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Welcome to the Fall 2018 Newsletter

This edition contains research updates and a comprehensive list of publications summarizing research conducted by faculty of the Oregon Wine Research Institute at Oregon State University. Dr. Elizabeth Tomasino, OSU Associate Professor, opens the newsletter with an article on the influence of two compounds on Pinot noir aroma. Drs. Laurent Deluc and Satyanarayana Gouthu, OSU Associate Professor and post-doctoral research associate, along with Mandie Driskill, OSU undergraduate student, provide valuable information on their research identifying Oregon Pinot noir clones confirmed through molecular methods. Dr. Vaughn Walton, OSU Professor, gives an update on the latest research studying how the spotted-wing drosophila contributes to the development of sour rot in wine grapes. Lastly, Beau Olen, OSU faculty research assistant, discusses the return on investment for wine grape insurance.

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Cheers,
The OWRI Team

Influences of β-ionone and β-damascenone on Pinot noir aroma

Dr. Elizabeth Tomasino, Associate Professor, OSU

Wine aroma is an important sensory and quality parameter as it directly links to consumer preference. The aroma of wine is caused by a complex combination of compounds that together, results in different aromas such as red fruit, floral, spice, or vegetal. While we have quite a bit of knowledge about negative or spoilage aromas associated with wine, we are still struggling to understand the causes of more desirable wine aromas. For Pinot noir wine, there is considerable interest in the influence of β-ionone and β-damascenone on aroma, as higher levels of these compounds may improve wine quality.

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These two compounds belong to the C13-norisoprenoid aroma class. By themselves, they have floral aromas with β-ionone described as smelling of violets and β-damascenone as smelling of roses. However, at concentrations found in wine, less than 10 µg/L, the influence of these compounds on wine aroma is varied. The concentration of these compounds in wine is impacted by their formation in grapes and by wine making processes. Both compounds are formed in the grape berry due to enzymatic and acid catalyzed hydrolysis of carotenoids (Figure 1) (Mendes-Pinto 2009). However, these compounds are bound to sugars in the berry and are nonaromatic. It is only during fermentation that they are released into their aromatic form (Swiegers et al. 2005).

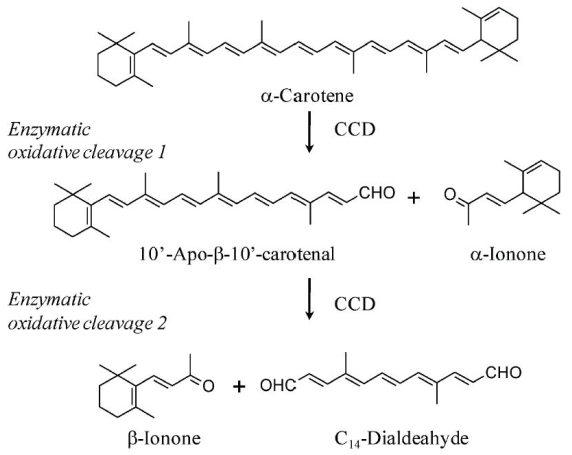

Figure 1. Oxidative enzymatic cleavage of α-carotene to yield α-ionone and β-ionone (Baldermann et al. 2010).

Our interest in studying the influence of these two compounds on Pinot noir aroma was driven by two unanswered questions. Firstly, are higher concentrations of these compounds beneficial to Pinot noir wine aroma? From conversations with specific wineries, it was clear that their goal was to boost these compounds as much as possible in their grapes and wines. But is more necessarily better when it comes to β-ionone and β-damascenone? As the concentration of aroma compounds in grapes and wines change, so will the aroma, but it is unknown if greater amounts of β-ionone and β-damascenone are beneficial or negative to Pinot noir aroma quality. The other question occurred from a sensory science standpoint. Much work has been done on the influence of different aroma compounds to aroma perception. However, this work was performed with one or two wines and then the results were applied to all wines. Was this correct or was the conclusion that was widely applied actually misleading?

We designed several sensory experiments to look into these questions. Our experimental design utilized three different Pinot noir wines (two from Oregon and one from New Zealand). We then altered the aroma composition of the wine so that different concentrations of both β-ionone and β-damascenone were achieved (Table 1). Concentrations were based on existing Pinot noir wines. We arbitrarily used a maximum that was three times greater than the current maximums in wine to determine if we really wanted more of these compounds in wine. Wine consumers were recruited to take part in a range of sensory tests.

Table 1. Concentrations (µg/L) of β-ionone and β-damascenone testing in triangle tests.

Level	β-ionone	β-damascenone
Low[1](L)	0.1	2
High[1](H)	1.5	7
Very High (3x)	6	21

[1]taken from Kotserdis et al. 1999: Fang and Qian, 2006: Song et al. 2014; Tomasino et al. 2015

Triangle tests are standard sensory tests that look at differences between samples. Each test contains three wines, two wines are the same and one is different. Participants were asked to smell each sample and choose the sample with a different aroma. With a three sample test there is a 33% chance that people will select the different wine simply based on chance. Therefore, a sample is considered significantly different if more than 33% of the participants choose the sample that is different. Other statistical methods such as signal detection theory or binomial distributions were also used to determine significant differences (Mohekar et al. 2016). After the triangle tests were completed, the Oregon Wine Research Institute Winemaker Panel evaluated the wines to provide descriptive information.

