Oregon State University

2019 Grape Day

Recent Advances in Viticulture, Enology and Wine Economics Research

LaSells Stewart Center, OSU Campus, April 3

Abstracts of Presentations and Posters

Program Schedule

8:30 AM – 9:00 AM	Registration and Refreshments
9:00 AM – 9:15 AM	Introduction and Welcome; *Mark Chien, Program Coordinator*
9:15 AM – 10:00 AM	**A Rising Tide Lifts All Boats: The Value of Cooperative Pest and Disease Management Programs** *Dr. Monica Cooper, Napa County Viticulture Farm Advisor, UC Cooperative Extension, Napa, CA*
10:00 AM – 10:55 AM	**Efficacy of an Intelligent Sprayer System on Grape Powdery Mildew** *Dr. Jay Pscheidt, Professor and Extension Plant Pathologist, Dept. of Botany and Plant Pathology, OSU, Corvallis, OR*
10:55 AM – 11:45 AM	**Interactive Poster Session** This session will provide you the opportunity to interact one-on-one with scientists and students conducting research at the OWRI. Posters will feature research findings that are in-progress for various research projects being conducted across a wide array of topics within viticulture, enology, and economics.
11:45 AM – 12:05 PM	**The Chemical Nature of Red Wine Mouthfeel** *Dr. Ludwig Ring, Research Associate (Postdoctoral fellow), Dept. of Food Science and Technology, OSU, Corvallis, OR*
12:05 – 12:25 PM	**The Influence of Scion/Rootstock Combination on Vine Vigor under High Nitrogen Availability** *Dr. Landry Rossdeutsch, Research Associate (Postdoctoral fellow), Dept. of Horticulture, OSU, Corvallis, OR*
12:25 PM – 1:15 PM	**Lunch**
1:15 PM – 2:00 PM	**Smoke Composition, Timing of Exposure, and Prospects for Mitigation** *Dr. Tom Collins, Assistant Professor, WA State University Tri-Cities, Wine Science Center, Richland, WA*
2:00 PM – 2:30 PM	**Break/Poster Session**
2:30 PM – 3:00 PM	**Red Blotch Disease Update** *Dr. Bob Martin, Research Plant Pathologist, USDA-ARS Horticulture Unit, Corvallis, OR*

Pest and Disease Management

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Economics

Under-vine cultivators in the Western USA: A farmer's guide to mechanical weed control tools

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Many growers face the challenge of successful weed control with reduced reliance on herbicides. Public opinion, human safety, and other factors drive this goal. In vineyards, a plethora of under-trellis cultivators are available, yet information about these cultivators is scarce and often provided by the equipment manufacturers, who have an economic interest in the adoption of these technologies. The current dearth of research and extension efforts in mechanical weed control limits the wide adoption of these practices in vineyards. Vineyard managers require independently-developed information to guide their selection and use of under-trellis cultivators. This project was initiated in 2018 in collaboration with local growers and industry representativies with the objectives of compiling information about under-trellis cultivators and vendors in the Western region and evaluating performance and costs of the under-vine cultivators. Field trials will be initiated in the 2019 season to compare four types of cultivators: brush-weeder, hoeing blade, rotary-tiller, and mower. These trials will generate specific information on operational capacity, weed control performance, costs, applications, and limitations of each type of equipment. Finally, we are documenting growers' perceptions and experiences with under-trellis cultivators to better inform other growers about equipment selection. This project will enhance our understanding of the applications and limitations of under-trellis cultivators in Oregon vineyards. By documenting the industry's current level of knowledge and generating research-based information, this project will address the information-gap on under-vine cultivators and help promote mechanical solutions as part of an integrated weed management program.

Influence of scions and rootstocks on vine vigor in response to high nitrogen availability

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Understanding scion and rootstock regulation of grapevine growth potential (vigor) is important to understand how to manage excessive vigor in vineyards. Studies indicate that nitrogen (N) and carbon (C) metabolism may play a role in vigor related to scion and rootstocks, but mechanisms involved are unclear. We examined the relationship between C and N metabolism in scions and rootstocks with varying vigor responses. Our objectives were (1) to evaluate growth response of three Pinot noir clones and four rootstocks to moderate and high N supply; (2) to measure their variability in metabolite allocation (sugars, starch, nitrate, amino acids) in four plant tissues (leaves, stem, trunk, roots); (3) to assess the physiologic and molecular variation of nitrate uptake and N transport in two different rootstocks. Objectives 1 and 2 were addressed by comparing 6 scion-rootstock combinations grown at two levels of N supply. This first experiment was then extended to evaluate the importance of reserve metabolites to support second year growth under N deprivation. Objective 3 was performed on Pinot noir cv. Pommard grafted to RG and 1103P rootstocks. Rootstock nitrate uptake capacity and molecular responses to N supply were assessed in roots and their nitrate transport capacity was measured in leaf xylem sap in response to low and moderate N availability. The first experiment showed that high N availability did not increase plant mass but highly increase amino acids concentration in all plant parts. The root N reserves may be responsible for plant vigor under N-deprivation. Scions and rootstocks exhibited variability in shoot vigor and in mass allocation pattern between shoot and root parts regardless of N availability. Interestingly, nitrate uptake capacity and N-signaling responses of RG and 1103P did not differ, but 1103P is characterized by higher N transport to the shoots.

Daily minimum leaf and stem water potential in vineyards with vertical shoot positioning

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Diurnal changes of vine water status and the appropriate time of the day to measure leaf and stem water potential (LWP and SWP) were examined in Willamette Valley vineyards employing vertical shoot positioning (VSP). Measurements of LWP and SWP were performed in 'Chardonnay' and 'Pinot noir' on cloudless days between fruit set and harvest over two years using a pressure chamber. Seven diurnal datasets for LWP and SWP were collected from three VSP vineyards representing warm and cool days, and days where vines experienced little water stress or moderate water stress. On warm days, LWP declined more rapidly in the morning, reached the daily minimum sooner (1 PM PST, midday), and remained at this level for a longer duration (1-5 PM PST) when vines were moderately water-stressed compared to vines under little stress. On cool days, LWP reached the minimum value later in the day (3 PM PST) in stressed and non-stressed vines. SWP reached the daily minimum level late in the day (3 PM PST) under all conditions, and in one case increased between late morning and midday before declining to the lowest level at 3 PM PST. If we consider only those days when it was warm and vines were experiencing moderate water stress, which is the key time to measure vine water status, the daily minimum LWP was stable from 1 to 5 PM PST. The corresponding daily minimum SWP was only stable from 3 to 5 PM PST. Our findings suggest that viticulturists can increase the time interval to measure LWP up to 4 hours on warm days beginning at midday for canopies with VSP. However, SWP measured at midday underestimates the level of vine water stress and should be determined between 3 and 5 PM PST in vineyards using VSP.

