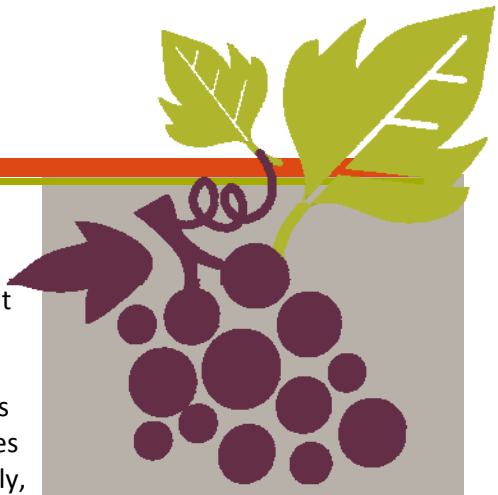
Oregon Wine Research Institute
Viticulture & Enology
Technical Newsletter

Summer 2015



Welcome to the Summer 2015 Newsletter

Our current issue of the OWRI Technical Newsletter is packed with Extension information, research results, and program updates. Paul Schreiner, Research Plant Pathologist, USDA-ARS, opens the newsletter with an article on his latest research assessing vine nutrient requirements in Pinot noir. Laurent Deluc, Associate Professor, OSU, reports on his research studying how seed content in grape berries influence ripening. Walt Mahaffee, Research Plant Pathologist, USDA-ARS, discusses the processes by which he develops models to assist with disease forecasting. Lastly, Elizabeth Tomasino, Assistant Professor, OSU gives an update on her latest sensory research and the OWRI winemaker panel.

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

What are the Nitrogen, Phosphorus and Potassium Requirements for Pinot noir?

R. Paul Schreiner, Research Plant Physiologist, USDA-ARS

Pinot noir producers in western Oregon want to achieve vine balance through management of vine nutrient supply, as high soil water content in the early summer leads to excess vigor. The primary tools growers use to manage vine access to nutrients are vineyard floor management and fertilization, but the impact of these practices is site-specific. Research trials to evaluate vine nutrition often lead to inconsistent results due to variability in hillside vineyards. To remove some variability and better understand how nutrient supply directly affects vine physiology and fruit quality, we designed an experiment using a pot-in-pot system for grapevines examining vine responses to nitrogen (N), phosphorus (P) and potassium (K) supply. In this system, the root environment is confined and vine access to nutrients is carefully controlled.

In the first trial (NPK 1), we tested own-rooted Pinot noir vines from 2006-2008. In the second trial (NPK 2), we tested grafted Pinot noir vines on 101-14 rootstock from 2012-1014. In both experiments, vines were established and grown for three years with complete nutrition (ample quantities of all nutrients supplied) prior to applying different nutrient levels beginning when vines were 4 years-old. In each experiment, N, P, and K supply were independently varied, while holding the rates of all other nutrients constant. Irrigation inputs were adjusted in all treatments to maintain similar soil and vine water status between the different nutrient regimes. Since canopy differences were observed between treatments, we applied different levels of leaf removal in the cluster zone in different treatments to obtain similar levels of berry shading. In both experiments, we reduced vine N, P, or K status in leaf blades or petioles at bloom and at véraison, to provide clear comparisons of how each of these nutrients affect Pinot noir.

Results from the NPK 1 trial (using own-rooted Pinot noir) demonstrated that N is the key driver of vine growth, yield, and berry metabolite profiles. Low N supply reduced dormant season cane weights within the first year of applying treatments, while yield was not reduced by low N supply until the third year (Table 1).

IN THIS ISSUE

Editorial Team

Danielle Gabriel
Communications & Outreach Manager
Oregon Wine Research Institute
Danielle.gabriel@oregonstate.edu

Mark Chien
Program Coordinator
Oregon Wine Research Institute
Mark.chien@oregonstate.edu

Dr. James Osborne
Enology Extension Specialist, OSU
Dept. Food Science and Technology
James.osborne@oregonstate.edu

Dr. Paul Schreiner
Plant Physiologist, USDA-ARS
Paul.Schreiner@ars.usda.gov

Oregon State University

Table 1. Effects of N Supply on Vine N Status and Growth of Pinot noir. **Bold green color** differs from Control (7.50 mM N) based on Tukeys HSD at 95% confidence.