Results show that consumers can perceive β-ionone at all tested concentrations (data not shown). This is interesting as many studies, particularly those that use odor activity

values (OAVs), deem β-ionone unimportant to wine aroma because it is found at such low concentrations. However, the results of our study showed that it influenced aroma of Pinot noir even at its lowest concentrations. Although Pinot noir aroma has not been extensively studied, the ubiquitous impact β-ionone had on all three wines suggests that β-ionone directly impacts Pinot noir aroma perception and is not matrix dependent (matrix being the solution to which the compound is added). Results from the descriptive winemaker sensory panel showed that wines with the lowest concentration of β-ionone were characterized by red berry aromas. These findings are in agreement with previous studies where low concentrations of β-ionone impacted red berry aroma in red wines (Escudero et al. 2007; Kotseridis et al. 1999). Wines with high concentration of β-ionone were described as flowery, and wines with extreme amounts of β-ionone were described as rotting potpourri (Figure 2).

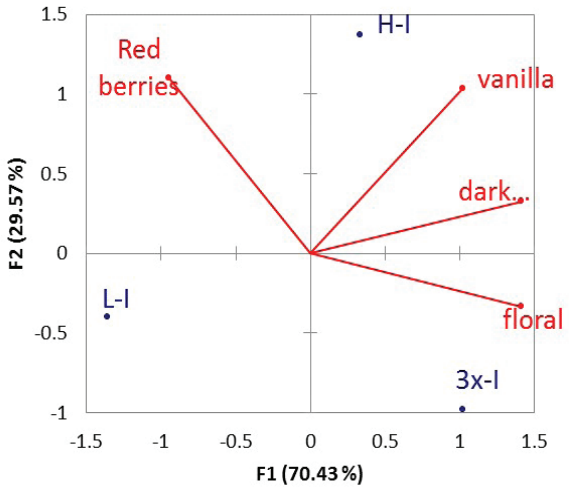

Figure 2. Principle Component Analysis (PCA) plot of sensory descriptors associated with Pinot noir wines with different concentrations of β-ionone. Concentrations levels found in Table 1.

Unlike β-ionone, β-damascenone perception was influenced by the wine matrix. As can be seen in Table 2, panelists could perceive β-damascenone at all tested concentrations for wine 1 but not for wines 2 and 3. For wine 2, β-damascenone was only perceived at very high levels (21 µg /L), and for wine 3, β-damascenone was perceived at high (6 µg/L) and very high (21 µg /L) concentrations. This would suggest that there are other components of the wine influencing the perception of β-damascenone. In a subsequent sensory test we determined that perception of β-damascenone is greatly influenced by the other aroma compounds present in the wine, and not by the nonvolatile compounds (e.g. tannins, acids, etc.). The results from the descriptive analysis were varied and did not clearly separate based on concentration (data not shown), which is due to the matrix interactions.

Table 2. Significance (α=0.05) of β-damascenone concentration on Pinot noir wine aroma from triangle tests calculated using signal detection theory (d-Prime).

Model Wine	β-Damascenone (µg/L)	d-Prime	*p*-value
1†	2	1.4	0.0006
	6	1.11	0.0099
	21	1.66	<0.0001
2‡	2	0.76	NS
	6	>0.33	NS
	21	1.4	0.0006
3§	2	0.72	NS
	6	1.68	<0.0001
	21	2.09	<0.0001

†OR wine #1. ‡ OR wine #2. § NZ wine

Our results suggest that higher concentrations of β-ionone and β-damascenone change red berry/fruity aromas of red wines to dried/musty/old fruit and old floral aromas. While we do not know the perfect concentration for these compounds to elicit a positive response, the very high (3x) concentration's effect is negative. Based on our results the optimal concentration of β-ionone and β-damascenone in Pinot noir wine for positive consumer perception is less than the very high concentration used in this study. This study suggests that the anecdotal belief that increased concentrations of β-ionone and β-damascenone improve the aroma quality of red wine is not necessarily true. While at low concentrations these compounds may result in red berry and fruity aromas, at higher concentrations undesirable aromas may occur. If more floral aromas are desired, then the mid concentrations we measured would be optimal.

It should be noted that all consumers that participated in the sensory test were screened for β-ionone sensitivity, as there is a well-established specific anosmia (the loss of the sense of smell) with β-ionone (Plotto et al. 2006). Consumers in the study had to be able to perceive

β-ionone at low and high concentrations, therefore very sensitive individuals were used. We then attempted to rerun the entire sensory panel with less sensitive individuals who could only perceive β-ionone at high concentrations. We could not find enough individuals who both consumed wine on average once a week and had a low sensitivity to run the panel. This raises interesting questions for research that looks into wine consumption and specifically who wine consumers are, versus consumption of other beverages.