Nitrogen Addition in the Vineyard or in the Winery?

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The impact of nitrogen (N) addition in the vineyard as compared to winery N supplementation is being evaluated in Pinot noir (PN) and Chardonnay (CH). For each variety, 5 treatments were evaluated: Control (No N in vineyard, No N in winery); +DAP (No N in vineyard, +DAP in winery); +ORG-N (No N in vineyard, +ORG-N in winery); +Soil N (N Fertilizer applied by fertigation, No N in winery); and +Foliar N (N Fertilizer applied to canopy, No N in winery). Three years of vine data have been collected in CH while only two years have been completed in the new block of PN. In CH, +Soil N increased vine N status (leaf blade and petiole N at bloom and veraison) in every year, but +Foliar N did not. Canopy growth and crop yield was increased by +Soil N in year 2 and 3, but +Foliar N did not alter productivity in CH. The larger canopies in the +Soil N vines resulted in slightly greater water stress in years 2 and 3, but only when all the data were pooled for a season. Must YAN levels in CH were increased by nearly 100 mg N/L in +Soil N vines over the Control, while Foliar N boosted YAN by half that amount. The rate of fermentation in CH musts across all years was primarily dictated by YAN levels. Sensory analysis from year 1 and 2 for CH showed that +Soil N had the greatest impact on wine aroma and resulted in more tropical aromas in wine. The +DAP wines were characterized as having green or vegetal characters. In PN, Soil N also improved vine N status in leaves and petioles in year 1 and 2, while Foliar N did not. Yield was not altered by N applications in PN, although leaf area at veraison was greater in the +Soil N vines in year 2. Leaf water potential was lower in the +Soil N vines in year 2. Must YAN levels were increased by both +Soil N and +Foliar N treatments to a similar extent each year in PN. Both vineyard N treatments fermented slightly faster than all other musts each year, even though the winery N additions also had high YAN. The sensory analysis for Pinot noir wines is just being completed for the 2017 vintage.

Role of Auxin-Response Factor 4 (ARF4) in the timing of ripening initiation in *Vitis vinifera*

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The expression dynamics of auxin response factor 4 at fruit ripening initiation stage plays an important regulatory role in the timing of ripening in tomato. Our studies on VitviARF4 at mid-véraison stage show similar behavior in grape berry and we found a strong correlation between ripening-initiation and decrease in the expression of VitviARF4. Since the timing of the ripening initiation is an important trait for wine grape production our research project aims to validate the regulatory function of VitviARF4 during the ripening initiation. The objectives are to: 1) produce microvine lines over- and under-expressing ARF4 gene and to identify other proteins interacting with VitviARF4 during the ripening process, 2) conduct functional and gene expression studies in microvine when the timing of ARF4 expression dynamics is altered, and 3) to evaluate the fruit composition of transgenic fruits when the timing of ripening-initiation is altered. We established the microvine, grapevine model system developed for genetic studies at OSU, and optimized protocols for producing embryogenic callus, agrobacterium-mediated transformation, and regeneration of plants from transformed embryos. Gene constructs were cloned into the Plant Gene Switch vector (PGSS) under the control of an inducible promoter, so that the expression of ARF4 can be either extended or reduced at mid-véraison. Agrobacterium-mediated transformations were conducted to generate genetically engineered microvines that are in the process of regenerating transformed microvine lines. The functionality of gene switch vector and gene-silencing system were verified in transgenic lines. The Yeast Two Hybrid (Y2H) screens conducted to find the interacting protein partners of ARF4 identified 170 potential candidates. They include proteins involved in ABA signaling sugar sensing, and ethylene signaling, all of which are known to influence fruit ripening. Interaction of these proteins with ARF4 are being confirmed through one-to-one interaction assay.

The *trans*-grafting: A technique to understand scion-rootstock interactions in grapevine.

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The physiology of a grafted grapevine results from the interaction between two genotypes. During grapevine development or under stresses, signals exchanged between the two parts of a plant are critical to plant responses. However, the nature and directionality of these signals as well as the influence of genetics on the signal perception are still unclear in many cases. Here, we present a method named *trans*-grafting that involves the grafting of genetically engineered (GE) grapevine material (microvine) to either rootstocks or scions varieties. This approach will aim to evaluate the influence of genotypic variability on the perception of signals generated and transmitted by engineered microvines to the other part of the plant (scion or rootstock). The *trans*-grafting technology was coupled with a conditional expression system for the GE microvine to allow a precise control of the produced signal during the development of the *trans*-grafted grapevines. As a proof of concept, we are studying two proteins that contribute to hydraulic and chemical signals responsible for the regulation of transpiration in scions and drought tolerance of rootstocks. Our main objective is to test independently the perception of these signals by either the scions or the rootstocks. As a first-step, we aim to 1) assess the rate of micrografting on homo- (one genotype on its own root) and heterograft (two different genotypes; one being the GE microvine) grapevines and 2) determine the rate of plant regeneration from these plants. Our preliminary results indicate that the efficiency for successful homograft and heterograft is greater than 50% and plant regeneration is above 75%. Heterografting developed with engineered microvines (scion or rootstock) are under analysis. Overall, the methodology to produce trans-grafted grapevine plants require a minimum of tissue culture training but it can be streamlined for high-scale experiment in a minimum of space.