NPK 1 - Own-rooted Pommard				NPK 2 - Pommard on 101-14 Mgt			
Treat-ment (mM N)	Véraison Leaf N (%)	Prune wt (g/vine)	Yield (ton/ acre)	Treat-ment (mM N)	Véraison Leaf N (%)	Prune wt (g/vine)	Yield (ton/ acre)
YEAR 1							
7.50	1.82 a	375 a	No data	7.500	2.06 a	367 a	2.54 a
3.75	1.66 ab	350 ab		5.625	1.96 a	323 ab	2.29 ab
1.50	**1.53 bc**	**267 b**		3.750	1.89 a	255 abc	2.21 ab
0.75	**1.47 c**	**272 b**		2.250	**1.65 b**	**231 bc**	2.16 ab
				1.125	**1.42 c**	**177 c**	**1.78 b**
YEAR 2							
7.50	1.85 a	378 a	2.20	7.500	2.21 a	379 a	2.73 a
3.75	**1.53 bc**	348 abc	2.33	5.625	2.13 a	**298 b**	2.54 a
1.50	**1.38 cd**	**269 c**	2.01	3.750	**1.87 b**	**213 c**	2.40 ab
0.75	**1.28 d**	**281 bc**	2.07	2.250	**1.72 bc**	**149 cd**	**2.05 b**
				1.125	**1.47 c**	**101 d**	**16.3 c**
YEAR 3							
7.50	2.05 a	409 a	2.29 a	7.500	2.39 a	460 a	3.48 a
3.75	**1.67 b**	**295 b**	**1.36 b**	5.625	2.19 a	**332 b**	3.53 a
1.50	**1.47 bc**	**243 b**	**0.73 b**	3.750	**1.92 b**	**214 c**	3.03 a
0.75	**1.32 c**	**251 b**	**0.85 b**	2.250	**1.70 bc**	**117 d**	**2.24 b**
				1.125	**1.55 c**	**84 d**	**1.66 b**

Yield loss in year three was largely due to smaller berries, because berry number per cluster did not change. Low P and low K supply did not affect growth or yield in any year in the NPK 1 trial (Tables 2, 3). Low N reduced must YAN (yeast assimilable nitrogen) levels in years two and three by as much as 70%. Some amino acids were altered more than others, changing the must amino acid profile available to yeast during fermentation. Arginine, which contributes the most amino-N to Pinot noir berries was affected the most by reducing vine N status. The concentrations of sugars, anthocyanins, and flavonol-glycosides were enhanced in berries from low N vines in year three, but this increase was attributed to the smaller berries that occurred in low N vines.

Table 2. Effects of P Supply on Vine P Status and Growth of Pinot noir. **Bold red color** differs from Control (0.50 mM P) based on Tukeys HSD at 95% confidence.

NPK 1- Own-rooted Pommard				NPK 2 -Pommard on 101-14 Mgt			
Treat-ment (mM P)	Véraison Leaf P (%)	Prune wt (g/vine)	Yield (ton/ acre)	Treat-ment (mM P)	Véraison Leaf P (%)	Prune wt (g/vine)	Yield (ton/ acre)
YEAR 1							
0.50	0.141	375	No data	0.50	0.154 a	367	2.54
0.25	0.127	328		0.25	0.142 ab	365	2.45
1.10	0.115	338		1.10	0.135 ab	375	2.47
0.05	0.112	333		0.00	**0.133 b**	317	2.56
YEAR 2							
0.50	0.140 a	378	2.20	0.50	0.175 a	379	2.73
0.25	0.119 ab	375	2.28	0.25	**0.137 b**	383	2.54
1.10	0.110 ab	378	2.20	1.10	**0.111 b**	391	2.49
0.05	**0.106 b**	360	2.15	0.00	**0.099 b**	332	2.62
YEAR 3							
0.50	0.179 a	409	2.29	0.50	0.165 a	460 a	3.48 a
0.25	**0.099 b**	350	1.91	0.25	**0.128 b**	398 ab	3.61 a
1.10	**0.085 bc**	354	1.58	1.10	**0.109 b**	406 ab	3.15 ab
0.05	**0.080 c**	396	1.61	0.00	**0.088 b**	**334 b**	**2.68 b**

However, condensed tannins and total phenolic acids increased in both years two and three under low N supply, independent of changes in berry size. Higher tannin levels in Syrah and Cabernet Sauvignon wines received higher wine grades based on price category (Mercurio et al. 2010, Smith et al. 2008). We suspect that higher tannin levels in Pinot noir berries would also equate to higher quality. More detailed analysis and discussion of the NPK 1 trial are reported in Schreiner et al. (2013 & 2014). The NPK 1 findings show that reducing N supply can increase some phenolic constituents (tannins and phenolic acids) in berries before altering yield, while anthocyanins and other phenolics cannot be enhanced until yield is reduced to an uneconomical level. Wines were not produced from the NPK 1 trial with own-rooted Pinot noir.

