensory properties of Styrian Sauvignon blanc wines at different ripening stages during harvest.

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**Discernible Response of the Peppery Sesquiterpene Rotundone during Fruit Ripening of *Vitis vinifera* L. Syrah grown in New Zealand**

**Gerard A. Logan**,\* Tracey E. Siebert, Laura Nicolau, Paul A. Kilmartin, Glen L. Creasy, Richard E. Smart, and Muralledharan G. Nair

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Rotundone was recently identified by the Australian Wine Research Institute as one of the compounds responsible for the peppery aroma in Shiraz (Syrah) grapes and wine. Consequently, rotundone is the topic of much recent interest as it provides a characteristic difference to wines produced from Syrah grapes. However, its biosynthesis during berry ripening and storage in the fruit is unknown. Thus, an attempt was made to identify the concentration of rotundone in Syrah fruit during berry ripening as a starting point for further investigation. Using a replicated design, 64 vines in a Hawke's Bay vineyard were managed uniformly with regard to viticulture. Vines were spur-pruned Syrah planted into moderate-vigor, silty, alluvial gravel soil. Complete leaf removal was imposed in the fruiting zone and all but the basal clusters were removed. Two, three-cluster samples were removed at random from each panel of four vines every 14 days between modified E-L growth stages 30–38. Cluster samples were immediately stored at -20°C before being transported frozen to the Australian Wine Research Institute in Adelaide. Samples were analyzed using previously published GC-MS methodologies for determining rotundone concentration. Results indicated that rotundone concentration was low until berry softening at which time it rapidly increased from about 7 ng kg<sup>-1</sup> to about 55 ng kg<sup>-1</sup> over 14 days and then remained stable. These results provide a platform for further investigations into rotundone biosynthesis in Syrah fruit and the impact of viticulture on this important character in wine.

*Funding support:* Department of Chemistry at The University of Auckland, Mission Estate Winery, Hawke's Bay, Craggy Range Vineyards, Hawke's Bay, Faculty of Science and Technology, EIT Hawke's Bay, Romeo Bragato Trust Viticulture Postgraduate Scholarship, and Department of Horticulture, Michigan State University.

**Fruit and Wine Aroma—Focusing on Objectivity*****Combined Viticulture & Enology Session – CONTINUED*****Aroma Chemistry of Riesling**

**Gavin L. Sacks**,\* Terry E. Acree, Justine E. Vanden Heuvel, Misha T. Kwasniewski, Bruce S. Pan, and James M. Meyers

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Riesling is widely planted in cool-climate regions and produces aromatically distinctive wines. In comparison to other aromatic white cultivars like Sauvignon blanc and Muscat, the aroma chemistry of Riesling wines is not well defined. The characteristic Riesling aroma is often assigned to the presence of monoterpene alcohols (e.g., linalool), but a survey of monoterpene concentrations in 30 New York State Rieslings revealed that only 10% had monoterpene concentrations approaching or exceeding sensory threshold. Based on a review of existing literature and gas-chromatography-olfactometry–mass spectrometry (GC-O/MS) studies, the characteristic aroma of Riesling is more likely due to a combination of several peri-threshold compounds, including monoterpenes, volatile thiols, vinyl phenols, sugar degradation products, and 1,1,6-trimethyldihydronaphthalene (TDN, “petrol”) alongside generic volatile products of alcoholic fermentation. Of these, only TDN is significantly higher in Riesling than in other white wines and is usually at or near sensory threshold. TDN is released during fermentation from carotenoid-derived glycoside precursors. In agreement with other reports, we observe a positive correlation between sunlight exposure and potential TDN, and TDN concentrations in finished wines are correlated to potential TDN measured in must. To understand the importance of cluster exposure timing on TDN precursor production, we applied fruit zone leaf removal to Riesling at three time points: 2-, 33-, and 68-days past berry set. Significantly higher total TDN in grapes and free TDN in wine were observed only with the 33-day treatment compared to an untreated control.

*Funding support:* New York Wine and Grape Foundation, Kaplan Vineyard Fund, and Shaulis Scholarship Fund.



**Disease Management—Sustainability and Innovation**  
**Concurrent Viticulture Session**

**The Expert System OiDiag-2.2: A Useful Tool for the Precise Scheduling of Sprays against Grape Powdery Mildew (*Erysiphe necator* Schwein)**

**Karl Bleyer** and Walter K. Kast\*

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OiDiag-2.2 includes knowledge about ontogenetic resistance of grapes, climatic conditions, and long-term observations of powdery mildew development for two different tools to forecast the date of the first spray and the time lag for application of the following sprays. Data collection (N=53) revealed that severity of powdery mildew disease correlates with the mean of the lowest temperatures of the two preceding winters ( $r=0.45^{**}$ ) and with the disease incidence of the preceding year ( $r=0.35^{**}$ ). On the basis of these results, a time lag for the first spray was calculated that started at the three-leaf phenologic stage. Secondly, the time lag for the following spray by means of the OiDiag index-values, which are based on the input of temperature (daily means), hours with humidity between 65% and 80% and >80% per day, duration of leaf wetness (hr), and the amount of rainfall (mm/d). Furthermore, the ontogenetic resistance of grape clusters according to Stark-Urnau and Kast (1999) was factored; higher index values were calculated for the time span 10 days before and after the bloom period and subsequently reduced after this period of extreme susceptibility. Sliding means for the last seven days were calculated as final results, the OiDiag 2.2 Index. Fungicides were evaluated for their preventive period for each of these five classes, and results were summarized in a table that allows winegrowers to take a reading for the next spray.

**Impact of Grapevine Leafroll-Associated Virus-3 on the Performance of Own-Rooted Merlot Grapevines (*Vitis vinifera* L.) in Cool Climate Viticulture**

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The effects of *Grapevine leafroll-associated virus-3* (GLRaV-3) on field performance of own-rooted Merlot grapevines in a commercial vineyard block were studied. Grapevines were selected in such a way that GLRaV-3-infected and healthy grapevines were adjacent to each other in a given row to minimize error in experimental results. Fifteen pairs of healthy and virus-infected grapevines from different rows in the vineyard block were included in this study. Leaves from virus-infected grapevines exhibiting grapevine leafroll disease (GLD) symptoms during postveraison stage showed reduction in chlorophyll a fluorescence (-8%) and net photosynthetic rate (-40%), when compared to corresponding leaves from neighboring virus-free grapevines. These differences were not observed between leaves from virus-infected and virus-free grapevines during preveraison stage, when GLD symptoms are not obvious in virus-infected grapevines. Cumulative fresh fruit yield/grapevine was reduced in virus-infected grapevines by 22

**Disease Management—Sustainability and Innovation****Concurrent Viticulture Session – CONTINUED**

and 30% in 2008 and 2009, respectively. This difference was due to reduction (15 to 17%) in number of bunches and weight (13 to 19%) of individual bunches from virus-infected grapevines. The pruning wood weight in virus-infected grapevines was reduced by 37%. Fruit maturity indices revealed consistently low juice sugar content and pH, and higher titratable acidity in berries from GLRaV-3-infected grapevines from veraison to harvest. Grape juice sugar content at the time of harvest in 2008 and 2009 was lower (6 and 9%) in berries from virus-infected grapevines. These results show negative impacts of GLRaV-3 on grapevine performance and quality of grapes produced by Merlot.

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**ITKVine: A New Decision Support System for Disease Management in Viticulture**

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Disease models are widely used for fungicide management in viticulture, but their interpretation remains fairly complicated. One of their main limits is that disease pressure is not the only information to consider. When treatments have already been applied, other factors such as persistence of the last applied treatment and canopy growth since the last application are as important as the contamination risk to decide whether a plot requires a new treatment or not. ITKVine is a web service designed by ITK to integrate all these factors. It includes downy and powdery mildew models, a canopy growth model, and a fungicide model which calculates the actual persistence of the treatments, according to intrinsic persistence of the products, rainfall, and canopy growth. It can be accessed and used by both growers and consultants. Thus it becomes an efficient communication tool. Consultants can easily compose provisional applications programs for each plot, and check that these programs comply with best practices, e.g., fungicide resistance management. Growers get a summary of ITKVine's most important results and can enter their fungicide applications as soon as these are made. They can check the daily disease risk level and the fungicide protection status of their plots, and ask for more details when necessary. Validation trials in France showed that ITKVine allowed an average reduction of 25% in fungicide applications and could be used easily by winegrowers who have never used disease models.



**Health Benefits and Consumer Interests**

**Concurrent Enology Session**

**The English Wine Industry: Developing a Golden Opportunity**

**Christopher J. Foss\***

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The English (and Welsh) wine industry has a very considerable potential for development, as long as it can effectively manage its rapid expansion. In the last few years, the industry has benefited greatly from a new interest in regional foods and wines, our wine producers have sparkled in international competitions, and there have been consistent improvements in our climate. With a total heat summation that is now at the level that our nearest wine-producing region enjoyed throughout the last century, some English wine producers are making wines that match Champagne in price and quality. The result of all this is an estimated growth in vineyard acreage of up to 20% each year over the last three years. This rapid development brings many challenges, among which are the maintenance of the high quality (and reputation) of the product, the development of a unique market image, and the assurance of sustainable development. The industry has recently been awarded a very substantial amount of funding, for the next 5 years, from the European Union that has been earmarked for “upskilling” its workforce. This has enabled it to organize an in-depth scoping study to evaluate the aspirations of the industry and its training needs, a sustainable wine production initiative, and Wineskills, a highly innovative project delivering training to the industry through workshops, masterclasses, and mentoring. This presentation will outline how a very exciting new cool-climate wine-producing area is working towards a successful future.

**The French Paradox Revisited: Vin, à Votre Santé?**

**Gregory Gasic\***

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Early epidemiological studies, which proposed that red wine in the French diet contributed to a lower incidence of heart disease (versus European countries) despite a considerable saturated fat diet, led to the term “French Paradox.” A description of this paradox on American television caused a spike in red wine consumption and its promotion as “healthy.” When the grape stilbene, resveratrol, was purified, shown to be a potent antioxidant and an in vitro inhibitor of all three stages of carcinogenesis, many speculated that it contributed to the French paradox and devised experiments to prove this hypothesis. Other grape-derived phenolic compounds, flavonoids, which have been shown to inhibit vascular fragility in pigs, might also be viable candidates. Although earlier epidemiological studies linked moderate wine, but not beer or spirits, consumption to a lower mortality, more recent studies found no difference between moderate consumption of alcoholic drink type and protection from myocardial infarction, cognitive decline, dementia, or total mortality. Furthermore, intestine

**Health Benefits and Consumer Interests**

***Concurrent Enology Session – CONTINUED***

and liver rapidly metabolize red wine polyphenols into glucuronate and sulfonate conjugates. Can their in vitro beneficial activities be restored in vivo through conjugate cleavage? Due to statistical methodology, which limits the number of correlations that can be considered, large numbers of behavioral, dietary, psychological, and socioeconomic differences between large groups may influence the main outcomes. Now, mechanistic studies in animal models need to provide potential measures for randomized clinical trials of alcohol, red wine, and components of red wine without the alcohol.