Developing a protein-protein interaction assay using grapevine protoplasts

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Protein-protein interaction is an important mechanism that influences plant developmental processes and responses to environment. In this case a Biomolecular Fluorescence Complementation assay (BiFC) will be used to determine if two candidate proteins studied in our lab interact, and to identify the location of this interaction in plant cell (cytosol, nucleus). Currently there is poor knowledge about how proteins interact in any aspect of grapevine research. The current project was initiated as a follow up of a Yeast Two Hybrid assay (Y2H) that identified almost two hundred protein interactors with an Auxin Response Factor VitviARF4 hypothesized to delay the timing of ripening initiation in grape berries. To validate the Y2H results, a BiFC assay is in development using protoplasts of microvine cells. The objectives of the project are to 1) streamline the generation of grapevine protoplasts (cells without cell wall), 2) optimize the expression of proteins of interest, 3) validate the cellular localization of the interaction between VitviARF4 and two candidate proteins: VitviETR4, an ethylene receptor, and VitviHXK2, a kinase playing a role in sugar sensing in plants. About 300 mg of microvine cells were used to produce protoplasts by digesting cell walls with macerozyme R-10 and cellulase R-10; these protoplasts were viable for almost two months in appropriate conditions. Fluorescein diacetate (FDA) tests were performed to estimate the viability of the protoplasts, which was found to be successful because the FDA was able to enter into the protoplasts. Polyethylene glycol transfection was then performed to facilitate the entry of a plasmid expressing a Green Fluorescent Protein (GFP) to microvine protoplasts. The GFP was found to be expressed after 48 hours. The next steps are to clone the proteins of interest into a 2 in 1 vector recently developed for BIFC assays and to transfect the microvine embryogenic cells.

Pinot noir hydroxycinnamic acid content under different aging conditions and volatile phenol production by *Brettanomyces bruxellensis*

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The volatile phenol precursors *p*-coumaric and ferulic acid are naturally present in grapes and typically found as esters of tartaric acid (coutaric and fetaric acid, respectively). *Brettanomyces bruxellensis* cannot metabolize the esterified precursors, but these forms can be hydrolyzed due to acid hydrolysis or microbial action. Information regarding the extent of hydrolysis during winemaking is limited. Therefore, this study investigated factors impacting the hydrolysis of esterified hydroxycinnamic acids (HCAs) during winemaking, including malolactic fermentation (MLF), pH, ethanol concentration, and wine storage temperature. Pinot noir wines were produced and underwent MLF with either a cinnamoyl esterase-positive (CE+) or cinnamoyl esterase-negative (CE-) *Oenococcus oeni* strain. At the end of MLF, significantly higher concentrations of free HCAs were present in wines where MLF was performed by the CE+ *O. oeni* strain compared to the CE- strain. After MLF, wines were adjusted to two different pH values and two different ethanol concentrations before being sterile-filtered, bottled, and stored at 13 or 21°C. Wines were assessed for esterified and free HCAs after 0, 30, 100, and 180 days of storage. The concentrations of esterified and free HCAs remained constant throughout aging. Concentration differences seen at the end of MLF remained after 180 days aging, regardless of wine pH, ethanol, or storage temperature. Following aging, wines were inoculated with *B. bruxellensis* and then assessed for volatile phenol concentrations after 60 days. Wines where MLF was conducted by the CE+ *O. oeni* contained significantly higher volatile phenol concentrations than wines which had undergone MLF with the CE- strain. In conclusion, the *O. oeni* strain used to conduct MLF had the largest influence on the concentration of free HCAs present, which subsequently impacted the amount of volatile phenols produced by *B. bruxellensis*.

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Impact of Grapevine Red Blotch Disease and abscisic acid treatment on wine aroma compounds

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Grapevine red blotch disease delays grape berry maturity and has a great impact on fruit quality. Endogenous abscisic acid (ABA) is an important plant growth regulator which contributes to berry ripening. In this study, we examined the impact of exogenous ABA on red blotch affected vines with regard to wine aroma composition. ABA was sprayed on red blotch affected and non-affected grapevines (ABA/RB+, ABA/RB-), while control groups were left unsprayed (CON/RB+, CON/RB-). Volatile profiles of wines made from grapes of the ABA trial were analyzed using the stable isotope dilution approach with SPME-GC-MS and SBSE-GC-MS techniques. Highly volatile compounds were quantified by HS-GC-FID. In general, red blotch affected wines (RB+) showed lower concentrations of isoamyl acetate, ethyl octanoate, isobutyl alcohol, and SBMP (2-sec-butyl-3-methoxypyrazine) than the non-affected wines (RB-). Within the red blotch affected wines, the ABA treatment (ABA/RB+) resulted in higher levels of isobutyl alcohol and isoamyl alcohol, whereas octanoic acid and decanoic acid were lower compared to the unsprayed control (CON/RB+). Non-red blotch wines treated with ABA (ABA/RB-) demonstrated higher concentrations of 2-heptanol, 1-hexanol, and β-damascenone, but lower levels in linalool, in relation to the unsprayed control (CON/RB-). While the ABA treatments had a clear impact on wine aroma composition, the trends need to be further investigated.

Impact of Grapevine Red Blotch Disease and irrigation treatments on wine aroma compounds

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This work looked into the impact of water status on red blotch affected vines with regard to wine aroma composition. A field experiment was established with two irrigation treatments (wet (W) and dry (D)) and two disease states (red blotch affected (+) and non-affected (-) grapevines). Volatile profiles of wines made from grapes of the field experiment were analyzed using the stable isotope dilution approach with SPME-GC-MS and SBSE-GC-MS techniques. Highly volatile compounds were quantified by HS-GC-FID. In general, wines with wet treatment showed higher concentrations of isoamyl acetate and hexanoic acid than in dry treatment, and red blotch affected wines demonstrated higher concentrations of isoamyl acetate and propanol. Within the dry treatment, red blotch affected wines (D+) resulted in higher levels of hexanoic acid, whereas ethyl propionate was lower compared to the non-red blotch wines (D-). Red blotch affected wines with wet treatment (W+) revealed lower levels of ethyl hexanoate, phenyl alcohol, and hexanoic acid. Overall, different irrigation treatments and red blotch disease states had an influence on the concentration of specific aroma compounds, further studies are still needed as the trend to date was not obvious.

