Fall 2016

Oregon Wine Research Institute
Viticulture & Enology Technical Newsletter

Welcome to the Fall 2016 Newsletter

Our latest edition of the OWRI Technical Newsletter contains research updates, the latest Extension resources, and a comprehensive list of publications outlining research conducted by members of the Oregon Wine Research Institute at Oregon State University. Dr. Patty Skinkis, Viticulture Extension Specialist & Associate Professor, OSU opens the newsletter with a research update on the Statewide Crop Load Project. Dr. James Osborne, Extension Enologist & Associate Professor, OSU along with Dr. Michael Qian, Professor, OSU, provide valuable information on their research exploring the impact of elemental sulfur and nitrogen on volatile sulfur compounds. Lastly, Dr. Elizabeth Tomasino, Assistant Professor, OSU provides a summery of her research assessing brown marmoarted stink bug taint in wine.

Make sure to check out the Practical Guides and Resources section, as we have some fantastic new resources, most of which are available online.

Cheers,
The OWRI Team

Statewide Crop Load Project Report: Investigating the Yield-Quality Relationship of Pinot noir

Dr. Patty Skinkis, Viticulture Extension Specialist & Associate Professor, OSU

Introduction

Many scientific studies have been conducted over the past century on grapevine productivity with a focus on fine tuning yields to achieve vine balance, that is, a productive vine that can produce both good quality fruit and maintain long-term health. Many crop management studies were conducted on high-yielding cultivars to determine yield targets to avoid over-cropping stress (Bravdo et al., 1985; Kliewer and Weaver 1971), and such research led to the development of vine balance guidelines using leaf area or Ravaz indices (yield:pruning weight) that have an impact on fruit and wine quality (Baeza et al. 2005; Bravdo et al. 1985; Kliewer and Dokoozlian 2005; Naor et al. 2002). However, practices used today for premium wine production have not changed much over the years with the preference for Guyot-trained vertically shoot positioned canopies and restricted yield that are thought to result in quality fruit and wines. In Oregon, the most attention to yield management is for Pinot noir, where the majority of producers conduct cluster thinning to a target of 2 to 2.75 tons per acre (Uzes and

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Skinkis 2016). However, this yield metric does not account for the diversity in vine density and production potential that exists across vineyards in Oregon's Pinot noir production regions. To address the yield-quality relationship for Pinot noir in Oregon, OSU established a large-scale, industry-collaborative project in 2012. A summary of results from the first four years (2012 to 2015) are reported here.

Methods

To date, 20 businesses have joined the project, with vineyards spanning five American Viticultural Areas (AVAs) and four counties within the Willamette Valley. Under the guidance of the Skinkis lab, each collaborator implemented a yield management trial by cluster thinning to two or more crop levels in their vineyards. Cluster thinning was conducted at lag phase (50 to 55 days post-bloom), and the same cluster thinning treatments and plots were used each year. Plots were organized in a randomized complete block design with each treatment applied to whole rows and spatially replicated three times across the vineyard.

Cluster thinning was applied as the following number of clusters per shoot: 0.5 (1 cluster every other shoot), 1 cluster per shoot, 1.5 (1-2-1-2 pattern of clusters per sequential shoot), and 2 clusters per shoot. The most common treatments applied included 1 cluster per shoot and 2 cluster per shoot or no thinning (no-thin). All cluster thinned treatments had wings removed from remaining clusters at the time of thinning. Vines that were not thinned (no-thin) had no clusters removed and all wings remained. Two collaborators opted for yield targets rather than thinning regimes, and their vineyards were thinned to specific target yields ranging from 1.75 to 3.25 T/A. Each vineyard was approximately 1 to 3 acres in size to ensure enough fruit to produce 1.5 tons of each treatment for wine production.

Vineyard data was collected according to protocols provided by OSU, including pre-bloom counts of number of inflorescences per shoot, cluster counts pre- and post-thinning, tissue nutrient sampling at véraison, harvest yields, and dormant pruning weights collected during winter following each growing season. All data were collected by vineyard collaborators and submitted to OSU.

Fruit composition was monitored pre-harvest for total soluble solids, pH and titratable acidity from 20-cluster samples collected at two or more time points prior to harvest. A 20-cluster sample was collected from each plot at harvest, and the Skinkis Lab quantified cluster weight and selected a sub-sample of whole berries for analysis of basic maturity, yeast available nitrogen components, and phenolics. Fruit analysis was conducted by ETS Labs. The rest of the fruit was harvested by the collaborator, bulked by crop level, and delivered to the collaborating winery for wine production. The majority of companies carried their experiments through wine production each year.

The vineyard data were statistically analyzed to determine the effects of crop thinning and yield on various growth parameters measured and fruit composition each season. Because the project was replicated at each site, statistics were run for each collaborator's site as well as across all sites and years in the project.

Results

Crop Levels. Yields varied considerably across the four years of the project as a result of differences in fruitfulness and fruit set each year. The first year (2012) was the lowest-yielding and 2015 was the highest yielding year (Figure 1). The 2015 season had 37% greater yield across all thinned treatments and a 47% increase in yield in non-thinned treatments compared to the four-year average. This was likely due to greater fruitfulness (number of clusters per shoot) and large cluster size that resulted from high fruit set in 2015. The mean cluster weight across all sites in 2012, 2013, 2014 and 2015 was 82, 92, 108, and 136 g per cluster, respectively. Cluster thinning reduced vine yields by 56, 31, 20, and 16% for the 0.5, 1, 1.5 and 2 clusters per shoot treatments, respectively when compared to the highest crop level treatments maintained on site, the majority of which had a full crop (non-thinned) treatment.

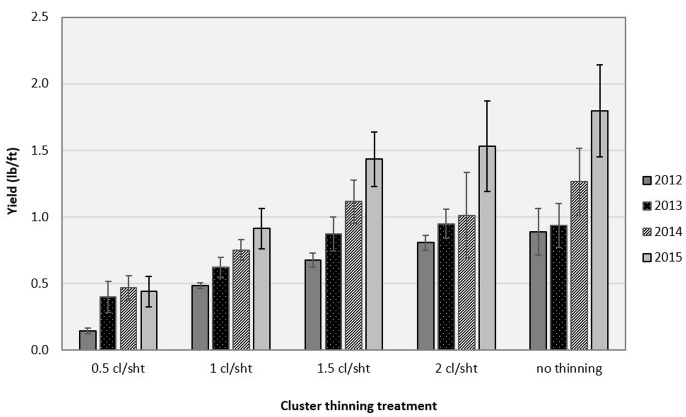

Figure 1. Yield measured at harvest across all Pinot noir vineyard sites in 2012 to 2015. The treatments include 0.5 clusters/shoot, 1 cluster/shoot, 1.5 clusters/shoot, 2 clusters/shoot and no thinning. Those sites with target yield treatments (n=2) were not summarized in these data. Means are shown with error bars that represent the standard error of the mean.