**Canopy Management—Beyond Fruit Exposure**

***Concurrent Viticulture Session***

**Effect of Vineyard Management Practices such as Winter Pruning, Cluster Thinning, Leaf Removal, and Shoot Trimming on Cool Climate Pinot noir Wines**

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It is estimated that 85% of Australian wines are consumed within 24 hours of purchase. With this in mind, we sought to identify vineyard management practices suited for near-term and long-term Pinot noir wine aging and quality. Vineyard management practices of winter pruning, cluster thinning, leaf removal and shoot trimming were all investigated in a commercial vineyard in Tasmania, Australia, and carried through to small-scale winemaking. Differences due to climate variation were greater than those due to management practices. This emphasized the need to modify management practices year to year to in cool climates. In warmer seasons, the Pinot noir vines were able to carry higher crop loads as a result of higher node numbers retained at winter pruning with little detrimental effect on fruit and wine composition. In cooler seasons, practices such as cluster thinning and leaf removal improved fruit and wine composition. Preliminary findings indicate that differences due to vineyard management may decline as wines age.

*Funding support:* Tasmanian Institute of Agricultural Research, Tamar Ridge Estates, Australian Grape and Wine Research and Development Corporation, and Australian Postgraduate Award.



**Canopy Management—Beyond Fruit Exposure**  
*Concurrent Viticulture Session*

**Comparison of Pruning Method and Severity on Vine Growth and Productivity of Chardonnay Grapevines**

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Low bud fruitfulness can often limit vine productivity in cool climates. Growth and productivity of Chardonnay vines were measured in the northern Santa Lucia Highlands appellation located in the Salinas Valley of California. Four- to 13-year-old, unilateral cordon-trained vines were pruned annually to the same node number using canes or spurs. Pruning severity was also compared annually on 6- to 13-year-old, spur-pruned vines, using 16, 24, and 32 retained nodes. When pruned to similar retained nodes, pruning method did not affect the 10-year average yield of vines. Spur-pruned vines had higher cluster numbers with lower cluster weights than cane-pruned vines. Spur-pruned vines had higher budbreak of retained nodes, shoots per vine, shoot length, pruning weight, and total leaf area. Fruit to pruning weight ratio or fruit composition was not influenced by pruning method. Retained node level greatly influenced vine yield and shoot growth characteristics of spur-pruned vines. Yield and cluster number increased while cluster and berry weight decreased with additional retained nodes. Shoot length, pruning weight, and clusters per shoot decreased and fruit to pruning weight ratio increased with additional retained nodes. No differences in fruit composition occurred among pruning severity levels that had an average yield response from 10.3 to 15.4 t/ha.

**Canopy Management—Beyond Fruit Exposure*****Concurrent Viticulture Session* – CONTINUED****VitiSim: A Simplified Carbon Balance Model to Help Address Environment, Productivity, and Vine Balance**

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The interactions between grapevines and the environment are critical issues that have implications for the balance between vegetative and reproductive growth, for our understanding of environmental effects on productivity and quality, and for the estimation of environmental footprints in variable climates, now and in the future. Vine models are required to integrate a myriad of data, make quantitative comparisons, and propose quantitative hypotheses. VitiSim, a simplified carbon production and distribution model, has been developed to provide quantitative, seasonally dynamic simulations. The model uses a daily time step, a big-leaf daily canopy photosynthesis light response, respiration of organs based on mass and specific respiration rates, and temperature-driven leaf area development. Weather inputs are daily maximum and minimum temperatures and radiation. Partitioning is based on the balance of total supply to total demand with relative sink strength partitioning coefficients if the carbon supply is limited. Fine root growth and respiration submodels have been recently developed based on recent root studies. A new fruit growth and abscission submodel has been developed based on abscission of berries that fall below critical growth rates. Validation studies indicate that simulated total and seasonal dry matter production amounts and patterns are realistic. Seasonal patterns of carbon supply to demand are very dynamic. Simulations can help visualize and quantitatively estimate climate, pruning, and thinning effects. Such models will be needed for understanding likely effects of climate change, such as the interactions between increased temperatures and increased CO<sub>2</sub>.



## Oxidation and Phenolics

### Concurrent Enology Session

#### The Myth of Fingerprints

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Grape berries accumulate anthocyanins in the skin during ripening. While coloration appears to be a steady process, the rate of anthocyanin accumulation, total anthocyanins, and anthocyanin composition at harvest appears to be highly variable between sites and seasons and even within sites. Differences in anthocyanins between sites and seasons have long been recognized by winemakers and growers; however, differences in anthocyanin composition and in the rate of accumulation are less well appreciated and to some degree, misunderstood. One of the more persistent misconceptions is that the proportional composition of anthocyanins represents a “fingerprint” by which cultivars might be identified and that this remains invariant, and independent of total anthocyanins. Here we present anthocyanin content and composition data over several sites and seasons in several *Vitis vinifera* cultivars. Data was generated by high-performance liquid-chromatography from skins extracted with 50% aqueous ethanol. Historically, the pattern of anthocyanin accumulation in a grape berry has been described by a sigmoidal curve with the bulk of accumulation occurring within the first few weeks after veraison. Here we show linear accumulation throughout ripening, slow initial accumulation with the bulk occurring in the few weeks before harvest, as well as declines toward harvest from an early peak in anthocyanin accumulation. In Shiraz grapes, changes were observed in the percent composition of the five parent anthocyanidins, cyanidin, delphinidin, petunidin, peonidin, and malvidin, with differences as great as 30% in total malvidin glucosides between seasons as well as significant differences in individual anthocyanin and glycoside composition. The research presented here demonstrates that the proportional composition of grape skin anthocyanin is too great to serve as a useful chemotaxonomic tool.

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#### Microoxygenation of Pinot noir: An Analytical Guide for the Determination of the Oxygen Demand

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In cool climate regions, winemakers often grapple with Pinot noir’s propensity to exhibit green tannins and low pigment content. Resulting wines may encounter problems with extended aging, as their color shifts rapidly toward brown hues. Microoxygenation has often been claimed as a technique to promote balanced tannins and enhanced color. In this study, different microoxygenation procedures before and after malolactic fermentation were carried out on Pinot noir wines from two consecutive vintages. In 2006, microoxygenation yielded light-colored wines with an

**Oxidation and Phenolics****Concurrent Enology Session – CONTINUED**

increasing yellow hue. By contrast, an increase in blueness, which was more pronounced upon microoxygenation prior to malolactic fermentation, was observed in 2007. Descriptive sensory analysis revealed that microoxygenation lowered green tannin intensity primarily in 2006. Dry tannin intensity decreased due to low oxygen doses in both vintages; however, an increased intensity was observed when applying high oxygen doses in 2007. A high flavan-3-ol to anthocyanin ratio in 2006 suggests that the oxygen-induced changes in color and astringency were strongly associated with the high flavan-3-ol concentration in this vintage. A rapid decrease of flavan-3-ols and high acetaldehyde concentration indicated an accelerated oxidation of phenolic compounds due to microoxygenation in 2006. In comparison to flavan-3-ols, the oxygen-induced degradation of monomeric anthocyanins was similar in both vintages. Analysis by LC-MS verified that constitution and size of pigments was related to the initial anthocyanin to flavan-3-ol ratio. Based on two vintages, the flavan-3-ol to anthocyanin ratio of Pinot noir wines can be regarded as a potential indicator for the oxygen dosage and timing of microoxygenation.

**Impact of Malolactic Fermentation on Red Wine Color and Color Stability**

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The effects of malolactic fermentation (MLF) on red wine color and the ability of malolactic bacteria (*Oenococcus oeni*) to degrade compounds important to the development of stable color were studied. Pinot noir and Merlot wines were produced, where simultaneous alcoholic and malolactic fermentations were induced in half of the wines. At dryness, all wines were pressed prior to sterile-filtration through 0.45 µm membranes. At this point, wines without malolactic (MLF-) were then either (a) inoculated with *O. oeni* or (b) pH adjusted to the same final level of wines that had completed the fermentation. All wines were then sterile-filtered, bottled, and stored at 13°C for analyses. All MLF+ wines had lower concentrations of acetaldehyde, pyruvic acid, and caftaric acid yet higher levels of caffeic acid. Conversely, MLF- wines contained less malvidin glucoside and monomeric anthocyanins. In addition, the concentrations of tannins in the Pinot noir MLF+ wines was lower than in MLF- wines. For both Pinot noir and Merlot, MLF+ wines had lower wine color, copigmentation, and polymeric pigment values compared to MLF- wines. Pinot noir wines produced by simultaneous fermentation had the lowest wine color, copigmentation, and polymeric pigment values. These trends continued during storage with pH adjusted MLF- wines having the highest color and polymeric pigment values after 12 months. These results demonstrate that MLF can affect red wine color independent of pH change and that *O. oeni* can impact the concentrations of phenolic and nonphenolic compounds involved in red wine color stability.



**Sensory Evaluation—From Grape to Glass**  
**Combined Viticulture & Enology Session**

**Elicitation of Ladybug Taint in Wine Is Not Limited to *Harmonia axyridis***

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The capacity for *Harmonia axyridis* (Multi-Colored Asian Ladybeetle; MALB) beetles to taint juice and wine when inadvertently introduced into the winemaking process is now well established. The tainting of wine by MALB has largely been a cool-climate phenomenon, both in North America and Europe. Most studies agree that methoxypyrazines – components of MALB haemolymph, and particularly 2-isopropyl-3-methoxypyrazine (IPMP), are the primary compounds responsible for eliciting ladybug taint. Another member of the *Coccinellidae* family—*Coccinella septempunctata* (seven-spot, or C-7)—is widely distributed in North America, the most prevalent ladybeetle in Europe, and commonly observed in vineyards. However, the report of Cudjoe et al. (2005) that C-7 produces only approximately 1% of the IPMP of MALB reduced concern that this species may also be implicated in ladybug taint. We investigated the possible effects of C-7 on wine quality under industrial conditions, by adding 0, 1, or 10 beetles/kg of Cabernet Sauvignon and Vidal grapes at crush and comparing methoxypyrazine concentrations (HS-SPME-GC-MS) and sensory profiles (descriptive analysis) in the finished wines. MALB were added to separate batches of fruit at the same densities and processed in an identical manner. Regardless of species, the addition of beetles at the higher density resulted in similar changes to the sensory profiles of the wines, consistent with ladybug taint. The sensory results were supported by IPMP concentrations, which were similar in both MALB and C-7–spiked wines. These results may widen concern over the presence of ladybeetles in vineyards at harvest, although it is unclear whether C-7 reach the vineyard densities required to affect wine quality as often or as rapidly as MALB.