Results from the NPK 2 trial with grafted Pinot noir also showed that N supply influences vine performance more quickly than either P or K supply. Low N supply reduced

growth and yield within the first year in grafted vines and effects grew more severe in years two and three (Table 1). Low P and low K supply only altered growth after three years (Tables 2, 3).

Table 3. Effects of K Supply on Vine K status and growth of Pinot noir. **Bold purple color** differs from Control (3.50 or 4.50 mM K) based on Tukeys HSD at 95% confidence.

NPK 1 - Own-rooted Pommard				NPK 2 - Pommard on 101-14 Mgt			
Treat-ment (mM K)	Véraison Leaf K (%)	Prune wt (g/vine)	Yield (ton/ acre)	Treat-ment (mM K)	Véraison Leaf K (%)	Prune wt (g/vine)	Yield (ton/ acre)
YEAR 1							
3.50	0.78	375	No Data	4.50	1.09 a	367	2.54
1.75	0.78	381		2.25	1.09 a	378	2.36
0.70	0.80	351		0.90	1.02 ab	357	2.29
0.35	0.69	379		0.00	**0.85 b**	313	2.10
YEAR 2							
3.50	0.87	378	2.20	4.50	1.04 a	379	2.73
1.75	0.79	382	2.54	2.25	**0.92 b**	378	2.55
0.70	0.73	361	2.47	0.90	**0.64 c**	369	2.64
0.35	0.73	386	2.06	0.00	**0.45 d**	353	2.47
YEAR 3							
3.50	0.87	409	2.29	4.50	1.01 a	460 a	3.48
1.75	0.78	378	2.26	2.25	**0.82 b**	403 a	3.51
0.70	0.75	353	1.92	0.90	**0.51 c**	372 ab	3.65
0.35	0.72	371	1.74	0.00	**0.38 c**	**304 b**	3.42

However, vines grown with low P began to show visual leaf symptoms (red coloration) just after fruit harvest in year two. Vines grown under low K supply showed leaf symptoms (marginal and interveinal chlorosis/necrosis) and developed late bunch stem necrosis (Holzapfel and Coombe 1998) on ~20% of clusters in year three. Ripening was also reduced by low K in year three, while must pH was reduced by low K in years two and three. Much to my surprise, flower production was not altered with the reduction of any nutrients, although fruit set was reduced by low N and low P supply, but only in year three. As expected, low N supply greatly reduced must YAN levels in all years, and fermentation rates declined when NOPA-YAN was below ~100 mg N/L. Low P supply reduced must P levels below 33 mg P/L without impacting the rate of fermentation. This is the first time that must P levels this low have been reported and indicates that yeast P requirements are indeed quite low. This is good news for western Oregon vineyards that are known to have very low soil P levels. Low K supply reduced must K levels to ~600 mg K/L without altering fermentation rate.

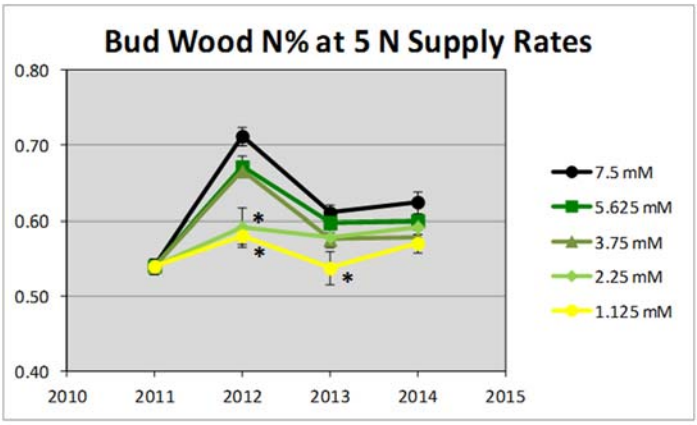
Wine aroma analysis from the NPK 2 trial showed that N supply has a profound impact on aroma volatiles with the greatest effect on yeast-derived esters and higher alcohols. N supply consistently raised or lowered the concentrations of seven esters and seven alcohols in wine across all years. In general, low N supply decreased straight chain esters and alcohols, but increased the branch-chained esters and alcohols in wine. The effect of N supply on monoterpenes in wine was not consistent from year to year. However, reducing N supply resulted in lower quantities of β-damascenone (a norisoprenoid) across all years. These changes in aroma metabolites alter the aroma perception of the wines. Sensory evaluation of wine aroma from year one (2012) wines of varying N status using a trained panel showed clear differences.