Impacts on ripening and fruit composition. Fruit composition at harvest was not universally affected by cluster thinning at all sites. Statistical analyses show that few fruit components at harvest differed due to cluster thinning treatments, with total soluble solids (TSS, °Brix), pH and titratable acidity (TA) being affected in only a few vineyards each year (Figure 2). These data also show that cluster thinning has more influence on fruit composition in higher yielding years (2014 and 2015). Ripening curve data from 2013-2015 show a trend of lower TSS and pH and higher TA in the highest crop levels (2 clusters per shoot or no-thin), but treatments were often not found to differ statistically, meaning TSS, pH and TA often were within the same ranges of values. The greatest differences in ripening data by crop level was found in 2015, the highest yielding year. By harvest, full crop (no-thin) treatments lagged in TSS by as much as 1.8 to 2.9 °Brix compared to thinned treatments at three sites in 2015, and these sites did not have higher yield or greater yield reduction by cluster thinning that would explain the disparity with the other vineyards that did not have differences by harvest. Only one site had a difference in pH due to crop level in 2015. These results show that cluster thinning at lag phase does not always hasten ripening. While some differences by cluster thinning treatment existed early in the ripening, many sites reached the same basic maturity by harvest. An alternative perspective: high crop levels in warm years may not maintain significantly lower pH or higher TA, as evidenced by lack of differences by harvest in 2014 and 2015.

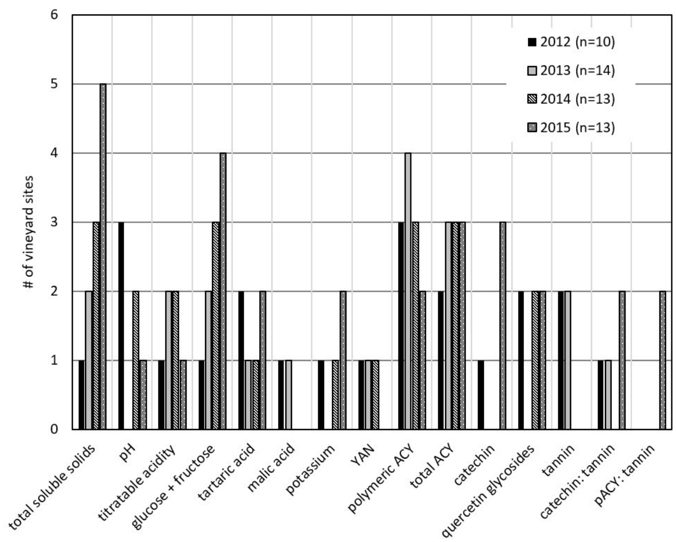

Figure 2. Number of Pinot noir vineyards with differences in fruit composition by thinning treatment (crop level) at harvest during 2012-2015 based on analysis of variance and α=0.05. Where there are no bars shown, there was no differences found for that parameter in that year. The legend above references the number of total vineyard sites (n) statistically analyzed for that year. Total soluble solids measured as °Brix, YAN=yeast assimilable nitrogen, ACY=anthocyanin, pACY: tannin=polymeric anthocyanin-tannin ratio.

The most common difference in phenolics based on cluster thinning was in total and/or polymeric anthocyanin concentration at harvest (Figure 2). When regression analyses were conducted, yield was the factor that most often influenced anthocyanin, and crop load (yield:pruning weight) was the second most common factor. Vine size (measured by dormant pruning weight) was rarely related to anthocyanin concentration. When the relationship was found in a given vineyard site, the higher the yield, the lower the total or polymeric anthocyanin concentration.

Figure 3 is an example of this relationship from one vineyard across three years (2013-2015) where a statistical

relationship was found for yield and total anthocyanin. Fruit from all sites did not show this response or the same slope of response in all years. The relationship of increasing total anthocyanin with decreasing yield was found in 10, 30, 30 and 45% of sites in 2012, 2013, 2014 and 2015, respectively. For polymeric anthocyanin, 20, 29, 42 and 36% of sites had increasing concentration with lower yields. Three sites have shown consistent effect of yield and anthocyanin (whether polymeric or total) in three or more years. The mean difference in anthocyanin concentration across years and sites had a statistical relationship with cluster thinning was 171 mg/L higher for total anthocyanin and 2.2 mg/L higher for polymeric anthocyanin in treatments that had been cluster thinned compared to the highest cluster thinning treatment on site (either 2 clusters per shoot or no-thin). Since light exposure is important factor in anthocyanin accumulation within the berry
(Dokoozlian and Kliewer 1996), we are conducting additional studies to determine if yield effect on anthocyanin is due to a physiological change of crop level or a change in cluster light environment as a result of leaf removal

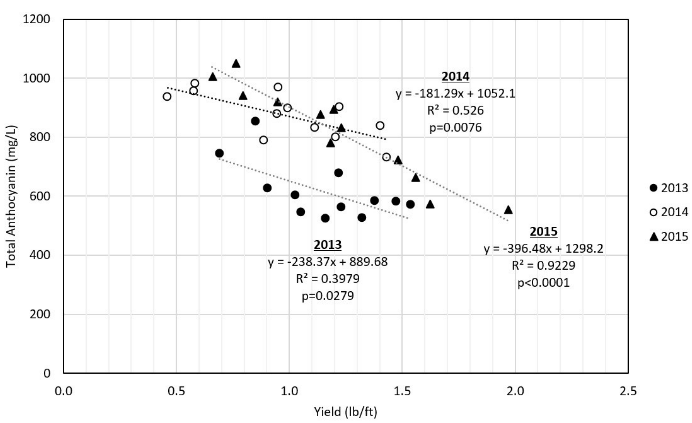

Figure 3. Relationship between yield and total anthocyanin from vineyard 3370 over three years (2013-2015). The relationships were determined through regression analyses, and equations, R^2 and p-values are shown for each year. The relationships varied by year (slope), and this serves as an example of the magnitude of change and the variability that existed between years.

Is yield sacrificing vine health? We hypothesized that maintaining higher crop yields would reduce vine vigor and would be detected as a reduction in dormant pruning weights, canopy leaf area, vine nutrient status, or fruitfulness (number of inflorescences per shoot in spring) over time. However, after multiple years of carrying different crop levels, no vineyards in the project showed differences in dormant pruning weights, vine nutrient status or fruitfulness as a result of cluster thinning. Vine vigor ranged considerably between the vineyards, and even low vigor vineyards did not have an impact of lower pruning weight in full crop (no-thin) vines. Canopy leaf area was measured at bloom and véraison in four sites from 2013 to 2015, and no differences were found by crop level. This was surprising, since many sites had been carrying full crop on vines for three or four years and 2014 and 2015 were record-breaking years for high yields. This suggests that the vines were not over-cropped from a vine health perspective over the past four years.