*Funding support:* Natural Sciences and Engineering Research Council of Canada, Wine Council of Ontario, Grape Growers of Ontario, and Ontario Grape and Wine Research Incorporated.

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**Using Experienced Wine Tasters for Wine Sensory Analysis: Variance of Random Effects**

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A panel of 21 expert wine tasters (15 professional winemakers, two viticulturists, and four wine scientists) with a range of experience from 8 to 25 years were asked to rank the intensity of sensory attributes using a 100-mm visual analog scale. These attributes included aroma, in-mouth flavor, and mouthfeel descriptors. A total of 25 attributes were investigated for 16 wines. Each panelist evaluated the wines in triplicate over three tasting sessions. The variance of the different random effects (panelist, tasting session,

**Sensory Evaluation—From Grape to Glass*****Combined Viticulture & Enology Session – CONTINUED***

and wine) was investigated to see how consistent panelists were for each of the given attributes. There was a significant ( $p < 0.05$ ) effect of panelists across 25 attributes, tasting sessions across six attributes, and wine across nine attributes. The panelist variance was expected as the tasters were not trained or calibrated to the analog scale. For interactions there was no significant ( $p > 0.05$ ) effect of panelist×tasting session, panelist×wine, tasting session×wine, and panelist×tasting session×wine. Two attributes (strawberry and chocolate) had a significant ( $p < 0.05$ ) effect across all random effects and interactions. This significance across effects and interactions may be due to the fact that the attribute names were not specific enough or training is necessary for strawberry and chocolate aromas. These interaction results show that panelists were consistent in evaluating attributes for each wine across all three of the tasting sessions. This information indicates that untrained but experienced tasters can provide good quantitative descriptive analyses of wines in comparative tastings.

*Funding support:* Foundation for Research, Science and Technology, NZ, Lincoln University, and Pernod Ricard, NZ.

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**Waste Stream Sourced Reflective Mulch Affects the Aroma Profile of Pinot noir Juice**

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The effect of different reflective mulches on Pinot noir juice was investigated in a Canterbury, New Zealand vineyard. Mulches were applied in 2005 as four treatments over three blocks. Treatments were a non-mulched control (CON) and mulches made from waste products including mussel shells (MS) and green (GG) and clear (CG) recycled crushed glass. Juice samples collected from each replicate at harvest (2007-2008 season) were analyzed with gas chromatography-olfactometry (GCO). The thrice-replicated responses of two panelists consisted of 1) retention time, 2) a qualitative descriptor, and 3) time/intensity of each aroma. Each panelist responded to the juice aromas slightly differently, but differences were found within each of their data sets. Statistically significant results were found for certain aroma peaks in various combinations of peak area and time/intensity across the four treatments. As an example, for one aroma peak, described as “berry floral” (tentatively identified as benzyl alcohol), peak area and peak duration were greater in all the mulch treatments compared to the control. Another, “vegetative” (possibly 2-hexenal), was higher in CON than any of the mulch treatments. This suggests that changes in reflected radiation (demonstrated in a companion study) alter the amounts of the compounds responsible for these aromas in the fruit. The experiment has demonstrated the aroma profile of Pinot noir juice through GCO and that primary fruit aromas are affected through the use of these mulches.

*Funding support:* Sandihurst Winery, Sustainable Initiatives Fund Trust, Sustainable Farming Fund, MetaNZ, Christchurch City Council, and Tertiary Education Commission.



## Enology and Viticulture

### Creating a Method for Assessing Bushfire Damage to Vineyards

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On the evening of 7 February 2009, via ember attack, the Yarra Valley complex bushfire burnt several vineyards near Yarra Glen (50 km Northeast of Melbourne, Australia). Extensive damage occurred throughout the entire vineyard to grapevines and infrastructure such as sheds, irrigation systems, and trellising. In order to determine the impact the fire had on the long-term viability of the vineyard, a robust assessment criteria needed to be developed. Several methods were used to assess and quantify the bushfire severity on grapevines and vineyard infrastructure. No one method was deemed sufficient on its own. Data showed a strong link between visual assessment results and node viability, where severe burn had <42.9% node viability. Trunk staining identified damage between 25-75% on all blocks, with vascular girdling also visible. Visual assessment and trunk staining are recommended approaches assess damage to a vineyard after bushfire and to guide staining accuracy.

### Historical Climate and Phenology in California's Napa Valley: Results from a Community-Contributed Data Set

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In the wine industry of California's Napa Valley, there is great community interest in using legacy and modern observations of grapevine phenological stages to track trends in both phenology and climate. Although management such as changing pruning and winemaking preferences can affect phenological records, grapevines can serve as sensitive climate indicators. In collaboration with a local vintners' organization, we conducted an outreach campaign to solicit contributions of climate and phenological data from winegrowers and winemakers. We received nearly 10,000 phenological records dating from 1940 to the present, including data on budbreak, bloom, veraison (color change), and harvest dates for 68 minor grape varieties (15% of the data) and 10 major varieties (85% of the data). Compiling a unified database from records collected by different individuals in different ways presented a challenge, and we developed several new approaches to using data from our newly compiled records to provide empirical corrections to standardize observations across the data set. The time series of phenological observations, along with a companion set of regional climate observations, reveal, expectedly, a strong linkage to seasonal temperature and, unexpectedly, a significant association with winter precipitation. The series of harvest timing reports contains influences of both management and climate. We will also present lessons learned on data management, confidentiality, and science-stakeholder partnerships relevant for others interested in conducting community phenological partnerships.

## Enology and Viticulture – CONTINUED

**Do Ice Nucleating Bacteria Trigger Frost in Grapevines?**

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Ice nucleation active (INA) bacteria are everywhere—perhaps because they seed clouds—and may be the main triggers of frost in grapevines. Paradoxically, though, there has been limited research into their occurrence, role, and sensitivity to antimicrobial treatments in grapevines. INA *Pseudomonas syringae* was isolated from cultivars in the United States and found to be almost ubiquitous on spring growth in France, with populations ranging from  $\leq 300$  to  $10^8$  per bud or shoot. The dilution plating used has limited sensitivity and underestimates INA populations. To test if INA bacteria play a principal role in triggering frost, detection of a few tens of cells is necessary. This is possible using a quantitative polymerase chain reaction (qPCR). From local vineyards we isolated INA *Pseudomonas syringae* from shoots of various cultivars (e.g., Chardonnay and Sauvignon blanc). Sequencing identified two *ina* gene alleles, *inaV* and *inaQ*. Primers for the qPCR reaction were thus designed to amplify a broad range of *ina* alleles. An initial survey detected the gene/s on roughly 75% of shoots in a frost affected vineyard ( $n = 30$ ). Sensitivity is now  $< 10$  gene copies (i.e.,  $< 10$  cells). Field tests of a range of potential anti-INA sprays (a film forming protectant, an osmolyte, kaolinite particle film, colloidal copper, acidified SDS, and oregano oil) were unsuccessful: treated and control vines suffered equally in moderate frosts. qPCR is being used to determine whether treatments failed because they were unable to eliminate INA bacteria, or whether freezing was triggered by a different mechanism.

**Possible Molecular Markers for Freezing Tolerance in *Vitis riparia*: A Potential Tool for Interspecific Breeding for Cold Tolerance**

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Wild *Vitis riparia* is more freezing tolerant (FT) than the winegrape species *V. vinifera*, and this was verified by electrolyte leakage tests using greenhouse-grown plants. The basis for this difference is most likely multigenic and, in fact, we discovered previously that over-expression of either *CBF1* or *CBF4* in the model plant *Arabidopsis* leads to an increase in FT. Sequencing many clones of these genes from both grape species revealed insertion-deletion (indel) regions which were exploited to design primers that identify different alleles. Subsequent “indel” PCR showed that all 17 *V. riparia* accessions from different locations in Canada and the United States have only one *CBF4* allele. In addition, one of their *CBF1* alleles is absent from the *V. vinifera* that were tested. To test our hypothesis that these *V. riparia* *CBF1* and *CBF4* alleles are required for high FT, we will test for their presence in progeny from a *V. vinifera* x *V. riparia* cross and correlate that with their FT as measured by the electrolyte leakage test.

*Funding support:* Ontario Ministry of Agriculture Food and Rural Affairs and the National Science and Energy Research Council of Canada.



**Enology and Viticulture – CONTINUED**

**Managing Grapevines after a Severe Spring Frost Event in Australia**

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Recovery responses of grapevines to spring frost are not well understood for the range of economically important cultivars in Australia. The interaction between the timing of frost in relation to vine development, the severity of the frost, and cultivar responses are important variables. Along with managing the current season's crop, management of the vines is also vital to ensure good canopy structure and maintain yield for the following season. The lack of quantitative information on recovery responses is an impediment to both the strategic deployment of resources in response to an impending frost event and subsequent management of frost-affected grapevines. The spring frost event of the 2006 season reminded the industry that frosts will not necessarily decrease in a warmer world, particularly in drought years. Although surveys conducted in 2006 covering many cultivars across the Victorian wine regions identified the proportion of affected areas, the effects on yield were, initially, more difficult to quantify. These effects relate to the proportion of secondary shoots that burst and their fruitfulness. For selected vineyards, assessments of recovery responses for frosted and protected vines (overhead sprinklers) were made. Also, vine responses to a range of post-frost vine management treatments were assessed. These responses included yield, canopy development, and fruit composition.