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Identification of Oregon Pinot noir clones confirmed through molecular methods

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The clonal selection of Pinot noir (Pommard, Dijon 115, Dijon 777, Wädenswil, etc.) is important for grape growers and winemakers. The vine performance in a specific growing environment (meso- and macroclimate) and the resultant flavor profiles of wine might vary from one clone to another. So, the genetic nature of the clones and their growth under Oregon vineyard conditions contributes to the typicity of Oregon Pinot noir wines. I have heard growers and winemakers comment that Pommard is the "gold standard" for Pinot noir in Oregon. Others prefer the Wädenswil clone because it better fits their soils and performs better in their local growing conditions. Blending wine from different clones can also build complexity in wine. Some clones are used for "structure," others for aromatics. Therefore, the common practice of planting several clones across vineyard blocks allows the winemaker to be creative and to express the "terroir" of the vineyard.

The first question is, what is a clone? A grapevine clone

does not have the same meaning as in animal sciences. A clone in plant sciences is a vegetative propagule from a single parent that resulted from "natural mutations" and were selected for over many years resulting in a change in genetic makeup. These changes may or may not result in visual morphological differences (e.g. loose versus tight clusters or variability in berry size), or attribute differences in the wine such as specific aromatic profiles or sensory characteristics (Reynolds et al. 2004). Due to its large family and several closely related cultivars, the genetic relationships among Pinot noir clones is not well understood. In Oregon, several periods of imported Pinot noir materials took place (mainly from France). When Oregon winemakers began working with Pinot noir in the late 1960s and early 1970s, the main clones planted were Pommard and Wädenswil. Then, the Dijon clones (113, 114, 115) were brought to Oregon, tested at Oregon State University for suitability, and became very popular. The Willamette Valley is mainly planted with Pommard, Wädenswil, and the Dijon clones, but a wide diversity of other less-used Pinot noir clones still exists.

In most cases growers obtained their material from germplasm collections, nurseries, or other industry colleagues in the United States and Europe. As a result of the varied sourcing of plant material and incomplete record-keeping, clonal authentication is difficult.

Similar to forensic sciences, one way to identify a plant with certainty is to conduct a molecular test that generates a specific genetic fingerprint. The use of molecular-based tools benefits the industry by providing growers with indisputable proof of their vineyard clones while also providing some insightful information about the growing habits and wine profiles that strongly depend on local growing conditions (i.e. soil specificity, microclimate conditions, and viticulture practices).

There are different ways to realize a plant's genetic fingerprint. One of them is to detect a micro-satellite region, also known as Simple Sequence Repeats (SSRs). These micro-satellite regions are repeated sequences of 2-5 bases pairs of DNA within the genome that are highly variable from one genetic material to another. They are commonly used for fingerprinting studies when the objective is to differentiate individuals from a population (Figure 1). In grapevine, SSRs studies are accepted as one strategy for identifying cultivar and clonal differences because it is a highly reproducible method (This et al. 2004). A study in Europe identified a series of SSR markers able to discriminate several clones of Pinot noir by amplifying DNA regions within the genome that are highly variable between clones (Regner et al. 2006).

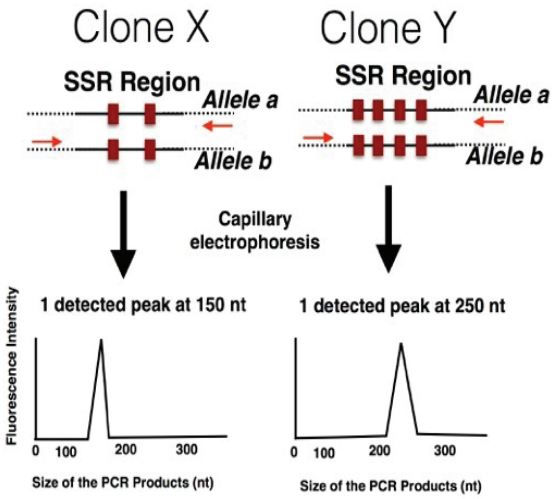

Figure 1. Simplified illustration of the methodology to identify variable -DNA regions of a SSR marker region from tissue samples of grapevine clones. In this particular case, the SSR marker region is homozygous. The two versions (alleles a and b) of the SSR marker that come from the two parents are the same within the clone but differ between clones due to a higher number of repeat sequences in clone Y generating a different genetic profile after the Polymerase Chain Reaction. nt: nucleotide, red arrow describes the primers used for the PCR-mediated amplification of the SSR markers. The primers are located in a conserved region of the genome and flank a highly variable region (SSR).

We conducted the same experiment to examine the potential of these SSR markers to validate the genetic origin of the Pinot noir clones commonly used in Oregon and to determine if these markers could be used to unveil the genetic origin of some "obscure" clones used in Oregon for which the genetic origin is unclear. We used a series of 19 markers identified by Regner et al. (2006).

The plant material tested was split into three main categories. In **group I**, we tested genetic materials that were certified for their identity by the UC Davis germplasm collection. **Group II** consisted of materials from Oregon for which the clonal identity has been properly tracked down since their importation into Oregon. **Group III** included genetic materials whose

lineage needed to be assessed. Procedures including the collection of samples, the extraction of genomic DNA, and the amplification of highly variable regions was carried out according to Regner et al. (2006). The unique or different products amplified from each SSR region were detected using an AB 3730 capillary DNA sequencer available at the Center for Genome Research and Biocomputing at Oregon State University. The data were analyzed using GeneMapper® software available at Oregon State.