Véraison leaf and petiole samples showed no yield effect on macro- or micronutrients to date, again suggesting that vines were healthy enough to support the crop levels maintained over the past four years. Furthermore, potassium and nitrogen in the fruit (the latter measured through ammonia and primary amino acid nitrogen), did not show an effect by yield for the majority of vineyards, again indicating that these nutrients were not limited by increasing yield. The high-yielding years also coincided with warm growing seasons, early harvests, and a long post-harvest period before leaf fall that may explain the lack of differences in vine growth and nutrient status observed.

Collaborator observations and next steps

When collaborators were asked about what they have learned from the project, many expressed newfound respect for the time and effort required in research. Secondly, they are amazed by the difference that each season brings and how little difference was found between crop levels when examining the data from their sites and that of others in the project. Implementing the trial, gathering the data, and making the wine is a significant time commitment for industry collaborators, and the majority have stayed with the project as active participants for the duration of the project; 14 companies are actively participating as of the 2016 vintage.

While this report focuses on some of the viticulture and fruit composition results, sensory analysis is also underway. Wines are to be evaluated by winemaker panel after two years of bottle-aging, and the 2012 and 2013 wines have been evaluated and are currently being statistically analyzed by co-PI Dr. Elizabeth Tomasino, OSU. Future work will include in-house wine evaluations to be conducted by each collaborator, and this information will further our understanding about yield management with respect to the level of wine quality and market potential. Collaborators will also be part of interviews and surveys to capture important observations obtained from the project. Stay tuned for more information as we continue through this long-term project!

Funding

This project was funded by the OWRI Pilot Project Fund, the Oregon Wine Board, and funds obtained by PI for teaching an online Extension course.

Further information

To learn more about the Statewide Crop Load Project and other crop load projects conducted by Dr. Patty Skinkis, see the following open-access online resources:
Impact of Cluster Thinning on 'Pinot Noir' Fruit Quality Across a Large-scale, Multi-site Study (abstract and video)
Defining Crop Load Metrics for Pinot Noir: Statewide Crop Load Project 3-Year Summary (video)

Impact of Yield Management Practices on vine Growth and Fruit Composition of Oregon Pinot noir (abstract)

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Impact of Elemental Sulfur and Nitrogen on the Formation of Volatile Sulfur Compounds in Wine

Dr. James Osborne, Extension Enologist, OSU
Dr. Michael Qian, Professor, OSU

The formation of volatile sulfur compounds (VSCs) in wine has been an issue since winemaking began. Although our knowledge of these compounds and their for-mation during winemaking has greatly increased over the last few decades, problems associated with VSCs persist. These compounds are particularly problematic because they are detectable in wine at very low concentrations and are difficult to remove.

The most common VSCs produced during winemaking is hydrogen sulfide (H_2S). This compound imparts a distinctive "rotten egg" character to the wine and is a product of either yeast sulfur metabolism during fermentation (Rankine 1963, Giudici and Kunkee 1994) or the reduction of elemental sulfur. H_2S production by yeast has been extensively studied and is impacted by yeast strain(Spiropoulos et al 2000; Kumar et al. 2010), nitrogen con-tent (Giudici and Kunkee 1994, Jiraneck et al. 1995), vita-mins (Edwards and Bohlscheid 2007), and fermentation conditions (Karagiannis and Lanaridis 1999). As our un-derstanding of factors influencing H_2S production by *S. cerevisiae* increases, we are developing strategies to mini-mize formation of H_2S such as addition of yeast nutrients, use of low H_2S producing yeast strains, and avoiding ex-treme fermentation temperatures. Despite this, H_2S problems still arise and the underlying causes are not completely understood.

In addition to the formation of H_2S during fermentation, volatile sulfur compounds are generated post-fermentation. These compounds include thiols, sulfides, and disulfides that have aromas often described as struck match, skunk, rotten cabbage, and onion/garlic-like. For-mation of VSCs post-fermentation pose a challenge for winemakers, and these compounds are less likely to be driven off by CO_2 (as often happens during fermentation) and many cannot be removed by copper fining. Their formation is difficult to predict as our understanding of what drives their production is limited and is not always linked to H_2S formation during alcoholic fermentation. Because of the potential detrimental effect these compounds can have on wine, our team undertook a multi-year study funded by the Oregon Wine Board to investigate factors influencing the formation of VSCs in wine post-fermentation.

After discussions with winemakers from around the state a number of similar observations were noted. First, winemakers reported that H_2S formation during fermentation was not a good predictor of which lots would have issues during barrel aging. In many cases winemakers noted that fermentations were very clean with no noticeable H_2S formation but that sulfur aromas were formed in the wines soon after going to barrel. The aromas appeared to originate in the wine lees as early removal of wine from lees often alleviated the issue. Furthermore, extended settling after pressing to lower the amount of lees going into barrel also seemed to help in some cases. Based on these observations a set of experiments was designed to determine the impact of lees content and concentration on VSC formation post-fermentation.

Pinot noir wines were produced using either a standard Pinot noir yeast (*S. cerevisiae* RC212) or a non-H_2S producing yeast strain (*S. cerevisiae* P1Y2). After fermentation the wines were pressed and settled for various lengths of time to create wines with different amounts of wine lees. These wines were then aged at 13°C for nine months and sampled monthly. Potential VSC precursor compounds cysteine, methionine, and glutathione, were measured as were an array of volatile sulfur compounds. Both lees levels and yeast strain impacted the concentration of the VSC precursor compounds. Treatments with higher lees levels contained higher concentrations of methionine and cysteine. In addition, wines fermented by the non-H_2S producing yeast strain (P1Y2) contained higher amounts of these compounds compared to wines produced by RC212 at each lees level. Glutathione was also higher in wines containing higher amounts of lees but was generally present in low amounts. However, while yeast strain and lees levels impacted the concentration of sulfur containing amino acids and glutathione, the increase in these compounds did not alter the formation of most volatile sulfur compounds significantly during nine months of aging.

The major differences observed were between wines produced by RC212 compared to P1Y2 where significantly higher amounts of methyl thioacetate (MeSOAc) and methionol (MeSH) were present in RC212 fermented wines. Methyl thioacetate is typically not present in wines in high enough concentration to cause off-aroma but it can be hydrolyzed to methionol, a volatile sulfur com-pound that has a very low sensory threshold in wine and smells like cooked cabbage and rotten eggs.