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**Climate Change, Viticulture, and Wine Production in the Puget Sound AVA of Washington**

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The Puget Sound American Viticultural Area (AVA) of Washington is the coolest wine producing region in the western United States. Historically at the absolute margin of cool climate viticulture, the region has seen changes in climate over the last 25 years that have increased its suitability for wine production. This research details the overall spatial climate structure across the region and documents the climate shifts that have transformed the region into a promising cool climate wine region. Overall the climate structure of the Puget Sound AVA is one of moderate temperatures due to its location relative to the ocean. Precipitation varies markedly across the region, but benefits tremendously from the rain shadow of the Olympic Mountains with many of the suitable areas experiencing from 400 to 800 mm of rainfall per year. Growing seasons across the best landscapes in the region are typically longer than 180 days with little frost pressure. Growing degree-days for the best landscapes vary from 800 to 1300 (C° units), providing a range of cool climate types suitable for early-ripening hybrid and *Vitis vinifera* cultivars. Vineyard development in the region has increased from only a few pioneering growers in the early 1970s to over 50 vineyards today that provide fruit

**Enology and Viticulture – CONTINUED**

to nearly 20 wineries. Observational evidence from existing vineyards and research trials shows that the AVA is currently suited to cool climate cultivars such as Madeleine Angevine, Müller-Thurgau, and Siegerrebe, with some clonal variations of Pinot noir, Pinot gris, and Chardonnay doing well in the warmer zones.

**Variable Temperature Microclimates of Sloping Vineyards: Weather, Topography, and Soil Interactions**

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In a marginal climate for winegrapes such as New York, site selection and vineyard microclimates are critical. In a key wine region of NY, the Finger Lakes, many of the best vineyards are located on slopes near the large narrow lakes. For 4 years, temperatures were monitored at 30-minute intervals year-round in transects and grids within vineyards of varying elevations, slopes, and aspects. Results suggest several conclusions. Topography had relatively little effect on coldest winter temperatures as they mostly occurred with winds. On cold clear nights, swales of 1 to 1.5 m could be several degrees colder than a few meters away. Under cold conditions, a direct warming “lake effect” was found as a deviation from the normal lapse rate with elevation above the lake. The effect was modeled as a right triangle with distance from the lake and elevation above the lake giving a constant area ( $D \times E / 2$ ) of 25,000 m<sup>2</sup>. Greatest differences across vineyards occurred on calm, sunny, hot days with differences in maximum temperatures up to almost 6°C within 200 m. In vineyards with variable soil, highest summer temperatures tended to occur in portions of the vineyard that had drought stress symptoms indicating the extra heating effect of altered Bowen Ratio.



**Enology and Viticulture – CONTINUED**

**Special Factors Affecting Weather Events in Meso-Climates**

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Large bodies of water and associated air currents have always been a primary consideration when locating vineyards in cool climate and marginal regions. A three-year mesoclimate study of hourly temperature changes throughout the Hudson Valley of New York State suggests that, while the buffering effect of large bodies of water may aid in avoiding low temperature mid-winter bud kill, they may have much less effect, and possibly even a negative one, when it comes to the effects of late spring freezes. In regions like the Hudson Valley, it appears that irregular, undulating topography can interfere with spring cold fronts, resulting in localized bud kill near warm river valleys and bud survival on inland steep slopes. Likewise, the interaction of the terrain with early summer cold fronts can develop hail corridors that recurrently destroy crops. While this study is limited by the short time frame, local social memory of the farming community independently supports the findings. Similar studies are suggested for irregular terrain near large bodies of water in other locations.

*Funding support:* NY State Combined Senate and Assembly agricultural grant and Hudson Valley Wine and Grape Association research funds.

**Influence of Water Deficit on Berry Weight Uniformity and Mass of Berry Tissue Components in Merlot**

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Vine water deficit during development of red-skinned winegrape reduces average berry weight at harvest, but little is known about its effect on the relative growth of berries within a cluster or among tissues within a berry. The intent of this research was to test the hypothesis that water deficit during berry development differentially influenced growth of berries within a cluster and of component tissues within a berry. Fruit was harvested at maturity from field-grown grapevines cv. Merlot that were differentially irrigated in a randomized block design to maintain a high or low level of vine water stress between fruit set and harvest. Berries were detached from clusters and individually weighed to determine their weight uniformity and to obtain samples of identical weight berries from well-watered and deficit-irrigated vines. Berry weight within each irrigation regime was distributed normally and weight uniformity at maturity was unaffected by vine water status. Berries from vines with the lowest midday leaf water potential had at least 8% heavier seed fresh weight, a greater number of seeds per berry, and a greater ratio of seed to berry weight. These differences in berry tissue components between

**Enology and Viticulture – CONTINUED**

irrigation regimes were independent of berry weight. Water deficit had a uniform influence on berry growth within a cluster but differentially restricted mesocarp relative to seed tissue growth. Results have implications for winemaking because a greater ratio of seed to berry weight may alter the quantity of seed relative to skin-derived compounds extracted during fermentation.

*Funding support:* USDA-ARS, Project Number 5358-21000-041-00.

**Disp'eau: Using New Soil and Plant Models to Manage Irrigation and Plot Selection in Viticulture**

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Vineyard irrigation can be managed with two kinds of methods, both with their pros and cons. Physical field measures, such as those obtained with pressure chambers, sap flow meters, or dendrometers, provide an accurate estimation of grapevine water status, but their results are very local and reflect only current situations. On the other hand, estimation of water balance allows short-term forecasts or even long-term simulations (to predict the effect of climatic change on yield and quality potential). But classical water balances do not integrate the adaptative interactions between plant growth and water availability (such as reduction of evapotranspiration and vegetative growth under water stress); therefore, they are not accurate enough to estimate leaf water potential, which makes it difficult to calibrate their results with field measurements. The aim of the Disp'eau project is to develop a new decision support system for irrigation management and site selection that is able to create a synergy between all kinds of methods. Disp'eau will include 3D models (for soil, root, and canopy) to produce a sophisticated water balance that will take into account interactions between grapevine growth (root and canopy) and water uptake. Leaf water potential will be an output data of the model, which allows a calibration of the soil model with field measures in places where the soil structure is not well known. Disp'eau will be used mainly for irrigation management, but can also be used for site selection in vineyards where irrigation is impossible.

*Funding support:* OSEO Languedoc-Roussillon, French FUI (Fonds Unique Interministeriel), and European fund FEDER.



### Enology and Viticulture – CONTINUED

#### Toward the Transcriptome of Berry Shivel in *Vitis vinifera* cv. Zweigelt:

##### First Results

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Berry shivel (BS) is one of the unsolved mysteries in viticulture. The symptoms (water loss, stop of sugar accumulation, disturbed anthocyanin synthesis, high acid contents, and low pH values) are known and have been described for several cultivars. The identification of the cause of this physiological disorder is essential to establish methods to circumvent high yield losses and low quality of berries. So far only hypothetical causes have been formulated, as for example, a lack of potassium, an imbalance of potassium and magnesium, or biotic causes, such as blocking of vascular tissues. None of these theories could be experimentally verified so far. The sequencing of the grape genome in 2007 and further gene annotations allow to efficiently employ microarrays for comparing gene expression. The transcriptome of BS berries and healthy berries was compared in order to identify altered physiological pathways and gene families. Candidate genes were selected and further investigated in different tissues with qPCR. The aim of this study is the identification of key processes responsible for BS symptoms and the identification of the causing agent or the complex of causes which lead to the start of these processes and to berry shivel.

**Enology and Viticulture – CONTINUED****Berry Shrivel in Austria: Symptoms Observed with Cultivar Zweigelt (*Vitis vinifera*)****Michaela Griesser,\*** Stefan Besser, and Astrid Forneck

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Berry shrivel (BS) is a physiological disorder of grape berry development which severely affects quantity and quality of the product. The symptoms include water loss, stop of sugar accumulation, disturbed anthocyanin synthesis, high acid contents, and low pH values, and can be observed after veraison. They appear to be randomly distributed within individual plants, within vineyards, between vineyards, and between years. The causes of this physiological disorder are unknown, and effective treatments do not yet exist. To analyze the complex of mechanisms involved in BS, detailed descriptions of the symptoms are essential. Three vineyards in the wine region Carnuntum in lower Austria were studied in detail on the basis of 117 Zweigelt/5BB vines, cordon-single-arm trellised. Quality parameters (sugar content, acid content, pH), berry size, firmness, color development, and nutrient (K, Mg, Ca) contents of healthy berries and berries with berry shrivel symptoms were determined. Furthermore, the distribution of symptomatic clusters within individual plants showed preference of BS clusters in the apical part of the cane. Significant differences between healthy berries and berries with symptoms were found. However, no significant differences between healthy berries on plants without BS and healthy berries on plants with BS clusters were observed. This indicates that there is no systemic effect of BS clusters on healthy clusters.



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**Leaf Removal to Regulate Grape Sugar Accumulation**

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Leaf removal was investigated as a means of slowing the accumulation of sugars into grapes. This was undertaken in response to warmer seasons where grapes were reaching the optimum sugar maturity three to four weeks earlier than average and during a hotter part of the season. Two timings, at four and one-and-a-half weeks before veraison, and three levels of leaf removal (50%, 67%, and 75%) were investigated. Timing of leaf removal did not significantly impact sugar accumulation in the grapes. The delay in reaching a target sugar concentration of 25 Brix compared with the control treatment was 7, 19, and 22 days respectively for the 50%, 67%, and 75% leaf removal treatments. Leaf removal reduced anthocyanin concentrations in the berries but not phenolic or tannin concentrations. This experiment demonstrated that sugar accumulation into the grapes can be regulated by leaf removal, but the full impact on grape and wine quality requires further investigation.

*Funding support:* Grape and Wine Research and Development Corporation, Department of Primary Industries, Victoria, Balgownie Estate, and the Bendigo Winegrowers Association Inc.

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**Effect of Water Deficit and Cluster Thinning on Ripeness Uniformity in Cabernet Sauvignon Grapevines**

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Uniformity of ripeness has been widely recognized as an essential quality parameter in wine grape production. However, there is little empirical information on practical ways to measure and manage ripeness uniformity in the field. Deficit irrigation and cluster thinning at veraison are popular techniques employed to increase fruit quality. Cluster thinning (e.g., “green drop”) is used to presumably increase fruit uniformity; nevertheless, several studies have shown no significant effects in wine or fruit sensory attributes from thinned vines. Early work found the lowest variance in fruit composition among vines in non-irrigated vineyards, which suggests that water deficit might play an important role in promoting ripeness uniformity. Irrigation and cluster thinning treatments were imposed in a commercial vineyard of Cabernet Sauvignon in the Dunnigan Hills (CA, USA) for three consecutive years. Measures of uniformity at a number of levels (vine-to-vine, cluster-to-cluster, etc.) included a variance components analysis and an ANOVA on absolute deviations (residuals) from the mean for soluble solids and pH. Irrigation deficits reduced leaf water potentials, but did not have a consistent effect on vine water status uniformity and no significant effects on vine-

**Enology and Viticulture – CONTINUED**

to-vine ripeness uniformity. However, irrigation deficits increased cluster-to-cluster uniformity for soluble solids. Cluster thinning in one year significantly increased soluble solids uniformity. Surprisingly, as fruit matured high soluble solids and high pH were both associated with higher variability at both the cluster and vine level, in contrast to current thinking that fruit compositional uniformity increases with fruit development.