Pinot noir clones (Wädenswil, Pommard, Dijon clones 114, 115, 667, 777, and others) were selected as reference material (Table 1). *Unfortunately, requests to obtain reference material for clones 828, 943, 47, 10-5, 10-18, 4407, AS-2, and Pinot "droit vines" were not granted either due to the lack of accession in the germplasm or because they were designated as proprietary material.* Samples of fresh leaves from 101 grapevines corresponding to 27 different clones were collected from thirteen vineyards in Oregon (11 in the Willamette Valley and two from southern Oregon).

Table 1. Clones tested for the genotyping assay. Test clones shown in gray are those that either the reference material was not available or there were proprietary rights that prohibited their use as in this study.

Pinot noir test clone name	Corresponding reference clone	UCD FPS selection #
114	FPS 46	1987-0-5048-46
115	FPS 89 and 73	1987-0-6957-89; 1988-0-6879 -73
777	FPS 71	1992-0-6877-71
667	FPS 72	992-0-6878-72
459	FPS 38	0000-0-4759-38
Swan	FPS 97	1996-0-7137-97
Pommard	FPS 91	0000-0-6955-91
60	FPS 19	0000-0-351-19
Coury	FPS 136	2013-14-10045-136
2A	FPS 02A	1952-0-332-02A
95	FPS 117	0000-0-7135-117
calera	FPS 90	1996-0-6931-90
Wädenswil	01A	0000-0-330-01A
828		
10-5		
10-18		
47		
Pinot Droit		
943		
4407		
2A		
QM1-Sel		

By excluding repeat sampling of the same clone across several blocks of a vineyard, 83 unique samples were tested. Optimization of procedures for genomic DNA extraction and quality controls and optimization of condition for Polymerase Chain Reaction (PCR) amplification of the SSR were conducted before running the genotyping assay.

During the preliminary studies, we started with the 19 markers (labeled VRG) from Regner's study but found that 14 markers were not suitable for detecting any clonal variation among the Oregon Pinot noir clones. In other words, the use of these 14 SSRs generated the same genetic fingerprint regardless of the reference and test clones. Though, five markers (VRG4, 5, 9, 10, and 16) were selected because they could distinguish either test clones between each other or they could be used to compare tested clones against their corresponding reference clones. The clonal authentication of most tested clones could be confirmed using these five markers when the reference clone was available (Figure 2).

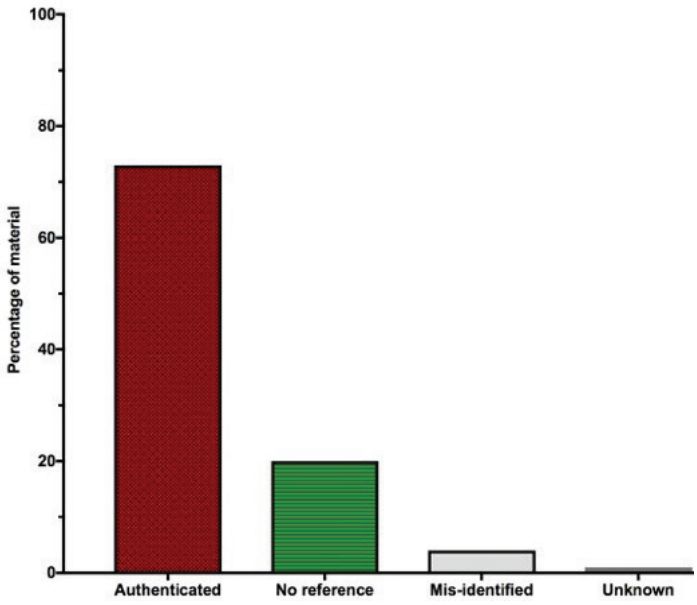

Figure 2. Percentage of tested clones across four identification categories: Authenticated: the clonal designation provided by the grower was validated, No reference: The tested clones could not be compared to their reference clones, Misidentified: The tested clones were mislabeled but we could trace back its ineage, Unknown: The clone was mislabeled and we could not trace back its lineage.

We only observed four discrepancies from the pool of test clones. Three out of four were showing a genetic profile for the VRG10 marker similar to Dijon 115 (clone 73). Unfortunately, we could not identify the lineage for one test clone among the available reference clones.

An interesting result was found in the Dijon 115 study. Among the leaf samples to be tested, ten were designated as "Dijon 115". The profiles of the VRG 10 marker is characterized by the amplification of three DNA products

that are 104, 114, and 116 base pairs in length. Half of the clones tested showed this pattern. The other half did not have the 104-long product. The UC Davis clone used as reference clone for Dijon 115 was clone 89 from Dijon via the Oregon State University catalog and registered by the mid-1980s. In the late 1980s, Domaine Mumm donated four other Pinot noir clones. One of them was Foundation Plant Services (FPS) clone 73 reported to be a French Dijon 115, but the UC Davis germplasm registered it only in the year 2000. We ordered the clone FPS 73 and generated its genetic profile using the VRG10 marker again. We could only observe two PCR products (diallelic profile) from the reference clone 73 that were 114 and 116 base pair long. In other words, the VRG marker 10 was able to discriminate between the two reference clones (89 and 73), both supposed to be Dijon clone 115, revealing that there are two sub-populations of Dijon 115 in Oregon.