At the same time that these studies were being conducted at OSU, samples were also being collected from wineries in the Willamette Valley for VSC analysis. Wineries collected wine samples from lots that had begun to develop sulfur off-aromas soon after going to barrel. Analysis of these samples showed that the wines contained predominately H_2S rather than more complex sulfur compounds such as mercaptens and disulfides (Table 1).

Winery Code	H_2S	MeSH	CS2	DMS	DES	MeSOAc
117	27.03	2.62	0.04	2.49	ND	13.82
643	24.14	1.94	0.04	1.45	ND	12.30
463	23.24	2.49	0.27	2.49	ND	10.43
629	18.61	2.30	0.04	2.07	ND	8.85
439	26.83	1.90	0.04	2.34	ND	17.39
751	9.45	1.91	0.22	4.17	ND	8.84
108	57.43	3.26	0.28	3.94	ND	15.80
336	96.22	4.03	0.31	4.21	ND	20.29
117	8.55	3.49	0.19	3.58	ND	16.92

ND = non-detectable

Winery Code	DMDS	EtSOAc	DEDS	DMTS	Methionol
117	0.05	0.82	ND	0.04	7.66
643	0.04	0.55	ND	0.08	4.19
463	0.09	0.49	ND	0.14	4.53
629	0.04	0.58	ND	0.10	3.33
439	0.00	0.93	ND	0.06	4.05
751	0.03	0.43	ND	0.04	3.25
108	0.05	1.29	ND	0.11	3.55
336	0.18	1.17	ND	0.27	4.08
117	0.37	1.18	ND	1.14	1.65

ND = non-detectable

Table 1. Concentration of volatile sulfur compounds (ug/L) in Pinot noir wine barrel samples from commercial wineries in the Willamette Valley.

One exception was that in wines containing high concentrations of H_2S there was also a high amount of methyl thioacetate. These results suggested that the early formation of sulfur off-aromas in the wines soon after going to barrel was likely due to H_2S (rotten egg smelling) and/or methyl thioacetate. Based on these results, as well as the lees aging study the focus of the project shifted toward H_2S production during alcoholic fermentation with an em-phasis on late formation of H_2S that may lead to high H_2S in wines going to barrel.

Pinot noir fermentations were conducted where the impact of elemental sulfur (S°), nitrogen concentration, and composition on VSC formation was investigated. We explored the presence of S° during fermentations. It is known that this compound can impact H_2S formation (Acree et al., 1972). However, the concentration of S° required to cause H_2S issues is ill defined, while its impact on the formation of other VSCs is not well understood. We also investigated nitrogen content as there is increasing evidence that the type of nitrogen (amino acid N compared to N from ammonia) as well as the concentration of nitrogen can impact H_2S formation.

For example, Uglanio et al., (2009) reported that an addition of diammonium phosphate (DAP) to a final yeast available nitrogen (YAN) of 250 or 400 mg/L resulted in increased formation of H_2S compared to a non-supplemented fermentation with 100 mg/L YAN. While Uglanio used only DAP to boost YAN, our study also used amino acids. This allowed a comparison of the relative effects of YAN concentration and composition on VSC formation. A high H_2S producing yeast (*S. cerevisiae* UCD522) and a non-H_2S producing yeast strain (P1Y2) were used in fermentations. The results demonstrated that H_2S production was significantly higher in fermentations conducted by UCD522 compared to P1Y2. H_2S still formed in fermentations conducted by P1Y2 if S^0 was present. Increasing amounts of S^0 result-ed in increasing production of H_2S during fermentation and also resulted in higher H_2S production late in fermentation. This is particularly important as H_2S formation late in fermentation is more likely to be retained in the wine due to the reduced production of CO_2 by yeast. Higher S^0 also resulted in wines containing higher concentrations of methyl thioacetate post-fermentation. Both of these find-ings suggest an important role for elemental sulfur in the formation of VSCs during and after fermentation.

H_2S production during fermentation was also impacted by the type of nitrogen present. DAP additions resulted in an increase in H_2S formation while addition of amino acids to the same YAN concentration did not (Figure 1).

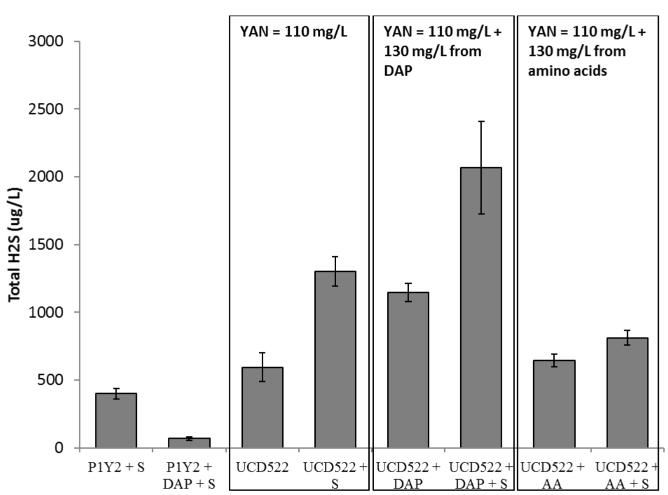

Figure 1. Total production of H_2S during fermentation of Pinot noir grapes by *S. cerevisiae* P1Y2 or UCD 522 with the addition of 10 ug/g elemental sulfur (S), diammonium phosphate (DAP) and amino acids (AA).

Fermentations where DAP and S^0 were added together produced the highest amount of total H_2S with 35-45% more H_2S being produced in these ferments than was produced in ferments where S^0 or DAP additions were made individually. Post-fermentation, YAN concentration and composition as well as S^0 impacted the concentration of VSCs other than H_2S. In particular, wines produced from fermentations containing S^0 and high YAN had very high concentrations of methyl thioacetate. The type of nitrogen added (ammonium vs. amino acid) impacted methyl thioacetate concentration less than the increase in YAN. The results demonstrate that the type and amount of nitrogen present during fermentation can impact the concentration of VSCs in wine, as can the presence of S^0. In particular, DAP additions led to increased H_2S formation during fermentation while high YAN (DAP and amino acid sourced) resulted in high methyl thioacetate concentrations in the wines post-fermentation.

Unfortunately, there is no silver bullet when it comes to preventing the formation of volatile sulfur compounds during winemaking. However, as we continue to research this problem we learn more about factors that impact VSC formation and how to conduct winemaking in a manner to minimize these compounds. Based on results from this study, the best strategy to prevent formation of VSCs in wine post-fermentation is to minimize the amount of residual elemental sulfur on grapes at harvest. Second, winemakers may use a low H_2S producing yeast, as H_2S produced during fermentation- especially late in fermentation, may result in sulfur off-aromas during barrel aging. Third, measure YANs and do not add high amounts of only DAP when supplementing (use a mixture of DAP and organic nitrogen supplements). While low YAN has often been associated with increased H_2S production, results from this study and others (Ugliano et al., 2009) have demonstrated that high YAN (especially if it is due to a large additions of DAP) may also cause increased formation of VSCs.