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### **Fruit Uniformity for Three Fruit Quality (Crop Value) Levels in Cabernet Sauvignon**

**Arturo Calderon-Orellana**, Mark Matthews, William Drayton, and Kenneth Shackel\*  
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Low ripeness uniformity can be a major disadvantage for winemaking because asynchronous fruit development can negatively affect enological quality by imparting over- or under-ripe characteristics or by diluting desirable characteristics associated with correctly-ripe fruit. Despite the wide acceptance of uniformity as an important quality parameter, little work has studied the relationship between fruit quality and fruit uniformity at harvest time. These studies have shown descriptive evidence suggesting that high-quality vineyards have more uniform fruit, i.e., the lowest standard deviation for soluble solids concentration, compared to low quality plots. In order to test if fruit quality is associated with fruit uniformity, three fruit quality levels were selected based on crop value (\$/ton) for vineyards of cv. Cabernet Sauvignon in California, with high (\$9,000–10,000), medium (\$4,000–5,000), and low (\$500–1,000) quality levels. This study was replicated three times using nine different locations, and random cluster samples were picked at the appropriate harvest time for each vineyard. Soluble solids, pH, and cluster weight were measured, and the absolute deviation (residual) from the sample mean was used as a measure of fruit uniformity. No significant differences in mean soluble solids, pH, or cluster weights were found between quality levels. Surprisingly, however, there were also no significant effects of quality level on fruit uniformity. Fruit from high quality vineyards had a lower uniformity in all parameters (soluble solids, pH, and cluster weight) compared to medium and low quality plots.

*Funding support:* Foster's Wine Estates Americas, Harold P. Olmo Scholarship, Orange County Wine Society Scholarship, Rhone Rangers Scholarship, Wine Spectator Scholarship, Pearl & Albert J. Winkler Scholarship in Viticulture, UC Davis–Horticulture and Agronomy Graduate Group, Ministry of Education Chile, Fulbright-MECESUP2, TECNOVID, Consorcio Tecnológico Vitivinícola, and University of Chile, Faculty of Agronomic Sciences.



**Enology and Viticulture – CONTINUED**

**High-Resolution Spatial Monitoring Improves the Understanding of Regional Temperature Patterns**

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The air temperature is a critical climate parameter that defines the limits, suitability, and potential risks of a region for producing winegrapes. Beginning in early 2007, relatively inexpensive precision temperature stations were installed throughout the vineyard areas of Santa Barbara and San Luis Obispo Counties, California, with dataloggers measuring air temperatures at 15-minute intervals. Currently there are 29 stations operating in each county. Once per year at the end of the growing season in early November, all data are collected and processed into hourly average values, and then placed online at public websites. The data collected with this project have been used to make detailed spatial evaluations of temperature conditions such as the damaging cold and heat events of the 2008 growing season, as well as the growing degree days throughout the region. A significant limitation of the annual data collection schedule is that events can generally only be evaluated well after-the-fact, but this is a necessary limitation to keep costs low. The equipment cost per location is about \$100, and ongoing maintenance costs have been minimal. The planned long-term operation of this project will build an increasingly valuable public temperature record which provides useful data for a wide range of viticultural decision-making needs, such as variety selection or the cost-benefit analysis of an investment in a frost protection system.

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**Increasing Sampling Efficiency for Ripeness Assessments and Yield Forecasting in Spatially-Variable Vineyards**

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Whole of vineyard assessment for ripeness and yield forecasting is common practice, often employing spatially randomized sampling. However, the level of spatial variability in yield and fruit composition within vineyard management blocks can be high, meaning that, unless many samples are collected, large potential errors in derived estimates are likely. We investigated whether vineyard sampling procedures that incorporate knowledge of vineyard spatial information that relates to yield and fruit composition variability would better estimate both the true ripeness level and the final yield. Previous studies have demonstrated patterns of quantifiable measures of vineyard spatial variability, such as vine vigor and soil electrical conductivity, correspond

### Enology and Viticulture – CONTINUED

to patterns of future yield and grape composition at harvest. Targeted sampling was conducted over two years, guided by a geographic information system's nested-cluster analysis of remotely sensed imagery in one vineyard and EM-38 soil maps in another. Subset modeling of targeted schemes with various numbers of samples produced significant efficiency improvements over equivalent random sampling. However, the level of variability in these vineyards was too high to produce accurate estimates of fruit composition and yield with a number of samples that would be considered reasonably practical using either random or targeted sampling strategies. Precision viticulture tools may nonetheless be able to further reduce potential sampling error by weighting samples according to the area of the vineyard that has similar characteristics to the sample locations, and by providing better estimates of vineyard spatial variability in yield and ripening.



### Enology and Viticulture – CONTINUED

#### Effect of Ultraviolet C on the Microbial Population and Total Phenolics on Postharvest Grape Berries

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Ripe grape berries from a hybrid grape cultivar, Máximo – IAC 138-22, obtained by crossing Syrah and Seibel, which is largely cultivated in vineyards in São Paulo State, Brazil, for table wine and juice production, were UV-C irradiated in order to evaluate its effects on the contaminating microbial population, based on colony forming units (cfu) and total phenolic contents. The UV-C irradiation doses were obtained by exposing the grape berries to different irradiances of 0.0, 0.10, 0.15, 0.20, and 0.25 J, respectively, using a chamber with the germicidal UV-C 30-W bulb Philips-Holland (85% of the wave length at 253.7 nm). After each exposure, five berries were randomly collected and the microbial population on its surface was developed in two different media, YPD and NA, with three replicates for cfu counts. Total phenolics in the must were evaluated using the Folin-Ciocalteu method. The irradiated berries showed a contaminant reduction of 99.0% (cfu-fungi, yeast, and bacteria) at the UV-C dose of 0.10 J. Besides its effect on the reduction in microbial population, we also observed an enhancement of 25% in total phenolic contents (mg gallic acid/L) at the dose of 0.15 J or 30 minutes of UV-C irradiation. The results demonstrated the potential of this physical postharvest treatment for the reduction in the contaminant microbial population, as well as its benefits for wine and juice production by the possibility of reduction or elimination of chemical treatment and enhancing the bioactive phenolic compounds.

**Enology and Viticulture – CONTINUED**

**Bacterial Analysis of Michigan Cherry Wine**

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The process of winemaking utilizes a number of microorganisms to enhance the quality and final flavor of wine. Some of the major microorganisms are lactic acid bacteria (LAB) and acetic acid bacteria (AAB). Since most wines are made with grapes, the typical flora of grape wine is well established, but the flora of cherry wine is unknown. The goal of this study is to identify the species of bacteria in cherry wine. Bacteria from cherry wine were grown on media plates. We used PCR to isolate a specific region of the 16S ribosomal RNA gene that differentiates between various bacteria. These PCR products were purified, quantified, and sent to be sequenced. The sequences were entered into an online database, where the genera of the bacteria were determined. Results show that *Acetobacter*, a genus of AAB, and *Lactobacillus*, a genus of LAB, are present in the flora of cherry wines.

**Comparison of Marquette Wine Produced Using Co-Inoculation and Sequential Inoculation of *Oenococcus oeni***

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The objective of this study was to compare the difference of co-inoculation of malolactic bacteria with sequential inoculation of malolactic bacteria on the production of Marquette wine. Cold climate grapes grown in Minnesota and other cold regions can have juice chemistry that can cause difficulties for malo-lactic fermentation (MLF). Marquette grapes as grown in Minnesota often have harvest chemistries with low pH (<3.1), high potential alcohol (>24 Brix), and high levels of malic acid (>4 g/L). These conditions are stressful for malolactic bacteria (MLB) and can result in long durations of MLF, increased potential for off flavors from MLB, and increased risk of microbial spoilage. Co-inoculation on average completed MLF faster than the sequential wines. The fermentations did not show differences in final acetate production that was outside of accepted volatile acidity levels. The improvement in fermentation duration is of little value if it results in a decrease in liking. To examine liking, the wines were compared using an Affective Labeled Magnitude scale. There was no statistical difference in liking between wines.



**Enology and Viticulture – CONTINUED**

**Changes in Grapevine Deep Roots under Different Interrow Management Strategies**

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Grapevine root distribution, aboveground biomass, and vine water status were investigated in a 19-year-old vineyard in Napa Valley under three cropping systems. Treatments consisted of a permanent cover crop of barley, a barley cover crop that was seeded every fall and incorporated every spring, and native winter annual tilled every spring in a conventional manner. Vines were grafted onto 110R and submitted to the same fertilization and irrigation management. In the 6th year, May 2009, a 1 m long, 0.3 m wide, and 1.5 m deep trench was excavated next to 3 vines per treatment. The trench was divided into five levels at increasing depths and a volume of soil was sampled from each level. Roots were separated from the soil, sorted into five diameter classes, from fine roots of <2 mm diameter to thicker than 5 mm, and dry weight and carbon content were obtained. During this experiment, grape yield and pruning weights were recorded annually. The number of roots thicker than 2 mm did not differ among treatments but their densities were significantly greater in the medium levels. Vines under permanent barley had lower leaf water potential, lower pruning weights, and lower yields. Fine root density (<2 mm) decreased with depth and was significantly higher for this treatment, increasing C storage and water uptake at shallower soil levels. Thus, there was a tradeoff between yield and C-sequestration in soil. This conflict might be solved by adjusting irrigation so that water stress caused by competition with the cover crop for water diminishes.

**Enology and Viticulture – CONTINUED****Effects of Cover-Crop Management on Weed Control, Soil Moisture, and Vine Growth in Establishing Vines**

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Cover crop biomass management is being evaluated in a 3-year trial to determine impacts on vine nutrition, water conservation, and reduced herbicide and fertilizer inputs in new vineyards. A winter annual cover crop of crimson clover and cereal rye was planted in a newly established commercial vineyard (2008). Cover was mown in spring and biomass distributed in four treatments compared to a non-cover treatment. In-row treatments of 0, 1X, and 3X biomass mulch rates were compared to biomass incorporations into the alleyway and a non-cover cropped treatment. Each treatment was replicated five times with 20 vines per replicate. Season one (2009) results indicate no difference in shoot length and leaf area. Leaf chlorophyll content did not differ between treatments, although mulched treatments had higher chlorophyll content than non-mulched treatments. Leaf blade and petiole nutrient analyses from bloom and veraison will be performed in December 2009. Vines were not water stressed in any treatment throughout the season. Leaf and shoot biomass in destructively harvested grapevines was four-fold greater in the 3X mulch treatment. Fine root biomass of commercial vines was significantly higher in the 3X mulch treatment. Volumetric soil moisture at 0-23 cm was greater in mulched than non-mulched treatments. In-row soil compaction was lowest in mulched treatments. In-row weed suppression was highest in mulched treatments with nearly 100% suppression of broadleaf and grass species. Preliminary data indicate that winter annual cover crops may not compete with young vines and may be managed to enhance growth in non-irrigated vineyards.