The role of esters and thiols on tropical fruit aromas in wine

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Wine aroma is complex and there are many different volatile compounds that may contribute to perception of fruity aromas. White wine aroma is mainly characterized by fruity aromas and their presence is important to the quality. Volatile thiols are impact aroma compounds that are well-known in the literature for imparting tropical fruit aromas in the wine, such as pineapple, mango, passion fruit, etc. Although volatile thiols are potent aroma compounds and there is scientific evidence that they impart tropical fruit aromas in the wine, there is a hypothesis that interaction effects of thiols and other volatile compounds occur in the wine and might enhance the tropical fruit aroma quality. Therefore, this study investigated the interaction effects of esters and volatile thiols in the fruitiness profile of white wine. A dearomatized Pinot gris wine was created at the OSU research winery and combinations of compounds were added to the wine, forming the aroma base. Treatment wines were composed of additions of volatile thiols and increasing concentration of esters. Samples were subjected to sensory analysis where forty-six white wine consumers participated in check-all-that-apply (CATA). Results were analyzed using Correspondence Analysis (CA). Thiols contributed to earthy and green aromas. Tropical aroma perception was only seen when a combination of esters and thiols were present. This study emphasizes the importance of studying the interactions that occur between aroma compounds in the wine matrix. Different concentrations of esters and thiols will be tested in a future study to evaluate where the threshold of tropical fruit aroma occurs.

The role of lipids and fatty acid composition in Pinot noir wine mouthfeel

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Mouthfeel is an important aspect of wine quality. Understanding the factors that contribute to wine mouthfeel is the key to develop wine making strategies that result in consistent, high quality wines. There are extensive studies that relate wine components such as alcohol, sugar, and phenolics to wine mouthfeel. However, there has been little success linking other chemical components to mouthfeel perception. In wine, the sources of lipids have been studied but the changes in lipid concentration and fatty acid composition and their sensory impacts on mouthfeel perception have yet to be discussed. This study investigates the presence of different lipid classes, total lipids, and fatty acid composition in Pinot noir wines. Bligh-Dyer method was used to extract total lipids in Pinot noir wines. Thin-layer chromatography (TLC) was used to separate the lipid classes. Fatty acid composition was quantitatively analyzed as fatty acids derivatives by gas chromatography mass spectrometry (GCMS). Principle component analysis and discriminant analysis were used to determine variables that contribute to the uniqueness of the wines due to lipids. Lipid content extracted from Pinot noir wines varied with maximum total lipids as 0.1% (w/v). Five lipid classes were identified by TLC; polar lipids (PL), sterols (ST), free fatty acids (FFA), triglycerides (TG), and cholesterol esters (CE). Palmitic, stearic, linoleic, and linolenic acids were found to be important contributors to fatty acid composition. The composition of other lipid classes also differed between wines. These lipid differences may directly or indirectly impact wine mouthfeel perception, as lipids are important contributors to mouthfeel of many food products.

Effect of late harvest on polysaccharide composition in red wine

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Red wine polysaccharides are highly versatile both in molecular weight and in composition. As shown in a recent study, the variation between different red wines is huge regardless of grape variety, vintage, and growing region, suggesting that winemaking techniques play a crucial role in altering the polysaccharide composition. As of harvest, one of the potentially decisive factors is grape maturity. The present project examined compositional changes in red wine polysaccharides that were produced from grapes with extended hang time of 11 days (HT) in comparison to control wines (Con) from normally harvested fruit. Starting brix of the control wine was 24.4 in contrast to 25.9 in the late harvest. An additional treatment was introduced, where must from grapes with extended hang time was diluted (HT-H_2O) close to starting brix of the control wine (24.5). Each approach was carried out in three ferments. The total carbohydrate composition was determined by GC of the TMS ethers after hydrolysis and derivatization of the polysaccharides. The analysis revealed an increase in the total amount of polysaccharides in the extended hang time wine (HT). However, the diluted HT-H_2O samples showed the same level as the control implying that a prolonged hang time per se does not increase polysaccharide content. Still, examining the composition, HT and HT-H_2O wines tended to accumulate slightly higher shares of grape derived arabinose and galacturonic acid, whereas the portions of yeast derived mannose and glucose appeared lower than in the control. The elevated polysaccharide content in HT samples presumably originated in generally higher concentrated grapes, but the compositional differences between HT-H_2O and control wines might also describe a trend towards a slightly enhanced accumulation of certain grape derived polysaccharides with prolonged hang time. Still, these differences are not significant and need to be analyzed more deeply.

The importance of nitrogen source: Vineyard versus winery nitrogen impacts on Chardonnay and Pinot Noir wine sensory attributes

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It is well established that yeast assimiable nitrogen (YAN) affects alcoholic fermentation. Beyond impacts to alcoholic fermentation, this study also investigates how YAN influences wine sensory attributes. The main objective was to investigate how the source and concentration of YAN impacted Pinot Noir and Chardonnay wine sensory perception. Five treatments were used including a control (no nitrogen additions), addition of diammonium phosphate (+DAP) or organic nitrogen (+Nutriferm) in the winery, and addition of nitrogen to the soil (+Soil N), or the foliage (+Foliar N) in the vineyard. Treatments were established with four replicates for each variety. The +Foliar N treatment did not begin until 2017 while all other treatments were conducted in both 2016 and 2017. Wines were produced using standard protocols and conditions, and underwent sensory evaluation using triangle tests and Napping® for aroma and mouthfeel. Results from triangle tests showed Pinot Noir and Chardonnay control wines were significantly different from all nitrogen boosted wines, except for the 2016 Chardonnay with DAP addition. Chardonnay wines produced with different nitrogen supplementation (DAP or Nutriferm) in the winery were also significantly different from each other. In contrast, the 2016 Pinot Noir winery nitrogen treatments were not significantly different. For both varieties, +Soil N wines were significantly different from all other treatments in both years, except for the 2017 +foliar N Chardonnay wine. In both the Chardonnay and Pinot Noir, Napping® showed that treatments were well grouped and described based on aroma but not mouthfeel. Based on these results, increasing YAN as well as using different sources of YAN alters the sensory attributes of Chardonnay and Pinot Noir wine. Ongoing work includes assessment of juice and must amino acid composition and wine volatile aroma compounds. This will provide further information on how nitrogen composition impacts formation of wine aroma compounds.