Finally, settle wines after pressing to reduce the amount of lees present when going to barrel. This will lower the amount of VSC pre-cursor compounds and will also result in a less reductive state in the bottom of your barrels.

Funding

This project was funded by the Oregon Wine Board.

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Exploring Brown Marmorated Stink Bug (BMSB) Contamination of Wine

Dr. Elizabeth Tomasino, Assistant Professor, OSU

Should you be concerned about BMSB and wine quality? Well, it depends. The brown marmorated stink bug (BMSB), is an invasive species that has significantly damaged agricultural crops and has been observed in some Oregon vineyards. When stressed, BMSB can release very "stinky" aromas and winemakers were concerned that when the bugs' aroma contaminated grapes, it may affect final wine quality. Research has been ongoing for the past four years at OSU to determine the impact of BMSB on wine quality and provide some strategies should this pest reach critical levels in vineyards.

BMSB was first detected in the United States in the mid-1990's in Allentown, PA. The US population is believed to have originated from China, most likely as a hitchhiker on shipping freight. Since its introduction into the US, BMSB has spread rapidly and is currently found in 43 states. Included among these are extremely important wine-producing states such as California, New York, Oregon and Washington.

In Oregon, the average number of BMSB captured per trap in vineyards increased from 34 BMSB in 2013 to 101 in 2015 (Walton et al., 2015). In addition, all BMSB life stages have been observed in vineyards, which indicates that grapes are a suitable crop for BMSB development. Adult BMSB may fly back and forth between vineyards and across field borders. Nymphs, however, are restricted to vines and therefore may cause much more feeding damage to the host plant as they disperse from egg masses (Walton et al. 2015). It has been estimated that the presence of 5 BMSB per grape cluster may lead to a 37% loss in grape yield as a result of BMSB damage.

Previous research shows that when disturbed, BMSB release a range of aroma compounds referred to as "BMSB taint." Analysis of stressed BMSB, adults and nymphs, shows more than 39 compounds in their aroma secretions (i.e., "BMSB taint") (Mohekar et al., 2015). The main compounds in the taint were found to be tridecane, dodecane, trans-2-decenal and trans-2-undecen-1-ol. After the outbreak of BMSB in Virginia in 2010, "stink bug taint" was reported in grape juice (Basnet 2014). The presence of the pest in grape clusters can also result in BMSB taint appearing in the finished wine (Tomasino 2013).

Research at OSU has focused on the effect of BMSB taint on contaminated grapes that entered the winery. Dr. Elizabeth Tomasino, in partnership with Dr. Nik Wiman, assistant professor, OSU Department of Horticulture, have been investigating this pest. Our research focused on Pinot noir and Pinot Gris and the impact of the taint compounds on several berry fruits. Major wine processing steps that can increase or decrease BMSB taint have been identified and several remedial treatments have been conducted in attempts to remove the taint.

Above: Grapes with stink bugs added prior to crushing and destemming. The amount of bugs is approximately 1bug/cluster.

Sensory work was conducted using the two aroma compounds that contribute the greatest to BMSB taint: trans-2-decenal and tridecane. Tridecane is an odorless aroma compound that may mask positive smells in wine, such as fruity aromas. Trans-2-decenal is an aroma compound described as green and musty. It is the main compound of the herb cilantro. As with tridecane, trans-2-decenal has the potential to mask positive wine quality aromas and both compounds should be minimized if possible. The first research task was to determine if BMSB impacted final wine quality. In 2012, Pinot noir wine was made containing different amounts of BMSB. The bugs were added during processing. Sensory testing indicated that wine drinkers could differentiate between wine with BMSB and wine without BMSB taint. Based on the results, a doctoral project was developed to understand the impact of BMSB on wine quality, specifically focusing on trans-2-decenal, the aroma compound that may significantly alter wine quality.

The detection (DT) and consumer rejection (CRT) thresholds of trans-2-decenal was determined in Pinot noir and Merlot wines. These two thresholds are used as controls to determine the concentrations of trans-2-decenal at which BMSB will be problematic. DT is the concentration at which a difference is noted in the wine. It is not until CRT that wine drinkers would consider the change in the wine to be negative enough to not consume it. DT for trans-2-decenal in red wine was found to be between 1.9-4.8 µg/L and CRT was between 4.8-12.0 µg/L. Wine containing trans-2-decenal above consumer rejection threshold was described as green, herbal, musty and less fruity by wine professionals. The CRT was used to determine control levels during wine processing, as it is desired to keep trans-2-decenal levels below CRT.

The effect of wine processing on BMSB taint in red and white wine was also investigated. While it is preferred to make wine free of BMSB and the resulting BMSB taint, this may prove to be difficult in the future due to the increasing prominence of BMSB in vineyards. If contaminated grapes are brought into the winery, it is possible to reduce/remove this taint through winemaking processes. We have determined that the critical step for BMSB taint in wines occurs after fermentation, specifically at pressing. It was found that trans-2-decenal and tridecane were reduced significantly during fermentation but taint introduced after fermentation (such as through pressing of red wine) resulted in an increase in the taint that lasted in wine. BMSB does not appear to be a problem for white or rose wines because pressing occurs prior to fermentation and BMSB insects are removed from the wine, with any taint reduced throughout fermentation.

BMSB taint does appear to impact red wine quality. As expected, the amount of pressure and time used in pressing will alter BMSB taint levels in wine. Use of free run or lighter pressing reduces the taint. There is also the possibility that malolactic fermentation may remove some of the taint compounds, although further research is required in this area. Additionally, to ensure that trans-2-decenal levels in final wine stay below the CRT, BMSB in the vineyard should be below 3 BMSB per cluster. Higher levels than this will result in significantly tainted wines. This density level should be followed with caution when wine is made with a heavier industrial press, higher pressure and longer press cycle, as taint levels may increase significantly.

Post fermentation treatments investigated to reduce BMSB taint in wine included fining, use of oak chips and reverse osmosis filtration. Fining using gelatin, egg albumin, potassium caseinate, bentonite and yeast lees were conducted on BMSB tainted wines. These treatments had no effect on reducing BMSB taint in wines. The use of oak chips did not reduce BMSB taint levels but when sensory tests were conducted, the oak chips were found to mask the aroma of BMSB taint. Reverse osmosis was able to reduce trans-2-decenal concentration in wine by 10%, which resulted in limited improvements in its sensory characteristics. Use of different filters and operating parameters may be able to reduce trans-2-decenal levels further.