*Funding support:* Agricultural Research Foundation and the Northwest Center for Small Fruits Research.



**Enology and Viticulture – CONTINUED**

**Epidemiology of Grapevine Leafroll Disease in Washington State Vineyards**

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Grapevine leafroll is the most economically important viral disease of winegrapes in Washington State. Using molecular diagnostic methods, six different *Grapevine leafroll-associated viruses* (GLRaV-1, -2, -3, -4, -5, and -9) were documented in different winegrape cultivars showing grapevine leafroll disease (GLD) symptoms. Among the GLRaVs documented, GLRaV-3 was found to be the most prevalent. Robust sampling strategies and diagnostic methods were developed for accurate detection of these viruses. Our results also revealed the presence of other grapevine viruses as mixed infections with GLRaVs in grapevines showing GLD symptoms. They include *Grapevine virus A*, *Grapevine virus B*, and *Grapevine rupestris stem pitting-associated virus*—all associated with the Rugose Wood complex—and *Grapevine fanleaf virus* causing grapevine degeneration disease. Using molecular biology techniques and bioinformatics tools, extensive variation in the genomes of these viruses was documented across winegrape cultivars. Studies on spatial distribution of GLD showed an aggregated pattern suggesting that the disease spread occurs between neighboring vines. In addition, our research indicated that GLD can spread to young plantings from a heavily infected neighboring vineyard block. Only grape mealybug (*Pseudococcus maritimus*) has so far been documented in the state’s vineyards. Molecular diagnostic assays were developed to determine if a single mealybug can simultaneously acquire more than one GLRaV from a source plant containing multiple viruses. An understanding of various aspects of the biology and epidemiology of GLD is providing opportunities for developing strategies to mitigate the negative impact of the disease.

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## Enology and Viticulture – CONTINUED

**Genetic Diversity of Grapevine Viruses in Own-Rooted Winegrape Cultivars Grown in Washington Vineyards**

Olufemi J. Alabi, Tefera A. Mekuria, Sridhar Jarugula, Linga R. Gutha, and **Naidu A. Rayapati\***

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Grapevine viruses are becoming a significant threat to sustainability of the winegrape industry in Washington State. We are analyzing genetic diversity of grapevine viruses occurring in own-rooted grapevine cultivars grown in Washington vineyards. A phylogenomic approach was used to study genetic diversity of *Grapevine leafroll-associated virus-1, -2, -3, -4, and -5*, *Grapevine fanleaf virus* (GFLV), *Grapevine rupestris stem pitting-associated virus* (GRSPaV), *Grapevine virus A*, and *Grapevine virus B* documented in different winegrape cultivars. Specific genome segments of individual virus isolates were amplified by one step-single tube reverse transcription-polymerase chain reaction followed by molecular cloning, sequencing and bioinformatic analysis of sequences. The nucleotide sequences specific to each of these viruses obtained from different cultivars were compared with corresponding virus sequences reported from other grapegrowing regions to assess the level of molecular diversity of different grapevine viruses. The results indicated a high degree of molecular diversity among grapevine viruses documented in Washington vineyards, probably as a result of the introduction of planting materials from several sources outside the state. In addition, potential recombination events were observed in the genomes of GRSPaV and GFLV, thereby increasing the level of their genomic diversity. From a practical point of view, the information on virus diversity is providing avenues for designing effective sanitation and management strategies to prevent the spread of the above-mentioned viruses through planting materials. The results are also contributing to an increased understanding of biological and molecular interactions between viruses and own-rooted grapevine cultivars.

*Funding support:* Washington Wine Commission's Wine Advisory Committee, Washington State Department of Agriculture Nursery Assessment Funds, Washington State Commission on Pesticide Registration, USDA-ARS Northwest Center for Small Fruits Research, Viticulture Consortium-West, and USDA-NIFA-SCRI (grant no. 2009-51181-06027).



**Enology and Viticulture – CONTINUED**

**Quantification of Delayed Ripening in Winegrapes Sprayed with Horticultural Oil**

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Previous research has demonstrated that oil sprays can cause delayed ripening of winegrapes; however, the spray volumes used were often not representative of commercial practice. The purpose of this research was to quantify any delayed ripening due to oil sprays using the typical rate of a 1% solution at 935 L/ha. Trials were conducted in San Luis Obispo County, California, with Cabernet Sauvignon and Merlot, using JMS Stylet Oil. In 2008, treatments consisted of 0, 2, 4, 6, and 8 applications made with a backpack sprayer beginning with early shoot growth until veraison. At harvest, there was a trend toward lower juice soluble solids with increasing numbers of sprays in the Cabernet Sauvignon (up to 2.5 Brix), but not in Merlot; however, yields were very low regionally. In 2009, similar treatments consisted of 0, 2, 4, 6, and 8 applications made with a backpack mist blower in Cabernet Sauvignon. Weekly berry sampling between veraison and harvest indicated lower juice soluble solids (up to 2.0 Brix), yet also increased berry size, with increasing spray applications. Compared as amount of sugar per berry, there were no differences among treatments. At a second Cabernet Sauvignon site, a treatment of seven sprays using a commercial vineyard sprayer was compared to an untreated control; berry sampling between veraison and harvest did not indicate any significant differences in soluble solids, berry size, or sugar per berry. The spray application method and rate appear to influence the degree to which horticultural oils can influence fruit ripening.

*Funding support:* JMS Flower Farms, Western Farm Service, Tony Domingos Farming Inc., and Mesa Vineyard Management.

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**Developing Foliar Damage Thresholds for Downy Mildew and Powdery Mildew in Juice Grapes**

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Foliar diseases such as powdery mildew (*Uncinula necator*) and downy mildew (*Plasmopara viticola*) necessitate frequent fungicide application in grapes in a cool, humid viticultural region like Michigan. The goal of this research was to develop damage thresholds for downy and powdery mildew in juice grapes in order to reduce the number of fungicide sprays. The specific objectives were to determine the effects of downy mildew in Niagara grapes and powdery mildew in Concord grapes. In 2008 and 2009, different crop levels (100%, 60%, and 30% of the highest yielding potential) were imposed and the effect of foliar infection evaluated on vine yield, basic fruit chemistry composition, and cold hardiness of the canes. Natural disease levels were modified using selective fungicides. In 2008, powdery mildew development was negligible; however, downy mildew developed. In 2009, both diseases were present. In both years, basic fruit chemistry was affected by crop levels, with higher soluble solids and pH at 60% and 30% of full crop. Soluble solids were on average about 1 Brix lower in downy mildew-infected vines than in healthy vines. Downy mildew infection reduced winter hardiness of cane cambium, but not of the buds. Additional trials are currently in progress to determine and validate damage thresholds for foliar diseases in juice grapes.

**Current Status of Grapevine Viruses in Washington State Vineyards**

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Washington State is the major grapegrowing region in the Pacific Northwest. We have undertaken a research project to document the occurrence of viruses in winegrape cultivars grown in Washington vineyards. Leaf samples were collected from individual grapevines showing symptoms of (or suspected to be infected with) grapevine leafroll disease (GLD) in red grape cultivars and random samples from white grape cultivars (asymptomatic) from commercial vineyards. Individual samples were tested by one tube-single step reverse transcription-polymerase chain reaction assay for the presence of viruses associated with grapevine leafroll disease, rugose wood disease complex, and fanleaf disease. Results from a five-year study have shown the presence of six different *Grapevine leafroll-associated viruses* (GLRaV-1, -2, -3, -4, -5, and -9), three viruses associated with Rugose wood disease complex (*Grapevine rupestris stem pitting-associated virus* [GRSPaV], *Grapevine virus A* [GVA], and *Grapevine virus B* [GVB]) and *Grapevine fanleaf virus* (GFLV) in several winegrape cultivars. Among the six GLRaVs documented, GLRaV-3 was found to be the most prevalent. Mixed infections of GLRaVs in different combinations were detected in a single grapevine. Our results also revealed presence of GRSPaV, GVA, GVB, and GFLV as mixed infections with



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GLRaVs in grapevines showing GLD symptoms. In addition, the Red Globe variant of GLRaV-2, *Grapevine fleck virus*, and *Grapevine syrah virus-1* were detected for the first time in some winegrape varieties. This knowledge is improving our understanding of the sanitary status of vineyards to mitigate negative impacts of viruses.

*Funding support:* Washington Wine Tax, Washington State Department of Agriculture Nursery Assessment Funds, Washington State Commission on Pesticide Registration, USDA-ARS Northwest Center for Small Fruits Research, and USDA-NIFA-SCRI (grant no. 2009-51181-06027).

**Quantification of SO<sub>2</sub> Binding Compounds in New York State Wines and Their Fate during Vinification**

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Many wines produced in cool climate regions face particular stabilization challenges due to high residual sugar concentrations and increased acetaldehyde content, especially in white wines. Acetaldehyde is the major binder of sulfur dioxide (SO<sub>2</sub>) along with others such as glucose, galacturonic acid, alpha-ketoglutarate, pyruvate, and acetoin. This study presents an improved method for the quantification of SO<sub>2</sub>-binding compounds and reports their concentration in commercial wines. 240 cool climate wines from across New York State were surveyed for SO<sub>2</sub>-binding species by derivatization to 2,4-dinitrophenylhydrazine followed by separation on a UHPLC system and spectro-photometric detection. The levels of SO<sub>2</sub>-binding compounds were wine color and type dependent, and showed significant winery variation. A subsequent vinification study with 10 wineries measured the kinetics of acetaldehyde from grape reception to bottling and allowed for the identification of critical control points for acetaldehyde management. Malolactic fermentation (MLF) was a major factor in reducing acetaldehyde levels. Accordingly, 12 commercial strains of lactic acid bacteria (LAB) were investigated for their ability to degrade SO<sub>2</sub>-binding compounds including acetaldehyde during MLF in white wine. Overall, mean pyruvate and alpha-ketoglutarate levels decreased during MLF by 100% and 59% respectively, in contrast to galacturonic acid, which remained unchanged, and acetoin, which increased by 167%. The findings demonstrate a new HPLC method that is both rapid and accurate for the quantification of SO<sub>2</sub> binders in wine. Critical control points could be identified for the management of acetaldehyde during vinifications, and the role of MLF in the reduction of SO<sub>2</sub>-binding compounds was further elucidated.