The impact of Chardonnay grapevine unhealthy stress on wine aroma and off-flavor

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In this study, we investigated the impact of unhealthy stress of Chardonnay grapevines on wine aroma composition. Chardonnay grapes were harvested in 2018 from both healthy and unhealthy grapevines of a commercial vineyard. After being pressed and racked, fermentations were carried out at 15°C using D47 yeast in triplicate. Fermentation of healthy wines completed at 16 days while unhealthy wines completed at around 20 days. Wine aroma compositions were analyzed by headspace (HS)-GC-FID, solid-phase micro-extraction-GC-MS (SPME-GC-MS) and stir bar sorptive extraction GC-MS (SBSE-GC-MS) techniques with stable isotope compounds as internal standards. In general, the healthy wines displayed higher fermentation esters, alcohols and acids compounds than unhealthy wines. The health status of grapevine appears not to affect the level of monoterpene compounds, but affected the C_{13}-norisoprenoids in both free and bound forms in those wines. It was found that both the free and bound β-damascenone and β-ionone were significantly higher in healthy wines. In addition, the bound vitispirane and TDN (1, 1, 6, -trimethyl-1,2-dihydronapthalene), released from aroma precursors by acid hydrolysis (pH 2.5, 100°C for 1 hour), were significantly higher in unhealthy wines. In addition to wine aroma, total phenolic content in unhealthy wines was 40% higher than that in healthy wines by the Folin-Ciocalteu colorimetric method. The implication of higher level of TDN on stressed vine off-flavor is under investigation.

Smoke composition, timing of exposure and prospects for mitigation

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Wildfires affecting Pacific Coast states in recent vintages have increased concern over the effects of smoke on the quality of grapes and wine. This presentation will review three ongoing studies in our smoke exposure research program. In the first, the composition of smoke from 16 plant species including sagebrush, cheat grass, rabbitbrush and others, was evaluated. Smoke collected using glass microfiber filters was analyzed using solid-phase microextraction (SPME) coupled with gas chromatography/mass spectrometry (GC/MS). Syringol, p-cresol, m-cresol and 4-ethylphenol were present in high concentrations in sagebrush smoke, while smoke from conifer bark mulch had high levels of guaiacol and creosol. Rabbitbrush smoke contained several polyaromatic hydrocarbons that were not present in most samples but had lower concentrations of guaiacol.

In the second study, field planted grapevines were exposed to moderate intensity smoke for 48-hour periods at four time points, including four weeks pre-véraison, at 50% véraison, 3 weeks post-véraison and 6 weeks post-véraison. The exposures took place between mid-July and late September 2018, finishing less than two weeks prior to harvest. Fruit from all four treatments was harvested in early October. Wines from this study had smoke-related aromas and flavors in the smoke treated wines for all four exposures including pre-veraison, while the control wines did not exhibit smoke related off-aromas or flavors.

In the third study, smoke affected wines were treated using a small-scale reverse osmosis (RO) filtration system. The permeate stream was passed through carbon filters to remove smoke-related compounds. The composition of both permeate and retentate streams was analyzed using GC-MS and UHPLC-QTOF/MS. In the RO treated wine, several smoke related compounds declined in abundance over the treatment period. Samples of the treated wines are being held at elevated temperatures to evaluate the release of free smoke related compounds from precursor forms as the treated wines age.

A pesticide-free alternative to reduce spotted-wing drosophila egg laying in damaged grapes

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Spotted-wing drosophila (SWD, *Drosophila suzukii*) is an invasive fruit fly species native of Southeast Asia. In vineyards, SWD lays eggs in damaged and intact fruit of the most soft-skinned varieties, and feeds on damaged berries during the harvest period. Feeding and oviposition activities increase the likelihood of vectoring spoilage bacteria, particularly when berry integrity is negatively impacted due to cracking, diseases, hail injury, and bird damage. The aim of this study was to evaluate the efficacy of a novel SWD management tool, a pesticide-free behavioral disruptor (BD), in vineyard systems. Data were collected from a series of laboratory and field trials on Pinot noir grapevines. Intact and damaged single berries or clusters were exposed to the pest either in presence or absence of the BD. The laboratory trials resulted in a reduction in oviposition in both compromised and intact grape fruits. The field trials resulted in a similar reduction in egg laying in commercial-standard conditions. These findings indicate that the BD has the potential to significantly impact SWD oviposition and feeding activities in commercial vineyard settings.

“A Rising Tide Lifts All Boats”: The value of cooperative pest and disease management programs

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In addition to vines, grape growers in Napa cultivate a collaborative spirit, consistent with their motto that a “rising tide lifts all boats”. This manifests in various ways, from personal communications between growers to regional meetings and formal educational events. In the early 2000’s and in response to the increasing threat from invasive insects, growers established a self-assessment managed by the Napa County Winegrape Pest and Disease Control District. The District funds support local activities such as county-wide monitoring programs, research projects and biocontrol releases. During the *Lobesia botrana* program, the prudent allocation of these funds facilitated a quick response that was key to eradication. Growers in Napa also meet informally to discuss invasive pest and disease populations and support regional control efforts. Topics of discussion include pest distribution and spread, management challenges and coordinated monitoring efforts. Researchers also participate and share emerging technical information. Most importantly, the groups are a place where growers share their successes. Although research may support the use of a particular management strategy, adoption is dependent upon verifying that it works in practice. When that verification comes from fellow growers in a small group setting, it is increasingly trusted. By supporting the uptake of data-driven control practices and providing independent verification of their usefulness, these groups have repeatedly increased positive pest management outcomes across the region. This validates the valuable role group members play in advancing short and long-term change and elevating the success of the industry.