The VRG 5 and 10 markers also revealed discrepancies for two test clones that were mislabeled Dijon 667 and Coury in two separate vineyards, respectively. Using the VRG 10 marker, we could infer that these two clones were more likely to be clone 89 instead of Dijon 115.

To conclude, this genetic study demonstrates greater certainty in the designation of clones in Oregon. For the major reference clones available (Dijon 114, 115, Pommard, Wädenswil, Dijon 777, 667), the genetic screen of leaf samples has confirmed a proper clonal designation in most vineyards (93% were properly labeled). Unfortunately, we did not have access to some interesting reference clones (clone 828, Dijon 47, Dijon 943) from FPS to complete our identification and authentication of these clones planted in Oregon.

Interestingly, the marker VRG10 was able to distinguish between two imported genetic materials (FPS 89 and 73), both labeled as Dijon 115. These two clones were imported to US at two different periods (mid-80s and 2002) from two French sources. I was told that they may perform differently in the vineyard as they appear to be separate clones, but this needs further investigation.

We also experienced a minor uncertainty in clonal identification. Mislabeled clones in the vineyard were observed. Should the grape grower(s) be worried by such discrepancy in our research findings? No, the sampling for our study was done on individual plants and the findings could reflect one outlier within the entire block that some misplants or replants over the years. Besides, ruling out the clonal authentication of tested material from only one SSR marker is “risky,” as those tests might be sources of cross-contamination leading to misinterpreted results.

What are the next steps for grape growers and winemakers? Today researchers can sequence a full grapevine genome for less than $10,000, a fraction of the cost of the same work 10 years ago, making the technology more accessible and affordable. Clonal genome-wide analyses of specific grape cultivars has been achieved (Gambino et al. 2017). With the emergence of ways to handle big-data generation, the science community is engaged in the era of more open data information. One can expect to see the development of large sequencing research programs that may soon enable scientists to uncover such questions as the "secret of the Pinot noir clones" and the impact on wine profiles.

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Spotted-wing Drosophila contributes to the development of sour rot in wine grape

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Spotted-wing drosophila (SWD), *Drosophila suzukii*, is a known crop pest for various fruits worldwide. Certain susceptible fruit (e.g. blueberries, raspberries, and cherries) can be damaged during ripening by the serrated ovipositor of female SWD. The SWD prefers small fruits over grapes. Laboratory studies and field observations of SWD oviposition (egg laying) report that very few eggs are laid on intact grape berries compared to small fruits and cherries (Bellamy et al. 2013; Ioriatti et al. 2015). Moreover, significant differences in susceptibility to oviposition are reported among different grape varieties and physiological conditions (Ioriatti et al. 2015). Based on research to date, there is currently no clear understanding of the commercial impact of SWD in wine grapes (*Vitis vinifera* L.) in Oregon.

Sour rot is a common pre-harvest disease that affects humid grape growing regions, and has just recently been characterized through research (Hall et al. 2018). Often drosophilids (fruit or vinegar flies) are associated with sour rot in vineyards, and research has been underway in various US labs to determine a potential link to SWD amongst other drosophilids. In order to investigate the association of SWD with grape sour rot development in the vineyard, we studied oviposition behavior during grape ripening. As berries develop, they change in size, composition, color, texture, flavor, and susceptibility to pathogens and pests. Grape susceptibility to SWD oviposition increases during the ripening period. Berry firmness is a critical component in host selection and more oviposition occurs when firmness reduces, but increases in oviposition have also been found with rising sugar content and a decrease in acidity (Ioriatti et al. 2015). The goal of this study was to determine if the presence of SWD on wine grapes plays a role in sour rot development.

Results

Our studies showed that spoilage microorganisms can be vectored in sound grapevine berries. The data suggest that this vectoring can result from direct insect contact and not necessarily by wounding berry skins by SWD egg laying (oviposition) (Figure 1).

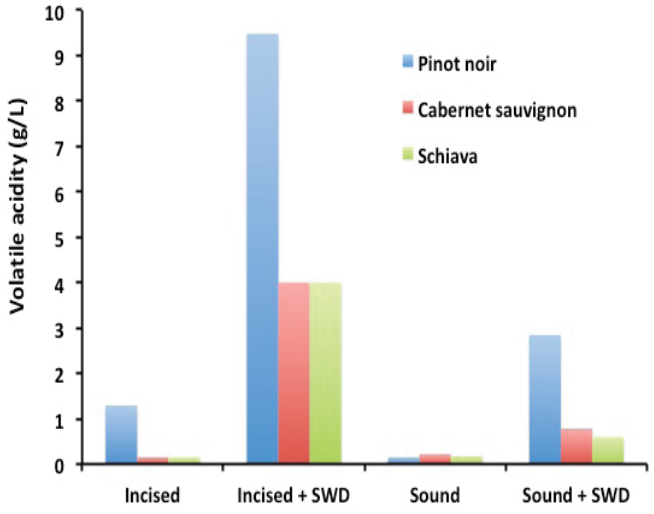

Figure 1. Content of acetic acid in grapes at the end of laboratory tests using Drosophila suzukii (SWD) as a vector of spoilage organisms on three grape varieties. Incised berries were surface-sterilized before being incised with a sterilized scalpel. Sources of contamination include the microorganisms as highlighted. Data are expressed as value of volatile acidity (g/L) of the whole mass of grapes used in each treatment (Adapted from Ioriatti et al. 2018).