*Funding support:* New York Wine and Grape.

**Enology and Viticulture – CONTINUED****Effect of Timing of Mechanical Leaf Removal on Pinot noir Berry and Wine Composition****Belinda S. Kemp**,\* Glen L. Creasy, and Roland Harrison

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Mechanical leaf removal is increasingly common in vineyards, but the effect that its timing has on Pinot noir fruit and wine qualities remains to be determined. A field trial was established in a commercial Waipara vineyard, New Zealand, to assess the timing of leaf removal effects on ripening parameters and fruit and wine composition, including tannin concentration. The study occurred in the 2007-2008 and 2008-2009 seasons using a Collard pulsed-air machine. Own-rooted, ~18-year-old Pinot noir (10/5 clone) vines trained on a vertical shoot-positioned trellis system were pruned to four 6-node canes. Treatments were applied to both sides of the rows and consisted of NLR: no leaf removal, LR7: leaf removal from the fruiting zone 7 days after flowering, LR30: leaf removal from the fruiting zone 30 days after flowering, and LRV: leaf removal at 5% berry color change (by visual assessment). LR7 was associated with the lowest berry weight in the first year and lowest seed number per berry in the second year. No significant differences were observed among treatments regarding yield per vine, cluster weight, cluster number per vine, berries per cluster, total tannin per berry, soluble solids, titratable acidity, or pH, but a significant difference in soluble solids between years was observed. A significant difference in wine tannin concentration between treatments in both years was observed.



### Enology and Viticulture – CONTINUED

#### Waste Stream Sourced Reflective Mulches Alter Grapevine Microclimate

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The effect of different reflective mulches on the grapevine environment was investigated in a Canterbury, New Zealand, vineyard. Mulches were applied in 2005 as four treatments over three blocks. Treatments were a non-mulched control (CON) and mulches made from waste products including mussel shells (MS) and green (GG) and clear (CG) recycled crushed glass. Significantly higher levels of reflected photosynthetically active radiation in the canopy were found for MS and CG. CG and MS showed greater reflectance of UV-A radiation and throughout the visible spectrum, while CON and MS had the highest far red intensity, followed by CG. GG absorbed the most energy at these wavelengths. During a 20-day period in February, canopy-level temperatures were warmer, on average, in CG and MS than GG or CON. All of the mulches were found to increase water retention in the soil. This was most apparent for MS, which had significantly higher values throughout the season, but CG and GG were also significantly higher than CON. Mulch effect on the presence and activity of microorganisms was ranked (from high to low): MS, CON, CG, and GG with significant differences between MS and the glass mulches. The soil pH and nutrient concentrations of Zn, Na, and Ca were also altered by treatment. The findings suggest that reflective mulches significantly affect the vine microclimate, which can affect vine health and grape and wine composition, as detailed in companion studies.

*Funding support:* Sandihurst Winery, Sustainable Initiatives Fund Trust, Sustainable Farming Fund, MetaNZ, Christchurch City Council, and Tertiary Education Commission.

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**Effects of Late Season Leaf Removal on Fruit Green Aromas, Mouthfeel Components, and Berry Weight of *Vitis vinifera* L. Cabernet Sauvignon and Merlot**

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A study was conducted during the 2007, 2008, and 2009 seasons to look at the effects of late season leaf removal on fruit green aromas, mouthfeel components, and berry dehydration in 12 commercial vineyards of *Vitis vinifera* L. Merlot and Cabernet Sauvignon located within the Sonoma and Central Valleys. Treatments involved leaf removal done either at fruit set (early-season treatment) or both at fruit set and in the first week of September (late-season treatment). For the Merlot vineyards, the late season leaf removal treatment showed lower concentrations of green aroma compounds (3-isobutyl-2-methoxy-pyrazines and C6 compounds) when compared to the early-season treatment. Timing of leaf removal had a less significant effect on green aromas of Cabernet Sauvignon fruit, but both treatments showed much lower concentrations at harvest when compared to Merlot grapes. For all vineyards, the late-season treatment resulted in higher concentrations of polymeric tannins and quercetin glycosides as compared to early-season leaf removal. Berry weight was reduced as a consequence of exposing the fruit later in the season, and this effect was greater in Merlot than in Cabernet Sauvignon. These results show that green aromas in grapes can be reduced by late-season leaf removal, while also positively affecting components related to mouthfeel.

**Climate Influences on the Size, Timing, and Development of Inflorescence Primordia in Australasian Vineyards**

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The purpose of this research was to bridge the gap between observation-based science and quantitative science in the field of grapevine reproductive biology. Annual yield fluctuations create problems for harvest intake scheduling, fruit ripening, and matching supply to demand. An understanding of the early development of yield components and the influence of environmental conditions on them is necessary to manipulate and ultimately stabilize yield. Electron microscopy techniques and subsequent morphometric analyses were carried out on three economically important *Vitis vinifera* cultivars representing varied environmental zones in Australia and New Zealand. The timing and extent of development of inflorescence primordia from latent buds was measured at key phenological stages for Chardonnay, Shiraz, and Sauvignon blanc. Vineyards located in warmer sites promoted earlier initiation, and differentiation of inflorescence primordia and development was more advanced at each phenological stage. Moreover, larger inflorescence primordia were observed where initiation and



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differentiation had occurred earlier in the season. The process of differentiation may be earlier and more dynamic than previously thought at warmer sites with anlagen visible in Chardonnay by October and tertiary branch formation occurring on the lower third of basal inflorescence primordia of Shiraz and Chardonnay by dormancy in some instances. This study provided new insights into the fundamental developmental stages of some important cultivars in response to environmental variables and the influence of these on yield.

*Funding support:* University of Melbourne, Australian Postgraduate Award (Australian Government), and New Zealand Foundation for Research Science and Technology (Contract UOAX0404) for yield data.

**Anatomical Variations in the Nodes of Cool Climate *Vitis vinifera* L. Cultivars**

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Grapevine buds are classified into three types: (a) the prompt bud (N+1) which forms first and from which the summer lateral develops, (b) the primary bud (N+2) which forms at the basal node of the summer lateral, and (c) the secondary buds (N+3) which are borne opposite each other in the axils of the two basal prophylls of the primary bud. The N+1 shoot may grow or may abscise above the prophyll, leaving a scar. The N+2 and two N+3 buds develop enclosed by the basal prophyll of the summer lateral and the two basal scales of the primary bud and constitute the compound (latent) bud from which the following season's shoots grow. Although it is generally accepted that in the grapevine only one compound bud develops at each node, bud dissections of dormant buds and in-season observations in 30 California winegrape vineyards during six years have shown that the N+1 bud can produce two basal nodes, each bearing a compound bud complete with N+2 and N+3 buds. These double buds occur only in the proximal nodes of the main (N) shoot and typically in cool-climate cultivars. The number of proximal nodes bearing double buds is cultivar-dependent, with Pinot cultivars having the most (up to 15 nodes) followed by Cabernet Sauvignon, Syrah, Merlot, and Chardonnay (one or two basal buds). Awareness of this arrangement is important for the assessment of fruitfulness through bud dissections. Yield potential of nodes bearing single vs. double buds is examined.

**Effects of Mechanized Canopy Management and Timing of Reduced Deficit Irrigation Stress on Shiraz Grapevines**

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Canopy microclimate of Shiraz/1103P was altered and exposed to reduced deficit irrigation (RDI) varying in severity and timing. Four canopy levels were imposed by dormant pruning the vines to 42 spurs (control), mechanically pruning to 10-, 15-, and 20-cm hedges, and mechanically thinning shoot density and cluster density to 16 shoots/m of row, 20 clusters/m (CIL); 23 shoots/m, 30 clusters/m (CIM); and 49

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shoots/m, 36 clusters/m (CIH), respectively. Control vines were irrigated to 70% of full-vine evapotranspiration (Et) until harvest (RDIC). Other vines either received 70% Et up to veraison, after which rate was cut to 50% of Et (RDIL) or had their irrigation cut to 50% of Et before veraison (RDIE), but not thereafter. At veraison, the shoots exposed per hectare were 53%, and 39% lower for the CIL and CIM; but 43% higher for the CIH when compared to control. The distance between shoots was 137%, and 81% higher for the CIL and CIM, but 29% lower for the CIH compared to control. Compared to control, leaf layer number was 55% and 50% lower for the CIL and CIM, but 20% higher for the CIH. The RDIE and RDIL lowered the leaf layer number by 22% and 10%, respectively, compared to RDIC. Berry weight was 2%, 5%, and 11% lowered by the CIL, CIM, and CIH, respectively. RDIE also reduced berry weight by 16% at harvest compared to RDIC and RDIL. Yield was reduced by 33% and 29% by the CIL and RDIE, but increased by 5% and 17% for the CIM and CIH, respectively. The CIL and CIM reduced the leaf area:fruit by 33%, and 54%, respectively, whereas the RDI treatments did not affect the leaf area:fruit. There was an interaction of canopy management and RDI stress on wine total phenolics, tannins, and anthocyanins where CIM with RDIL had the highest tannins and total phenolics. The highest wine anthocyanins were seen with the CIM with the RDIE. This study provides important information for growers considering mechanizing canopy management operations while scheduling reduced deficit irrigation, where best results were achieved with the CIM and RDIE treatments.

**Assessment of Winter Injury in Grape Cultivars following the 2009 Freezing Event****Imed Dami\***

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Extreme subfreezing temperatures occurred in January 2009 throughout the grapegrowing regions east of the Rocky Mountains. In Ohio, temperature lows ranged between -21.1°C and -30.6°C, which were considered critical for grapevine survival. In order to evaluate the extent of winter injury, canes were collected, and bud injury was determined in several cultivars grown at research and commercial vineyards. A pruning experiment was also conducted with a cold-sensitive cultivar, Pinot gris, to identify the best pruning practice for rapid recovery. Pruning consisted of four treatments with increasing buds retained per vine. Winter injury assessment showed expected results with the highest bud injury in the sensitive cultivars of *Vitis vinifera*, and the least injury in hybrid and American cultivars. Nevertheless, the extent of injury in *V. vinifera* cultivars was surprisingly not as severe as originally anticipated. Another unexpected observation was that moderately tender *V. vinifera* cultivars (e.g., Cabernet franc) that should have lower bud injury than tender cultivars (e.g., Pinot noir) did not. Prior to pruning, all treated Pinot gris had 87% primary bud injury. Pruning treatments with



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the highest buds per vine resumed growth, and canopy filled the trellis the earliest and had the highest yields, but fruit composition was not affected. It was concluded that temperatures preceding the freezing event are critical for maximum cold hardiness, cultivars that ripen in midseason sustained less winter injury than late-ripening cultivars, and minimum or no pruning is recommended for quick recovery of tender cultivars.