Supplemental vineyard inputs may partially mitigate negative effects of Grapevine Red Blotch Disease in Oregon Pinot noir

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Grapevine red blotch disease (GRBD) poses an increasing threat to winegrape production by altering vine physiology and reducing fruit quality. While progress has been made in understanding GRBD pathology and epidemiology, few pragmatic horticultural strategies have been identified to manage disease effects in the field. Consequently, two field experiments were initiated in a commercial vineyard to determine the potential of cultural practices to mitigate negative effects in Grapevine Red Blotch Virus-infected (GRBV+) Pinot noir grapevines. In experiment A, vines received factorial combinations of grower control (GC) and supplemental (SUPP; 2x GC) irrigation (I) and fertilization (F). In experiment B, vines grafted to Couderc 3309 (3309C) or Riparia Gloire (RG) rootstocks received factorial combinations of GC and SUPP irrigation (I; 2x GC) and crop thinning (T; one cluster/shoot). Across both experiments, SUPP-I significantly reduced disease severity (% red leaves per vine) at harvest, and increased yield compared to GC-I. SUPP-I reduced disease severity by 19.6% in experiment A, and by 15.2 and 10.0% in experiment B for 3309C and RG, respectively. Yields increased by 20-30% with SUPP-I across both experiments. SUPP-F or SUPP-T had no effects on disease severity and SUPP-F had no effects on yield. There were no effects on total soluble solids (TSS) at harvest across both experiments, though SUPP-F and SUPP-T significantly increased berry pH. SUPP-F increased pH by 0.09 pH units in experiment A, and by 0.22 and 0.13 pH units in experiment B for 3309C and RG, respectively. The first year's data suggests that increasing irrigation can significantly reduce disease severity and increase yield with no significant reduction in TSS in GRBV+ Pinot noir grapevines. In contrast, supplemental fertilization and crop thinning have no effects on disease severity and TSS but can increase berry pH. Ultimately, increasing vineyard inputs may partially mitigate negative effects of GRBD.

In-field spread of *Grapevine Red Blotch Virus* and associations with treehopper feeding damage

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Grapevine red blotch virus (GRBV) is a virus infecting grapevines. To determine possible spread of GRBV, grapevine petiole tissues were collected in southern Oregon and the Willamette Valley from 2013-2018 and tested using quantitative PCR. A vineyard near Jacksonville showed an extreme 36-fold increase in virus incidence over a three-year period. At Talent, GRBV incidence doubled over the course of the same period. A third site near Medford was removed from production prior to assessment of virus spread, but initial results indicated that nearly half of the tested vines contained GRBV. Infections approximately doubled over the study period in two blocks of a vineyard near Yamhill, in the Willamette Valley. The patterns of spread of GRBV suggest that a vector is involved in transmission. Locally abundant treehopper species (Hemiptera: Membracidae) are suspected vectors in Oregon vineyards. Membracids were found primarily along the edges of vineyard blocks and in unmanaged vegetation adjacent to the vineyards. Feeding damage was apparent through characteristic girdling of leaf petioles and small-diameter stems (~2mm caliper). Girdles were recorded in southern Oregon and Willamette Valley sites. Vines near the edges of vineyard study sites were more likely to show signs of treehopper feeding, compared to interior vines. No correlation was observed over a three-year period between the incidence of GRBV in vines at Yamhill that were asymptomatic but with girdles in 2016, compared to vines that were asymptomatic and without girdles in 2016. This indicates a potentially lengthy incubation period of the virus, or alternatively that cryptic feeding went unnoticed. GRBV is a serious issue in Oregon wine production due to its year-over-year spread in affected vineyards and its interactions with native insect species.

Seasonal sampling procedure for increased accuracy of grapevine red blotch virus detection

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For the confirmation of grapevine red blotch virus (GRBV) infection, it is recommended that vines be tested for virus and not rely on symptoms as we do for other disease diagnosis. In the summer of 2018, we conducted virus detection trials in southern Oregon to identify the best tissues to use for sampling and optimal vine phenology to best detect GRBV during the growing season. Four leaf petioles were collected from base, middle, and top of vine canopies at three phenological stages including fruit set, verasion, and harvest from twenty infected and eight non-infected grapevines. Total nucleic acids were extracted from petiole samples and amplified using standard primer sets via PCR. Petioles from non-infected vines were all negative regardless of phenological stage or position in the vine canopy. From 180 tests of infected vines, only 53% were positive for GRBV in the PCR assay used. From the infected vines, the accuracy of test results were consistently high (90 to 100%) for the samples collected from base of canopies and low (0-10%) from the samples collected from top of the canopy. Samples collected from base of the canopy at harvest from infected vines were all (20 of 20) positive. During fruit set, 95% of the petioles collected from base of the canopies were positive, but that number decreased significantly in medium and top petioles, where only 15 and 5% of vines tested positive, respectively. During veraison, detection from mid-canopy increased to 90% of sampled petioles, whereas all petiole samples from top of the canopy were negative. During harvest, GRBV detection from middle and tops of canopies did not differ significantly from detection at veraison. These results suggest older petioles are more suitable tissues for testing GRBV, and that the accuracy of test results increases with samples collected later in the season.

Effects of grapevine red blotch disease and management strategies on Pinot noir in the Willamette Valley

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Grapevine Red Blotch Disease (GRBD) is a grapevine virus found to affect wine quality. Some studies report reduced soluble solids and anthocyanins in GRBD+ fruit, causing concern for cool climate production regions. A series of experiments were conducted in a commercial Pinot noir vineyard in Oregon's Willamette Valley in 2018 to understand and mitigate the effects of GRBD. The physiology of GRBD+ and GRBD- vines where monitored through the growing season to determine its effects on vine growth, photoassimilation, stomatal conductance, and fruit composition. In addition, two vineyard blocks were used for management studies. One block contained both GRBD+ and GRBD- vines and used to test the cluster zone application of abscisic acid (ABA) compared to untreated vines in an attempt to chemically induce ripening and enhance ripeness by harvest. The other block was 100% infected and two leaf removal treatments were evaluated, including pre-bloom 100% cluster zone leaf removal and east side only leaf removal at fruit set. There were no differences in photoassimilation, stomatal conductance, and leaf chlorophyll between GRBV+ and GRBV- vines during mid-late summer. Fruit from GRBD+ vines had lower total soluble solids (TSS) and total anthocyanin, but higher total phenolics compared to GRBV- fruit at harvest in the physiology study. In the ABA trial, the ABA treatment had higher yields and lower seed tannin than untreated. However, ABA application did not affect basic ripeness parameters for the virus-infected or healthy vines, as GRBD+ fruit had 5% lower TSS than GRBD- regardless of the ABA application. The early season leaf removal trial did not affect ripeness or fruit phenolic parameters measured, however the 100% cluster zone leaf removal at bloom had 15% smaller clusters than east side leaf removal at fruit set.