This work has shown that it is still best to attempt to remove BMSB from the grape clusters prior to wine processing. If levels can be kept below 3 bugs per cluster in the vineyard then the impact to wine quality is minimal. However should this not be possible then wine processing steps can be altered to reduce taint levels.

For more information, or to request a copy of one of the four papers from the doctoral thesis from this project: "*Brown Marmorated Stink Bug taint in Pinot noir: Detection and consumer rejection thresholds of trans-2-decenal and effect to wine quality*", "*Investigating drivers of wine consumer segmentation for trans-2-decenal rejection threshold*", "*Effect of red and white wine processing on Brown*

Marmorated Stink Bug, Halyomorpha halys taint production" and "*Effect of fining agents, reverse osmosis and wine age on Brown Marmorated Stink Bug, Halyomorpha halys taint in wine*" please contact Dr. Tomasino at elizabeth.tomasino@oregonstate.edu.

Funding

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Tomasino, E., P. Mohekar, T. Lapis, N.G. Wiman, V. Walton, and J. Lim. 2013. Effect of Brown Marmorated Stink Bug on Wine - Impact to Pinot noir Quality and Thresh-old determination of taint compound trans-2-decenal. 15th Australian Wine Industry Technical Conference, Sydney, Australia.

Walton, V., N. Wiman, K. Daane, F. Zalom, M.L. Cooper, L.G. Varela, 2015. Brown Marmorated stink bug risk and impacts in western vineyards. California Department of Food and Agriculture, 2015 Research Progress Reports on Pierce's Disease and Other Pests and Diseases of Winegrapes.

Practical Guides & Resources

This section provides resources written by members of the Oregon Wine Research Institute and our partners. Many of these publications are developed and delivered through Extension and are available online, and others are from reputable trade magazines.

2016 Pest Management Guide for Wine Grapes (EM8413)

This publication is developed for use by the commercial winegrape industry in Oregon and intended for use as a decision making tool for the management of insect, disease and weed pests**.** It is updated annually by Extension experts at Oregon State University and other authors. Published by *Oregon State University Extension Publishing*. Authors: P. Skinkis, J. Pscheidt, A. Dreves, V. Walton, E. Peachey, and C. Kaiser. Revised in March 2016. Available online here: https://catalog.extension.oregonstate.edu/em8413

Are Your Weed-control Products Damaging Nearby Vineyards? (EM 9132)

This brief informational guide will help anyone living near a vineyard understand the damaging effects common herbicides can have on grapevines. The Oregon grape industry is growing rapidly near urban boundaries throughout the state. Herbicides used in home gardens, residential and urban landscapes can cause serious damage to local vineyards. Published in February 2016 by *Oregon State University Extension Publishing* Authors: M. Kennedy and P. Skinkis. Available online here: https://catalog.extension.oregonstate.edu/em9132

True Armyworm Pest Alert (8-29-2016)

The true armyworm is a pest found in grass fields and in nurseries where grasses were grown as cover crops between rows. Although there are no reports of true armyworms causing direct damage to grapevines, this alert contains information on how to detect and identify the pest. This document was published in August 2016 by *Oregon State University Extension Publishing.* Authors: A. Dreves, N. Anderson, and C. Sullivan. Available online here: http://oregonstate.edu/valleyfieldcrops/sites/default/files/true_armyworm_pest_alert_2016.pdf

Compendium of Grape Diseases, Disorders, and Pests. Second Edition

This book contains valuable information for growers and vineyard managers. Divided into four parts, this comprehensive guide provides information on grape diseases, disorders, and pests ranging from mites, and insects to abiotic factors. And, lastly, tips that help managers save money and minimize pesticide use. Editors: Wayne Wilcox, Walter Gubler, and Jerry Uyemoto. This book is available for purchase online through the American Phytopathological Society: http:// www.apsnet.org/apsstore/shopapspress/Pages/44792.aspx

Considerations and Resources for Vineyard Establishment in the Inland Pacific Northwest (PNW634)
This publication provides information on vineyard development for those new to the region. Published in 2012 to by *Pacific Northwest Extension Publication.* Authors: Moyer, M., C. Kaiser, J. Davenport, and P. Skinkis. Available online here. http://wine.wsu.edu/research-extension/files/2012/07/WA-Resources-for-Establishment-PNW634.pdf

Establishing a Vineyard in Oregon: A Quick-start Resource Guide (EM 8973)
This is a great resource for anyone considering establishing a vineyard in Oregon. It is also a useful resource for new and up-to-date information sources. Published in September 2014 by *Oregon State University Extension Publishing.* Author: P. Skinkis. Available online here: https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8973.pdf

Field Guide for Integrated Pest Management in Pacific Northwest Vineyards (PNW 644)
The guide provides practical information about pest and disease management throughout the Pacific Northwest. It is beautifully illustrated and includes information about specific pests, management techniques (chemical and cultural), and IPM principles. Published in June 2013 by Washington State University, Oregon State University, and University of Idaho through *Pacific Northwest Extension Publishing.* Edited by M.M. Moyer and S.D. O'Neal. Available for purchase online at http://cru.cahe.wsu.edu/CEPublications/PNW644/PNW644.pdf

Fungicide Efficacy Trial Results Available Online
Dr. Jay Pscheidt, OSU Extension Plant Pathologist, conducts research on the efficacy of fungicides for many crops throughout Oregon, including winegrapes. Results of his research are summarized and published annually in the *Pest Management Guide for Wine Grapes in Oregon*. This information is important to consider when designing a disease management program, and we suggest that you explore the full fungicide booklet online for further details about Jay's trials: http://www.science.oregonstate.edu/bpp/Plant_Clinic/Fungicidebooklet/index.htm

How to Measure Dormant Pruning Weight of Grapevines (EM 9069)
Pruning weights are the best way to monitor vine growth and vine size changes caused by vineyard management practices. It is easy to gather the data during routine, annual pruning. Published in June 2013 by *Oregon State University Extension Publishing*. Author: P. Skinkis. Available online here: https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9069.pdf

Leaf Removal's Influence on Pinot noir
This article summarizes a three-year research project conducted by OWRI faculty Patty Skinkis and Michael Qian evaluating the fruit composition at harvest as a result of varying levels of cluster zone leaf removal. Published in June of 2016 by *Practical Winery and Vineyard Journal*. Authors: H. Feng, F. Yuan, P. Skinkis, and M. Qian. Available online here: http://files.ctctcdn.com/27fc1a43201/85469b81-aef1-46a9-aa2a-b256e7f2a34b.pdf

Loss of Pinot Noir Color and Polymeric Pigment
An article assessing the loss of Pinot noir wine color and polymeric pigment due to malolactic fermentation (MLF) and the potential causes. Published in February 2016 by *Practical Winery and Vineyard Journal*. Author: J. Osborne. Available online here: http://www.winesandvines.com/

Mobile Access to Pesticides and Labels (MAPL)
(www.npic.orst.edu/mapl)**:** The National Pesticide Information Center at OSU developed this tool to access federal pesticide labels and information. MAPL retrieves data from two EPA databases and can be queried by product name, pest, site, and registration number. This tool functions on computers but is best displayed on mobile devices. If you want further information or have feedback on this tool, please contact the National Pesticide Information Center at OSU (npic@ace.orst.edu, 1.800.858.7378).