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#### **Bunchzone Temperature Measurement for Optimum Chardonnay Exposure**

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Small electronic data loggers which hourly record the temperature in the area of representative clusters in the vine canopy were inserted at veraison in ten Chardonnay vineyards located in the Macedon Ranges, a cool region of southeast Australia. Preharvest data were downloaded and calculations were performed from the previously programmed set points of 0, 15, and 35°C, resulting in cumulative heatloads and degree hours below 15°C as well as percent of time between 15 and 35°C. The degree hours in a variety's beneficial bracket (Shiraz 15 to 35°C and Pinot noir 15 to 26°C) was previously shown over four years to have a strong impact on grape quality. Having more than 95% of "hangtime" in such conditions was found to coincide with excellent grape color, acidity, sensory attributes and also led, in the absence of disturbances like drought, diseases, or winemaking errors, to high wine scores. A high amount of degree hours in beneficial temperatures was brought about by good foliage management practice opening the canopy to the early morning sun and protecting grapes from midday and afternoon summer heatloads. As enlarged diurnal curves show how gaps in canopies led to heat-related spikes in the data logger graphs, or confirmed good protection by a shoulder or a leveling off in the temperature curves, foliage management could be tailored to the sites and seasonal temperature conditions. This affordable tool is well accepted by the grapegrowers in the Macedon Ranges and should become part of vineyard monitoring.

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#### **Cofermentation of Syrah with Varied Amounts of Viognier: Effect on Color and Phenolic Extraction**

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Syrah (SY) and Viognier (VG) grapes are sometimes cofermented in Washington State in an attempt to improve color and enhance overall aroma. A small-scale experiment (100 L) was designed to test these ideas. Four treatments were tested: 100% SY and addition of 5%, 10%, and 20% VG to SY at crushing. Three replicates per wine were produced and analyzed for color (Cie-Lab and Glories color parameters) and phenolics (BSA precipitable tannins) at the beginning of maceration (M), at pressing (7 days, P), and after malolactic fermentation (MLF). A multivariate analysis using sampling

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date and treatment applied as independent factors was applied to the whole data set. Results showed that the sampling time (M, P, and MLF) was the most important factor in differentiating the wines (LSD < 0.05). The treatment affected all color parameters except H\* (Cie-Lab hue) whereas this factor only affected the anthocyanin content of the wines. Differences among treatments appeared to be higher at P, with 100% SY and 5% VG displaying higher values of color index, a\* (red tones) and C\* (Cie-Lab saturation), and lower values of L\* (Cie-Lab Luminosity). After MLF, only differences in the anthocyanins were found. Our study provides practical information about the suggested effect on color and tannins of the addition of VG grapes to SY fermentations. Complementary analyses of the wines (HPLC, sensory assessment) are currently undergoing.

**Early Phenolic and Sensory Properties from the Cofermentation of Syrah and Viognier****Rodney Chittenden\***

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Cofermentation of Syrah with a small proportion of Viognier is practiced to produce a wine with superior sensory properties. Anecdotally the benefits of cofermentation include better texture, improved color and color stability leading to complexity, and enhanced aging ability. In this study anthocyanin-derived pigment profiles and selected phenolics in 100% *Vitis vinifera* L. cv. Syrah (Control) and 5 and 10% coferments with crushed destemmed *V. vinifera* L. cv. Viognier were compared for impact on sensory characters in the resultant wines. We report the compositional changes in color contribution of monomeric, copigmented and polymeric anthocyanin, short polymeric anthocyanin, and long polymeric anthocyanin; concentrations of iron reactive phenolics, anthocyanin and tannin by spectrophotometer; anthocyanin concentration by HPLC, and wine bitterness and astringency using a sensory panel. At 42 days, cofermentation resulted in an increase in copigmented anthocyanin color and a decrease in monomeric anthocyanin color with no corresponding decrease in color density as a result of dilution by the white grapes. At 52 days, cofermentation resulted in increased iron reactive phenolics, anthocyanin and tannin concentrations; an increase in the ratio of long to short polymeric color, and a decrease in the ratio of long polymeric pigment to tannin. At 157 days, HPLC analysis showed higher anthocyanin concentrations in the 5% cofermented wine compared with the control. At 119 days, sensory evaluation showed that differences existed between wines made using Syrah/Viognier cofermentation compared with those fermented as straight Syrah. Wines made using cofermentation were more astringent and less bitter than wine fermented using only Syrah.

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**Uncovering the Regional Styles of New Zealand Pinot noir**

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There has been a lot of excitement about the different Pinot noir styles emerging from New Zealand. While many people have commented on differences between regions, there has yet to be an overall determination if the regions themselves have their own style or if it is strictly the wines that are different. Regionality is used greatly in marketing and wine education and is considered to be a very important aspect of a wine’s identity. Twenty-two expert wine tasters assessed four commercial wines from each of the main NZ Pinot noir regions: Martinborough, Marlborough, Waipara and Central Otago (a total of 16 wines). Each wine was analyzed for aroma, in-mouth flavor, and mouthfeel attributes by all tasters in two separate sessions. Clear regional differences were identified using canonical variate analysis of results from 25 preselected attributes, 14 of which were most important. These were raspberry, black cherry, chocolate, oak, herbal, smoky, black berry, dark fruit (flavor), spice (flavor), fruit density (flavor), balance, body, oak tannins, and graininess. These differentiating attributes include some that can be attributed to each of the senses, smell, taste, and mouthfeel and also include aromas that arise from winemaking as well as the grapes. While there were some between-wine differences, it was found that an overall style for each region did emerge.

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**Impact of Ethanol on the Volatility of Aroma Compounds in Model Wines**

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Ethanol plays a major role on the volatility of flavor and aroma compounds and in the interactions between aroma compounds and other components in wine. This study evaluated the impact of different concentrations of ethanol on the volatility of eight volatile compounds representing the major aroma categories commonly found in red wines. Model wine solutions containing sucrose (5 g/L), tartaric (4 g/L), tannin (1 g/L), and varying ethanol concentrations (0, 8, 10, 12, 14, and 16 % v/v) were prepared, adjusted to pH 3.4, and spiked with odorants at concentration ranges observed in red wines. Volatiles were sampled and quantified using headspace solid-phase microextraction with a polydimethylsiloxane/divinylbenzene fiber, and analyzed with gas chromatography-mass spectroscopy. Generally, the recovery of odorants

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decreased as the ethanol concentration increased from 0 to 16%. Addition of ethanol to 8% significantly decreased the peak areas of test odorants compared to the control (0%) except for 3-methyl-1-butanol and 1-octen-3-one ( $p < 0.05$ ). The reduction in peak area was lowest in dimethyl disulfide (61%) and highest in  $\beta$ -damascenone (97%) at 16% ethanol. The present study suggests the significant contribution of ethanol in altering the physicochemical properties of wine volatiles and its potential impact on aroma and flavor perception.

**Cover Crop, Rootstock, and Root Manipulation as Tools to Regulate Vine Vegetative Development in a Humid Environment**

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Cover crops, rootstocks, and rootzone restriction were evaluated as means of regulating vegetative growth of Cabernet Sauvignon grapevines. Treatments were arranged in a strip-split-split plot arrangement with under-trellis cover crops (UTCC) compared to row-middle only cover crop combined with 1-m weed-free strips in the vine row as main plots. Rootstocks Riparia Gloire, 420-A, and 101-14 were subplots, while sub-subplots comprised two treatments: vines were either planted in root-restrictive, fabric bags ( $0.16 \text{ m}^3$ ) at vineyard establishment (2006) or were planted without root restriction. All three factors were effective in suppressing vegetative development as measured by rate and extent of shoot growth, lateral shoot development, trunk circumference, and dormant pruning weights. Canopy leaf layer number was also affected by UTCC and root restriction, and generally unaffected by rootstock. UTCC reduced cane-pruning weights by 47% relative to vines grown on herbicide strips. Vines grafted to Riparia Gloire had approximately 25% lower pruning weights than vines grafted to 420-A or 101-14. The principal effect of the UTCC and the root-restriction treatments was a sustained reduction in stem (xylem) water potential. Stomatal conductance ( $g_s$ ) and net assimilation rate ( $A$ ) were depressed by increasing water deficit ( $-0.8 \text{ MPa}$  or lower), but  $g_s$  and  $A$  appeared adequate at  $\Psi_{\text{stem}}$  values that were effective for shoot growth suppression. Results suggest practical measures can be used to create a more favorable vine balance under conditions of variable rainfall such as exist in the eastern United States.

*Funding support:* VA Wine Board and the Viticulture Consortium:East.



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### A Certification System to Manage and Monitor the Production and Supply of Environmentally Responsible Wine Products

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The Forest Stewardship Council (FSC) is an international non-profit organization that provides a certification system for producers and consumers that choose resources and products made from well-managed forests. Reputable world organizations, such as the World Wildlife Fund and Greenpeace, support the FSC efforts to legislate and monitor the materials and products that originate from harvested forests that meet their inhabitants' social, economic, and ecological needs. Certification of corporations involved in the production of FSC goods is undertaken by organizations such as the Rainforest Alliance and its SmartWood forestry certification program. The Rainforest Alliance grants two types of certificates: one type allows the environmentally responsible harvest of animal, plant, and renewable forest resources and the other type pertains to the processing (value adding and distribution) of FSC resources (also called chain-of-custody certification). Final products bearing an FSC claim are recognized by the end consumer with an on-product label that defines them as made with either 100% (PURE) FSC materials or a blend of FSC pure, FSC controlled, and/or FSC recycled materials (MIXED SOURCES). Sustainable production of wine is a mission pursued by many grapegrowers and winemakers. Natural cork closures, as one of the components that make a bottle of wine, are produced from the bark of *Quercus suber*, a Mediterranean oak tree mostly found in the Iberian Peninsula. Consumption of products with FSC components help support the people that depend on these forests as well as guaranteeing the survival of endangered species found in these habitats.

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