The controlled conditions in our trials suggest that the elevated yeast loads of sterilized intact berries were due to SWD transferring the yeast to berries (Table 1). Physical berry damage triggers the release of several compounds including sugars from inside berries. These sugars in turn stimulate an increase of the yeast growth (Barata et al. 2012b). Our study showed that bacterial loads in damaged berries reached elevated levels, which confirms that berry injury is the primary cause of sour rot development. Therefore, it is clear that damaged berries are a source of microbial contamination in wines, which can easily be vectored by SWD as the insects move from berry to berry during feeding and oviposition.

Table 1. Comparisons of microbial load of sound and incised (damaged) berries after 7 days of exposure to non-ovipositing Drosophila suzukii flying from different sources of contamination. Sound berries were surface-sterilized and free of any damage. Incised berries were surface-sterilized before being incised with a sterilized scalpel. Sources of contamination include the microorganisms as highlighted. Comparisons are made within columns (Adapted from Ioriatti et al 2018).

Berry status	Source of contamination	Acetic acid bacteria level	Lactic acid bacteria	*Saccharomyces* yeast	non-*Saccharomyces* yeast
sound	none	↓	↓	→	→
sound	incised	→	→	→	→
sound	incised + AAB	→	→	↓	→
incised	none	↑	↑	↑	↑
incised	incised + AAB	↑	↑	↑	↑

When we tested grape varieties in order to determine if variety affected contamination, SWD laid eggs in higher numbers on visually damaged berries compared to intact berries. Our data suggest that for both incised and sound berries, the concentration of acetic acid bacteria increased significantly compared to the treatments where the flies were excluded. The availability of fermentable substrates, typical of damaged berries, stimulated acetic acid bacteria proliferation due to two phenomena: 1) the direct utilization of sugars, especially by the bacteria belonging to the genus *Gluconobacter*, and 2) the oxidation of ethanol previously produced by the fermentation of yeast on account of *Acetobacter* bacteria (Gullo et al. 2009).

An increase in acetic acid was consistent across three winegrape varieties tested (Pinot noir, Schiava and Cabernet sauvignon) when exposed to SWD oviposition (Table 2). The acetic acid content rapidly increased when the damaged berries were exposed to SWD. These data are especially relevant when considering that the accumulation of acetic acid was observed prior to wine production. We conclude that the presence of SWD causes a significant alteration of microbial presence of grape berries, potentially making them unsuitable for the production of wine.

Table 2. Oviposition and microbial contamination of three wine grape varieties after contact with Drosophila suzukii. Incised berries were surface-sterilized before being incised with a sterilized scalpel. Sources of contamination include the microorganisms as highlighted. Data are presented as mean ± SD. Different letters indicate significant differences among treatments after two-way ANOVA followed by Tukey's HSD post hoc test ($p<0.05$) (Adapted from Ioriatti et al. 2018).

Wine grape variety	Year	Oviposition (number of eggs)		Acetic acid bacteria (cfu/g)	
		Incised	Sound	Incised	Sound
Cabernet sauvignon	2015	14.3 ± 2.4^{d}	3.7 ± 1.7^{bc}	$7.9\pm1.6E+06^{b}$	$0.6\pm0.2E+06^{a}$
Pinot noir	2015	5.5 ± 3.3^{c}	1.2 ± 1.4^{ab}	$3.4\pm0.6E+08^{c}$	$9.0\pm1.9E+06^{b}$
Schiava	2014	3.3 ± 2.2^{abc}	0.8 ± 0.9^{a}	$1.5\pm0.4E+06^{b}$	$1.4\pm0.3E+07^{b}$
average±SD		7.7±5.5	1.9±1.9.	1.2±0.5E+07	7.9±1.9E+06

In one of our studies, bagged grape clusters were infested with SWD at 10 and 20 days before harvest. The results show that SWD preferred to lay eggs in berries with higher sugar and lower relative density level and lower malic acid levels (Ioriatti et al. 2015). Malic acid varies greatly as berries develop and mature, with maximum accumulation just before véraison. Malic acid begins to break down at the onset of ripening due to the induction of malate oxidation, suggesting that malic acid is transformed to fructose and glucose (Conde et al. 2007). During berry ripening, the berry cuticle contains micro fissures (Barata et al. 2012a) through which sugar can reach the berry surface, increasing the susceptibility to SWD.

A wide range of microorganisms may negatively affect grape quality during late season, particularly when berries are damaged. Among them, sour rot bacteria cause issues close to harvest, affecting late-ripening varieties with tightly packed, thin-skinned, and dense bunches. Sour rot may cause significant crop losses and negatively affect

wine quality (Barata et al. 2012c). However, the presence of SWD eggs in the grape berries does not necessarily affect quality if not followed by larval development. Results from our work demonstrate that SWD can vector spoilage bacteria through contact and feeding on both damaged and undamaged berries. We demonstrated, under controlled laboratory settings and field conditions, that inoculative infestation with SWD and subsequent larval development within grape berries can lead to increased volatile acidity. Volatile acidity is an indicator of increased sour rot levels.