Noncrop Host Plants of Spotted Wing Drosophila in North America (EM 9113)
Noncrop habitats can meet requirements that favor Spotted Wing Drosophila (SWD) adults and can support developing larvae. As populations of SWD build in noncrop hosts, these areas can become "hot spots" from which SWD can move into fields as commercial fruits begin to ripen. In some regions, these plants may be more important in post-crop dynamics by providing opportunities for late season population buildup. Published in April 2015 by *Oregon State University Extension Publishing.* Authors: A. Dreves, J. Lee, L. Brewer, R. Isaacs, G. Loeb, H. Thistlewood. Available online here: https://catalog.extension.oregongonstate.edu/em9113

Preventing Herbicide Drift and Injury to Grapes (EM 8860)
This guide provides information on how to prevent herbicide drift. It covers identification of herbicides that are harmful to grape production and the symptoms of injury. It also provides information on how growers can protect vineyards from herbicide drift injury. Published in February 2014 by *Oregon State University Extension Publishing.* Authors: D. Ball, M. Corp, and I. Dami. Available online here: https://catalog.extension.oregonstate.edu/files/project/pdf/em8860.pdf

Pest Management Handbooks – 2016
These handbooks are developed for use by commercial producers Oregon, Washington, and Idaho. They provide information on insect pests, diseases, and weeds of many crops, including vineyards. All are available online through the Oregon State University Extension Service.

Pacific Northwest Plant Disease Management Handbook
This handbook is a ready reference guide for control and management tactics for more important plant diseases in the Pacific Northwest. The specific cultural, biological, and chemical recommendations are intended to manage a specific plant disease but may not always be appropriate under all production circumstances. The synthesis of a specific management recommendation should be done by a qualified individual. Revised June 2016. Edited by J. Pscheidt and C. Ocamb. Available online here: http://pnwhandbooks.org/plantdisease

Pacific Northwest Weed Management Handbook
This is the most comprehensive guide for weed management for the region. It is authored by Extension specialists from throughout the Pacific Northwest, and provides information on weed management strategies, herbicide lists, herbicide resistance, and more. Edited by E. Peachey. Revised in June 2016. Available online here: http://pnwhandbooks.org/weed/

Pacific Northwest Insect Management Handbook
This handbook involves provides a wealth of information for crops in the Pacific Northwest, as its co-authors are OSU and WSU Extension faculty with extensive expertise in entomology and horticulture across. It serves as a tool for making decisions regarding the control and management of important insect pests. For grape pest information, click here. Grape section authors include P. Skinkis, V. Walton, J. DeFrancesco, B. Edmunds, and N. Bell. Commercial chemical control recommendations are to be used only by licensed pesticide applicators. This handbook is published for free online through *Pacific Northwest Extension Publishing.* Edited by J. Hollingsworth. Available online here: http://pnwhandbooks.org/insect

Recognize the Symptoms and Causes of Stunted Growth in Vineyards (EM 8975) (*Publication and phone application)*
This Extension publication is also a free app that can be downloaded and viewed offline. Spring frost, herbicide drift, water or nutrient stress, diseases, insect and mite pests can cause similar symptoms of stunting or distorted growth in grapevines. Recognizing symptoms and distinguishing their causes is the first step in diagnosing problems and developing a management plan. With many color photos, this publication will help identify probable causes of distorted shoot and vine growth in vineyards and provide resources that can lead to solutions. Published in February 2016 by *Oregon State University Extension Publishing.* Authors: P. Skinkis, V. Walton, A. Dreves, C. Kaiser, S. Renquist, S. Castagnoli, R. Hilton and L. Bewer. Available online here: https://catalog.extension.oregonstate.edu/em8975

Scouting for Grape Powdery Mildew (EM 9067)
This publication provides vineyard owners with approaches for finding the first occurrence of grape pow-

dery mildew. The publication covers tactics to manage powdery mildew, including use of fungicides and canopy management. It also discusses effective scouting techniques based on the key characteristics of the fungus. Published in May 2013 by *Oregon State University Extension Publishing.* Author: J. Pscheidt. Available online here: https://catalog.extension.oregonstate.edu/files/project/pdf/em9067.pdf

Winter Cutworm: A New Pest Threat in Oregon (EM 9139)
Damage from winter cutworm is a growing concern. In 2015, large numbers of larvae were observed around homes, within golf courses, field crops located in Oregon and Washington and in some Willamette Valley vineyards. This publication highlights general information about winter cutworm, including identification, scouting recommendations, and potential control measures. Published in February 2016 by *Oregon State University Extension Publishing.* Authors: J. Green, A. Dreves, B. McDonald, E. Peachey. Available online here: https://catalog.extension. oregonstate.edu/em9139

Continuing Education/Educational Opportunities

Growing Farms: Successful Whole Farm Management
This is an online self-paced course for those interested in starting their own small farm business or are within the first five years of establishing a farm business. It also has components that are helpful to those who are interested in changing their farm business plan. Although content is not specific to vineyard establishment, it covers the basic information needed in establishing a vineyard business. To learn more about the program and to register, see the OSU Professional and Continuing Education (PACE) website: https://pace.oregonstate.edu/catalog/growing-farms-successful-whole-farm-management

Pesticide Applicator's Course Series
This is a series of six online courses that can be taken in sequence or a la carte. This is an excellent way to get training for yourself or your employees on important topics related to pesticide use and application. They are available at any time and qualify for Oregon Department of Agriculture (ODA) pesticide recertification credits. With new changes to the Worker Protection Standards (WPS), you may want to prepare yourself with some basic pesticide handling and safety information provided in these courses. To learn more about the courses offered, see the OSU Professional and Continuing Education (PACE) website: https://pace.oregonstate.edu/catalog/pesticide-applicator-course-series

Pest & Degree Day Models Seminar Series
Learn how to use the website, USPest.org, for obtaining pest, disease, and degree day model information that may be helpful in vineyard management. The series is presented by Dr. Len Coop of the Integrated Plant Protection Center at OSU. Each short seminar provides active examples of how to use different components of the website. While the three seminars do not specifically focus only on vineyards, you can find information on the website that is useful for vineyards, including location-based disease models for Botrytis and Grape Powdery Mildew (Gubler Thomas Model), and pest spe-cific models for Spotted Wing Drosophila (SWD), Brown Marmorated Stink Bug (BMSB), and European Grapevine Moth.