Rapid sampling techniques to monitor group 11 fungicide resistant grape powdery mildew

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A competitive TaqMan qPCR assay was developed to monitor FRAC Group 11 (Storbilurin) fungicide resistant grape powdery mildew (GPM). While this assay is effective for detecting the presence of the resistant genotype, it is not clear how to sample vineyards to get an accurate assessment of the resistance frequency in a field population. We compared direct colony collection techniques (ToughSpot stickers or cotton swabs) to glove swab sampling techniques (spores were collected from vineyard crews conducting regularly scheduled canopy management) and investigated the sampling spatial density required to estimate frequency of resistance within a vineyard. Over 1500 samples were collected May – Sept 2018 from 12 commercial vineyards in the Willamette Valley of Oregon via a linear stratified sampling pattern where sample types were collected from same row and leaf. ToughSpots and leaf swabs were in 100% agreement; thus, only swabs were used for the 2018 season. For each row, the aggregated direct swabs and glove swab had 65% agreement for disease presence. For 31% of the rows sampled, glove sampling was able to detect the presence of GPM when no mildew was visually detected, indicating that the glove swabs may be able detect disease at lower levels. When mildew was detected both visually and via the glove swab, the samples were in agreement 98% of the time for resistance genotype. Commercial growers also collected glove swab samples throughout the season and these were closely correlated with the researcher glove samples. These results indicate that glove swabs can be a viable technique to assess the risk of fungicide resistance in a field with minimal interruption to grower production schedules. Further methods for FRAC groups 3, 7, 13 are under development.

Red Blotch disease update

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There is ongoing grapevine red blotch virus (GRBV) research coordinated by members of the Oregon Wine Research Institute that focuses on virus vector identification and distribution, transmission, non-crop hosts, vineyard management to mitigate disease symptoms, identifying virus impact on wine quality, and winery management. This research has been in progress since 2013, but efforts increased in 2018 due to funding from Domaine Serene Winery (Dundee, OR). There are two areas of emphasis in vector research, including studies with Oregon treehoppers species due to their close relationship to a confirmed vector in California studies, the Three Cornered Alfalfa Hopper. Treehopper life cycle and feeding behavior in alternate host plants, and damage to grapevines was studied. The second approach investigates the potential of other insect species from within infected vineyards (vine canopy, vineyard floor, and surrounding vegetation) to see if they can transmit the virus under controlled conditions by feeding collected insects on infected plants. Also, confirmed virus-free potted grapevines were placed in vineyards with high levels of GRBV during two growing seasons at monthly intervals to identify when virus is transmitted in the field. In efforts to mitigate the impact of GRBV in the vineyard, several management studies are underway, including irrigation, nutrition, and crop level management, timing and intensity of leaf pulling, and foliar applications of abscisic acid (ABA). Also, detailed physiological measurements of vine water stress and photosynthetic activity is being monitored throughout the growing season. The enology research group is doing basic fruit analysis before making wines and then characterizing the aroma and phenolic compounds in wines made from the vineyard management trials. Similar research teams are in progress with virus, vector, and management studies between USDA-ARS and institutions on the West Coast (UC-Davis, Oregon State University, Washington State University) and East coast (Cornell University).

An international mildew management problem - fungicide resistance from coast to coast

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Throughout 2018, a monitoring program for strobilurin resistance in *Erysiphe necator* (grape powdery mildew (GPM)) was expanded to the major grape production regions of British Columbia, California, Georgia, Michigan, Oregon, and Washington. A total of 1335 ToughSpot kit samples were received and analyzed for presence of the G143A alelle that has been shown to confer resistance to quinone outside inhibitor (QoI) fungicides (FRAC Group 11). The G143A qPCR assay results indicated widespread resistance throughout all grape growing regions (86% contained *E. necator* with the G143A alelle). However, the frequencies varied greatly by state with higher frequencies in California (92%), Washington (89%), Georgia (84%), Michigan (81%), and British Columbia (78%), than in Oregon (48%). Analysis of air samples collected using impaction spore samplers from commercial vineyards throughout western Oregon from 2013-2018 showed that QoI resistance was detected 2 years prior to the first reports of control failures in 2015. The frequency of the G143A allele peaked in 2016, and has shown a continuous decline through 2017 and 2018 in fields where QoI and DMI use has ceased completely. Air samples collected from Washington vineyards during the 2018 growing season showed a decrease in the frequency of the G143A allele from 93% in 2017 to 81% in 2018. These samples and isolates will be further characterized using various molecular techniques and newly developed fungicide resistance bioassays to determine resistance to demethylation inhibitor (DMI) fungicides (FRAC group 3), succinate dehydrogenase inhibitor (SDHI) fungicides (FRAC group 7), and quinoxyfen (FRAC group 13) is ongoing.

Succinate dehydrogenase inhibitor resistance in isolates of *Erysiphe necator* from the Western U.S.

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Grape powdery mildew (GPM) caused by *Erysiphe necator*, is a devastating fungal disease of grapevines worldwide. The fungus infects leaves and berries reducing yield and wine and juice quality, and paves the way for other diseases such as gray mold. The succinate dehydrogenase inhibitor (SDHI, FRAC 7) class of fungicides has been a useful management tool for GPM for many years. Unfortunately with SDHI use there is a medium to high probability of resistance development and subsequent potential for field control failures with over reliance. Although SDHI resistance in *E. necator* is not currently of critical concern, *E. necator* resistant to SDHIs has been reported in several wine grape regions of Europe. Due to the current concerns of resistance to dimethyl esterase inhibitors (DMI, FRAC 3) and quinone outside oxidase inhibitors (QoI, FRAC 11), the emergence of SDHI resistance could pose a serious threat to the Western U.S. grape industry. To assess the current status of SDHI resistance, *E. necator* isolates collected over the 2017 growing season from across Oregon, Washington and California were bioassayed. Isolates were inoculated on water agar amended with the active ingredients (AI) boscalid, fluopyram and benzovindiflupyr in the form of brand fungicides Endura®, Luna® Privilege and Aprovia®. Most isolates had EC50 values below 1 ug AI/ ml. However, 4 isolates were found to have an EC50 for Boscalid that was greater than 20 ug/ml. One of these isolates was also resistant to fluopyram with an EC50 greater than 100 ug/ml. Boscalid resistance was associated with the H242R mutation in the SDHB gene and Boscalid and Fluopyram resistance was associated with the I244V mutation in the SDHB gene. No resistance to benzovindiflupyr was detected. Our results indicate the emergence of SDHI resistance and a need for continued surveying in all grape growing regions of the United States.