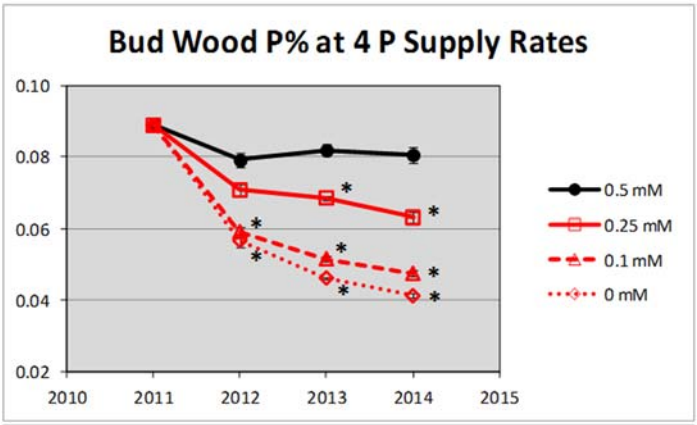
Early sensory results indicate that wines from lower N supply show an increase in floral and dark fruit characters while wines from the high N supply have more herbaceous and spicy characters. Further sensory work is underway to confirm these trends. The aroma results combined with the yield data suggests that wine bouquet is altered by reducing vine N status prior to having a negative impact on yield, similar to our findings with tannins in berries from the NPK 1 trial. Low P supply did not have reproducible effects on wine aroma volatiles from year to year, while reducing K supply resulted in lower quantities of six aroma volatiles in two of the three years, most notably lower β-damascenone and β-ionone.

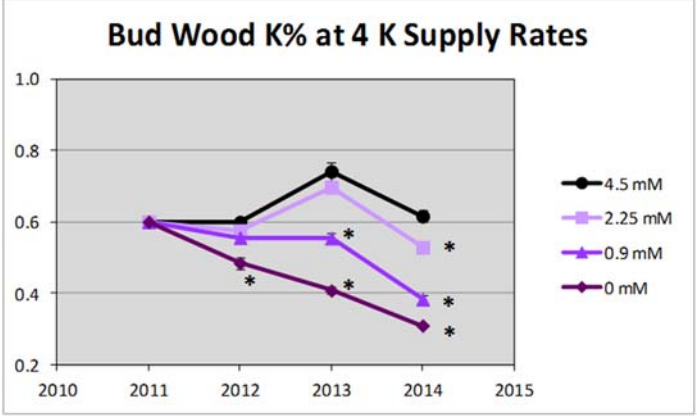
In both trials, leaf blade N at véraison was a good predictor of must YAN levels even though yield varied across years. Petiole N values were also correlated to must YAN levels, but leaf blade N values were superior. We tested a new protocol for diagnosing N, P, and K status from the NPK 2 experiment by examining nutrients in dormant season (winter) bud wood samples. Results from that work indicate that bud wood samples can provide a good diagnosis tool for vine P and K status in Pinot noir, but

dormant wood samples do not appear to be useful for diagnosing N status (Figure 1).

Figure 1. Impact of N, P, or K supply on dormant season bud wood nutrient concentrations in Pinot noir NPK 2 Experiment. * indicates significant difference from full nutrition control (black symbols & line).







Results from both NPK experiments provide a more complete characterization of how nutrient status influences vine productivity and fruit composition of Pinot noir. We are using this information to refine N, P, and K leaf blade and petiole standards, and to provide practical monitoring guidelines for early indicators of inadequate levels of N, P, or K in vines. There is no doubt that N supply has the greatest impact on vine vigor, and berry and wine composition. Therefore, monitoring vine N status and managing N supply in the vineyard probably has the greatest overall impact on production and quality of Pinot noir. Further work to more thoroughly understand how nutrient supply (N in particular) influences berry and wine metabolites is underway. Low nutrient status thresholds for P and K that result in either growth reductions, leaf or fruit deficiency symptoms, or reduced sugar accumulation and low berry pH will be further investigated in 2015 to develop more robust tissue standards.

Literature Cited

Holzapfel, B.P. and B.G. Coombe. 1998. Interaction of perfused chemicals as inducers and reducers of bunchstem necrosis in grapevine bunches and the effects on bunchstem concentrations of ammonium ion and abscisic acid. *Aust. J. Grape Wine Res*. 4:59-66.

Mercurio, M.D., R.G. Dambergs, D. Cozzolino, M.J. Herderich, and P.A. Smith. 2010. Relationship between red wine grades and phe-nolics. 1. Tannin and total phenolics concentration. *J. Agric. Food Chem.* 58:12313-12319.