Using the My Pest Page:
https://media.oregonstate.edu/media/t/0_wq0bzkxx
Making Degree Day Maps:
https://media.oregonstate.edu/media/t/0_mw8l60oj
Accessing Pest & Degree Day Models:
https://media.oregonstate.edu/media/t/0_pzlvgso1

Learning the Basics of Viticulture and Enology
Are you or your employees in need of knowledge about grapevine growth, wine microbiology, or the basics of vineyard or winery production? If so, you may want to consider taking some online, self-directed course modules this winter. Washington State University has a number of courses in viticulture and enology that are available on topics ranging from vineyard design to insect management, wine production, sensory and more! To learn more about the various modules available, visit: https://ecommerce.cahnrs.wsu.edu/ViticultureAndEnology/shop/

Research Publications

Results of research conducted in viticulture and enology are published in peer-refereed academic journals, peer-reviewed reports, or books, which validates the scientific work of the authors. The following articles describe research conducted by members of the Oregon Wine Research Institute at Oregon State University.

Pest & Disease

Kunjeti, S.G., F.N. Martin, A. Anchieta, Y.J. Choi, M. Thines, R.W. Michelmore, S.T. Koike, C. Tsuchida, W. Mahaffee, K.V. Subbarao, and S.J. Klosterman. 2016. Detection and quantification of Bremia lactucae by spore trapping and quantitative PCR. *Phytopathology.* 106(11):1426-1437. https://www.ncbi.nlm.nih.gov/pubmed/27392175

Villari, C., W. F. Mahaffee, T.K. Mitchell, K.F. Pedley, M.L. Pieck, and F.P. Hand. 2016. Early detection of airborne inoculum of Magnaporthe oryzae in turfgrass fields using a quantitative LAMP assay. *Plant Disease.* 0 0:0, PDIS-06-16-0834-RE. http://apsjournals.apsnet.org/doi/10.1094/PDIS-06-16-0834-RE

Mahaffee, W.F. and R. Stoll. 2016. The Ebb and Flow of airborne pathogens: Monitoring and use in disease management decisions. *Phytopathology* 106:420-431. http://apsjournals.apsnet.org/doi/abs/10.1094/PHYTO-02-16-0060-RVW

Viticulture

Feng H., F. Yuan, P.A. Skinkis, and M.C. Qian. 2016. Influence of cluster zone leaf removal on Pinot noir grape chemical and volatile composition. *Food Chemistry* 173:414-423. http://www.sciencedirect.com/science/article/pii/S0308814614015374

Feng, H., P.A. Skinkis, and M.C. Qian. 2017. Pinot noir wine volatile and anthocyanin composition under different levels of vine fruit zone leaf removal. Food *Chemistry*. 214: 736-744. http://www.sciencedirect.com/science/article/pii/S0308814616311438

Howland, A., P.A. Skinkis, J.H. Wilson, E. Riga, J.N. Pinkerton, R.P. Schreiner, I.A. Zasada. 2015. Host status of own-rooted *Vitis vinifera* varieties to *Meloidogyne hapla*. *Journal of Nematology.* 47:141-147. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4492289/

Reeve, A., P.A. Skinkis, A. Vance, J. Lee, and J.M. Tarara. 2016. Vineyard floor management influences 'Pinot Noir' vine growth and productivity more than cluster thinning. *HortScience*. 51: 1-12. https://www.ars.usda.gov/research/publications/publication/?seqNo115=334914

Schreiner, R.P. and C.F. Scagel. Arbuscule Frequency in Grapevine Roots Is More Responsive to Reduction in Photosynthetic Capacity Than to Increased Levels of Shoot Phosphorus. *J. Amer. Soc. Hort. Sci.* 141(2):151–161. 2016. http://journal.ashspublications.org/content/141/2/151.abstract

Song, J., R. Smart, H. Wang, B. Dambergs, A. Sparrow, and M.C. Qian. 2016. Effect of grape bunch sunlight exposure and UV radiation on phenolics and volatile composition of *Vitis vinifera* L. cv. Pinot noir wine. *Food Chemistry*. 173:424-431. http://www.sciencedirect.com/science/article/pii/S0308814614015386

Uzes, D.M. and P.A. Skinkis. 2016. Factors influencing yield management of Pinot Noir vineyards in Oregon. *Journal of Extension*. 54:3. http://www.joe.org/joe/2016june/rb5.php

Vondras, A.M., S. Gouthu, J.A. Schmidt, A.R. Petersen, & L.G. Deluc. 2016. The Contribution of flowering time and seed content to uneven ripening initiation among fruits within Vitis vinifera L. cv. Pinot noir clusters. *Planta*. In Press. http://www.ncbi.nlm.nih.gov/pubmed/26874729

Enology

Chescheir, S., D. Philbin, and J.P. Osborne. 2016. Impact of *Oenococcus oeni* on wine hydroxycinnamic acids and volatile phenol production by *Brettanomyces bruxellensis*. *Am. J. Enol. Vitic*. 66: 357-362. doi: 10.5344/ajev.2016.14108. http://ajevonline.org/content/early/2016/04/24/ajev.2016.14108.abstract?sid=a103592c-67cd-4498-9b57-d2cab01c1ccd

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Song, M., Y. Xia and E. Tomasino. 2016. Investigation of a Quantitative Method for the Analysis of Chiral Monoterpenes in White Wine by HS-SPME-MDGC-MS of Different Wine Matrices. *Molecules.* 20(4):7359-7378. http://www.mdpi.com/1420-3049/20/4/7359

Strickland, M.T., L.M. Schopp, C.G. Edwards, and J.P. Osborne. 2016. Impact of *Pediococcus* spp. on Pinot noir wine quality and growth of *Brettanomyces*. *Am. J. Enol. Vitic.* 67: 188-198. doi: 10.5344/ajev.2015.15011. http://www.ajevonline.org/content/67/2/188

Thesis

Kraft, D.N. 2015. Impact of Lees Content, Nitrogen, and Elemental Sulfur on Volatile Sulfur Compound Formation in Vitis vinifera L. cv. 'Pinot noir' wine. Thesis. Oregon State University, Corvallis.

Navarrete, A. 2015. Characterizing Grapevine Canopy Architecture. Thesis, Oregon State University, Corvallis.

Sereni, A. 2016. Exploration into the Influence of Malolactic Fermentation Parameters and Prefermentation Juice Treatment on Chardonnay Mouthfeel. Thesis. Oregon State University, Corvallis.