In conclusion, a number of factors affecting skin integrity (rainfall, wind, temperature, diseases, insect pests, viticultural practices, etc.) can influence grape microbiota that are primarily responsible for development of grape sour rot (Barata et al. 2012a). Sound grape berries are less susceptible to the development of microbiota associated with sour rot and spoilage. The production of spoilage bacteria may attract both SWD and other drosophilids (e.g. vinegar flies) (Mazzetto et al. 2016), which, by feeding on the infested grape berries, contribute to further spread of the disease.

These findings indicate that growers should be aware of the risk of spoilage during seasons when risk factors are high. Growers should identify hot spots within vineyard where the crop quality is negatively affected and strongly consider removing these fruit in a timely manner in order to minimize spoilage.

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Return on investment in wine grape insurance in the U.S. west coast

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Few Oregon vineyards purchase crop insurance. This is somewhat confounding because there are many risks to growing wine grapes in Oregon, including variations in input markets, diseases, pests, natural disasters, weather, and trade wars (Countryman and Muhammed 2018). The crop insurance price—premium—is highly subsidized by the federal government (see glossary for crop insurance terms). Furthermore, wine grape insurance is widely available through multiple peril crop insurance and the Whole Farm Revenue Protection Program (Olen and Wu 2017). Oregon had 30,435 acres of wine grapes in 2016, but only 28 percent of this acreage was insured, compared to 82 percent in California and 74 percent in Washington. Crop insurance increases the minimum yield or revenue received—i.e., increases the revenue floor—and simultaneously reduces its variability—i.e., reduces risk—which helps protect vineyard cash flow. Sufficient cash flow is necessary to pay the costs of current vineyard operations and to prevent vineyard failure. However, discussions with growers suggests that few keep records of their cash flow and they often base their decision to purchase crop insurance on whether "it pays".

Indeed, growers with higher expected indemnity payments from insurance are more likely to insure (Knight and Coble 1997). Other major findings from the literature are a) larger farms are more likely to participate in insurance, b) diversified farms—crop and livestock— are less likely to participate and c) higher yield variability or income risk increases participation even if the cost of insurance accurately reflects higher expected indemnities. Lee and Sumner (2013) evaluated the return on investment (ROI) in buy-up coverage for California almonds, wine grapes, rice, and cotton for 2002-2011. They found that the ROI is 0.01 for almonds, 0.19 for wine grapes, 1.22 for rice, and 3.33 for cotton. In other words, the average returns for cotton insurance were 330 percent higher than the farmers' cost of insurance, while the returns for wine grape insurance were only 19 percent higher than the farmers' cost. The authors conclude, "We would expect a high participation rate by almond and grape growers if net benefits from crop insurance participation for these crops were as high as they are for cotton."

Applying Lee and Sumner's ROI measure to west coast wine grapes

To assess whether it pays to purchase crop insurance for west coast wine grapes, we followed Lee and Sumner's (2013) approach for evaluating the expected ROI in insurance, and apply it to wine grapes in California, Oregon, and Washington for 1995-2017. However, while Lee and Sumner (2013) evaluated the ROI for crops in California, we evaluated the ROI at the state- and county-level to assess whether there is intrastate variation in the ROI. The expected ROI is evaluated as the net returns of insurance—indemnity minus the grower cost of insurance—all divided by the grower cost of insurance:

$$ROI = (Indemnity - Premium + Premium\ Subsidy) / (Premium - Premium\ Subsidy) \quad (1)$$

There are three possible outcomes to this ROI:

1. ROI>0 is a positive return on investment. The net return is positive.
2. ROI = 0 is a zero return on investment. The net return is zero.
3. ROI < 0 is a negative return on investment. The net return is negative.

A positive expected return on investment in insurance is an incentive to purchase insurance, while a negative expected return on investment is a disincentive to purchase insurance. ROI = 0 is the breakeven case where the costs and returns of insurance are equal and there is neither an incentive nor disincentive to purchase insurance. Nonetheless, even if the long-term ROI is not positive, crop insurance may be worthwhile in the short term because it reduces variation in farm cash flow and helps prevent farm failure.

The data analysis is for 1995-2017 to control for structural and quantitative changes to the federal crop insurance program (Olen and Wu 2017). The Federal Crop Insurance Reform Act of 1994 introduced CAT (catastrophic level of coverage) and significantly increased premium subsidies. Both of these changes would affect the ROI as calculated by equation (1). Since there is no premium for

CAT, we evaluate the ROI separately for CAT and buy-up coverage. It is important to control for these changes because Oregon growers did not purchase insurance before the Federal Crop Insurance Reform Act of 1994. Data from 1995 onward represents a period in which growers in all three states purchased insurance under the same structural and quantitative characteristics of the federal crop insurance program. The data for this analysis is the USDA Risk Management Agency's Summary of Business Reports and Data. This includes information on the number of policies sold, indemnified acres, liability, premium, subsidy and indemnity for each year, state, county, insurance plan—e.g., APH—and coverage category—CAT or buy-up. The data is aggregated by county and year, resulting in 897 county-year observations for the west coast for 1980-2017. There are 713 observations for the 1995-2017 period. These data are aggregated by state and county to evaluate the ROI in wine grape insurance.