A vibrational pest management strategy to control treehopper pests

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As plant-feeding insects, treehoppers (Hemiptera: Membracidae) affect a multitude of crops. Recently, Grapevine red blotch virus (GRBV), a newly recognized virus infecting grapevine, has been associated in vineyards with three treehopper species of the Smiliinae subfamily. In California, the threecornered alfalfa hopper *Spissistilus festinus*, has been shown to be a vector of GRBV, the causal agent of red blotch disease, whereas two other species of the genus *Tortistilus* have been associated with the presence and spread of GRBV in Oregon vineyards.

In order to limit the spread of GRBV, a management strategy of its vector is needed. Although treehoppers have cryptic lifestyles and are difficult to observe in affected vineyards, knowledge of their intra-specific signals can be used to manipulate the insect's behavior. The goal of this study was to acquire the background knowledge of intra-specific communication in *T. albidosparsus*. To study the mating pair formation, singles and pairs of adult treehoppers were simultaneously recorded by means of a laser vibrometer and a video camera. Next, recorded female signals were used in playback experiments to stimulate and attract mated and unmated males to the vibration source. Results from the mating communication studies on *T. albidosparsus* illustrate that these signals can be used to develop a behavior control strategy. Acquired information on the intra-specific communication is discussed together with ecological data about the distribution of the pest, allowing for the follow-up design of possible pest management strategies.

Efficacy of an intelligent sprayer on grape powdery mildew

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The Intelligent Sprayer Project consists of a multi-discipline research team across the USA working on improving spray application technology in specialty crops. The team has moved from proof of concept to evaluation of standard sprayers retrofitted with intelligent spray system (ISS) components. A Rear's 50-gallon Pak-blast sprayer was retrofitted in 2018 with ISS components and, in consultation with vineyard managers, four sulfur treatments were evaluated in a block of 'Pinot noir'. After a single season, the intelligent spray system did not control powdery mildew on leaves or clusters as well as a standard sprayer. Factors that contributed to this result included severe powdery mildew pressure, use of the non-systemic fungicide sulfur, and use of initial ISS settings. Spray card coverage was similar between treatments which indicated the main factor was low spray volume (not enough sulfur/A) applied with the ISS. Future trials should test higher pulse width modulation (PWM) duty cycles by setting the spray volume higher or use of more concentrate fungicide solutions. With some minor adjustments the ISS should prove to be an effective system to reduce pesticide quantity, water and/or labor.

A high throughput assay to rapidly characterize demethylation inhibitor resistance in *Erysiphe necator*

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Fungicide resistance of *Erysiphe necator* to demethylation inhibitors (DMI) and quinone outside oxidase inhibitors (QoI) is widely prevalent, placing increasing pressure on FRAC 7, 13, 50 and U6 fungicide chemistries. Currently, resistance to some fungicide can only be detected using time and resource expensive live leaf assays. We hypothesize that the conidium does not contain enough metabolic precursors for successful growth before having to begin synthesizing them; thus, fungicide resistance will likely be expressed as increased germination tube length on fungicide amended matrix. *E. necator* conidia were dispersed onto a 24-well plate with fungicide amended gellan gum medium and imaged immediately, and again after 24 hours to measure the development and elongation of germination tubes. The images were processed in ImageJ using the "HyphaTracker" macro (Brunk et al., 2018). The relative decrease in the percent increase in growth over 24 hours compared to the control was measured for each concentration of fungicide. Preliminary results show that at approximately 3µg/ml myclobutanil, the germination tube development is adversely affected for known sensitive isolates and is not inhibited for tolerant isolates. Results have been similar to leaf disk bioassays for DMI resistance. This method has the potential to objectively assess 4 to 5 isolates with only 3-4 hours of labor and a 24-hour incubation period, as compared to leaf disks bioassays, which require 9-12 hours of labor, a 14-day incubation and return subjective estimations of infected area. Work is underway to further optimize this bioassay and expand it for testing other fungicide chemistries.

Developing Economic and Financial Benchmarks for Mechanizing Northwest Vineyards

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Specialty crop industries with high labor requirements are experiencing increased labor costs and a diminishing workforce, impacting the economic viability of individual businesses. These labor issues have many Northwest vineyard owners struggling with the future of their industry. Industry leaders are offering potential solutions, such as mechanization of vineyard tasks, reorganizing staff roles to achieve efficient operations, recruiting from a domestic workforce, using the H-2A program, or a combination of the above. Mechanization seems to be one solution captivating grower interest without a great deal of economic and financial information. This project provides insights into the profitability and feasibility for labor-saving machines with the aim of preserving and enhancing fruit and wine quality.

The tree fruit industry of the Pacific Northwest recognized in 2001 that technological innovation would be required to address a future created and continually changed by the globalization of world markets. With a vision to reduce the cost of production of its highest quality fruit by 30% by the year 2010, the Washington Tree Fruit Research Commission led an industry effort to meet these challenges by creating a Technology Roadmap. As a result of this effort, the tree fruit industry today is not the industry of 20 years ago!

This project is defining the economic and financial benchmarks and metrics that could lead to a technology roadmap for the U.S. wine grape industry. The research first assesses the mechanized vineyard tasks of pruning, shoot thinning and desuckering, leaf pulling and harvest to determine their economic benefits and second, to provide financial guidelines to whether an operation can purchase, lease or custom hire these tasks based on improving a business' liquidity, solvency, and repayment capacity.

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