Does it pay to purchase crop insurance?

The ROI in wine grape insurance is positive for both CAT and buy-up coverage in all three states (Table 1).

Table 1. The ROI in wine grape insurance is positive for both CAT and buy-up coverage in all three states, 1995-2017. Note: percentages are rounded to the nearest percent.

	ROI		Premium Subsidy Rate	
	CAT	Buy-up	CAT	Buy-up
California	4,773.53	0.34	100%	56%
Oregon	12.89	0.15	100%	57%
Washington	603.46	0.12	100%	55%

The ROI for CAT in California, Oregon, and Washington are 4,774, 13, and 603, respectively. This indicates that on average the returns in CAT are many times higher than the costs. On the other hand, the ROI for buy-up coverage in California, Oregon and Washington are 0.34, 0.15, and 0.12, respectively. This indicates that on average the returns for buy-up coverage are 12-34 percent higher than the costs. One reason why the ROI is significantly higher for CAT than for buy-up is that nearly 100 percent of the CAT premium is subsidized (Table 1). Subsidies increase the value of the numerator in equation (1) and decrease the value of the denominator, both of which lead to a higher ROI.

Most counties in California and Washington have positive ROI in buy-up coverage for wine grapes, but most counties in Oregon have negative ROI (Figure 1). With the exception of Umatilla County, which has an ROI greater than 1, all counties in Oregon that purchased wine grape insurance have a negative ROI. On the other hand, 4 out of 7 counties in Washington that purchased insurance have a positive ROI. In California, 19 out of 26 counties that purchased insurance have a positive ROI. Thus, Umatilla county is the only Oregon county where historically "it pays" to purchase crop insurance from the grower perspective.

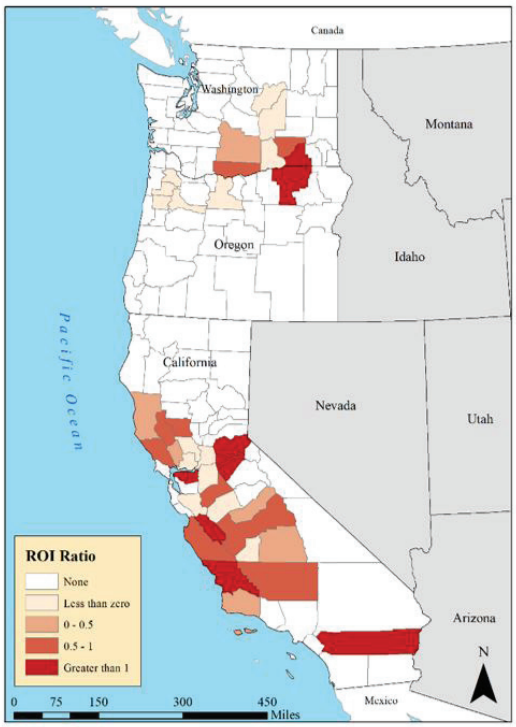

Figure 1. Most counties in Oregon have negative ROI in buy-up coverage for wine grapes, 1995-2017. Note: Map producted by Michael Weinerman, Department of Applied Economics, Oregon State University.

Policy tidbits to protect vineyard cash flow

Umatilla county is the only Oregon county where historically "it pays" to purchase crop insurance from the grower perspective. Wine grape insurance participation rates are relatively low in Oregon because, from the grower perspective, there are few places where it pays to purchase buy-up coverage. However, growers should note

that even if the long-term ROI were not positive, crop insurance can be worthwhile in the short term because it increases the minimum yield or revenue received—i.e., increases the revenue floor—which can protect vineyard cash flow and help prevent farm failure in response to disasters.

CAT coverage would protect grower cash flow from catastrophic yield losses of greater than 50 percent. Although yield losses of 50 percent are relatively rare for Oregon wine grapes, CAT coverage is essentially free—costing a $300 administrative fee to insure each crop in each county. CAT fee waivers are available for beginning, limited resource, and socially disadvantaged farmers. This basic coverage can prevent some vineyard failures for a negligible cost to growers.

From the Risk Management Agency's perspective, the loss ratio—indemnity divided by premium—is a more important measure to track than the ROI (Gans 2018). There would be solvency issues for insurance programs that consistently have a loss ratio higher than 1.0. However, the loss ratio and the ROI would be positively correlated, which indicates that increasing program solvency would decrease the ROI for growers. This discrepancy highlights the ongoing dual challenge for the Risk Management Agency: simultaneously increase the size of the insurance pool and maintain program solvency.

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Glossary

Risk: Exposure to uncertainty.

Liability: An insurer's financial debt or obligations to the insured; the value of the insured asset.

Coverage level: The percentage of the insured value covered by insurance.

Premium: The amount payable by the insured to the insurer for the period—or term—of insurance granted by the policy; the price of insurance.

Premium subsidy: The amount of the crop insurance price—the premium—that is paid by the federal government on farmers' behalf.

Indemnity: The amount payable by the insurer to the insured in the event of an insured loss.

Loss ratio: Indemnity divided by premium, with a value of one representing a program that breaks even and higher values representing less efficient programs.

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Research publications

Results of research conducted in viticulture, enology, and economics 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.

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