Schreiner, R.P., J. Lee and P.A. Skinkis. 2013. N, P, and K supply to Pinot noir grapevines: Impact on vine nutrient status, growth, physiology, and yield. *Am. J. Enol. Vitic.* 64:26-38.

Schreiner, R.P., C.F. Scagel and J. Lee. 2014. N, P, and K supply to Pinot noir grapevines: Impact on berry phenolics and free amino acids. *Am. J. Enol. Vitic.* 65:43-49.

Smith, P.A., M.D. Mercurio, R.G. Dambergs, I.L. Francis, and M.J. Herderich. 2008. Grape and wine tannin–Are there relationships between tannin concentration and variety, quality, and consumer preference? *In* Proceedings of the Thirteenth Australian Wine Industry Technical Conference. R. Blair et al. (eds.), pp. 189-192. Adelaide, Australia.

Influence of Berry Seed Content on Uneven Cluster Ripening

Dr. Laurent Deluc, AssociateProfessor, Oregon State University

Dr. Satyanarayana Gouthu, Faculty Research Associate, Oregon State University

It has long been understood that grape berry seeds contribute both to berry growth and the tannin profile of red wine in winemaking. During the first phase of grape berry development, growth and development of berry and seed occur together—the rate of berry cell division correlates with the rate of seed growth. Further, the number and size of seeds influence berry growth during the initial growth phase. The second growth phase of berry development is characterized by cessation of seed growth and the beginning of embryo growth, which also coincides with the ripening onset or véraison. However, it is not clear whether the seed plays an important role during the ripening phase of the berry.

Several phytohormones (auxin, cytokinin, gibberellins) control berry development and promote growth. The grape seed is assumed to play a role in supplying some of these hormones to the surrounding tissues. For example, in pea and strawberriy plants, the removal of seeds leads to cessation of fruit growth, but fruit growth is restored with the application of either auxin or gibberellin. Interestingly, removal of the seeds at the end of the growth phase actually accelerates ripening of strawberry fruits, which indicates a role of seed in the timing of ripening initiation.

From the uneven appearance of a grape cluster at véraison, it is clear that all berries do not transition to the ripening phase simultaneously. Some berries are still green with high acid levels and no sugar accumulation or softening, while others are red and have sugar levels of up to 12 °Brix. This uneven ripening within a cluster has generally been attributed to the flowering time differences and environmental variables. Yet, in our lab we observed that the berries originating from early or late flowers within clusters had an equal chance of being either green or red at mid-véraison. Green berries at mid-véraison had significantly more seed weight than pink or red berries. Also, seed tissue has significantly higher concentrations of auxin compared to the surrounding pulp and skin. It is known that auxin promotes initial fruit growth but inhibits ripening and its level declines in the berry before the commencement of ripening. These observations led us to hypothesize that auxin may be transported from the seed to the pericarp, and that differences in auxin levels between berries are related to their seed weight. This could result in differences in timing of ripening initiation between berries.

To examine the relationship between seed weight and ripening initiation, we divided the berries in a mid-véraison cluster into two groups based on their seed to berry weight ratio (SB), defined as berries with a low seed content or berries with high a seed content relative to their weight. We observed that 90% of the berries with a low seed to berry weight ratio were either pink or red and 80% of the berries with a high seed to berry weight ratio were still green (Figure 1). Our findings indicate that seed weight relative to berry weight influences the timing of ripening transition.

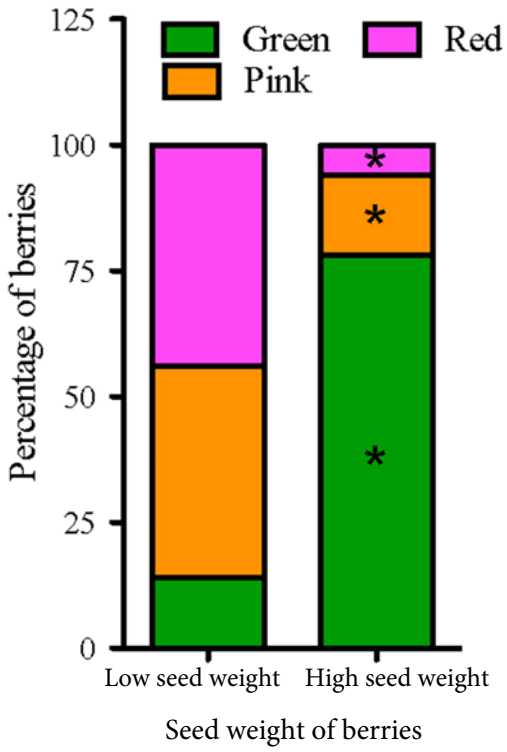
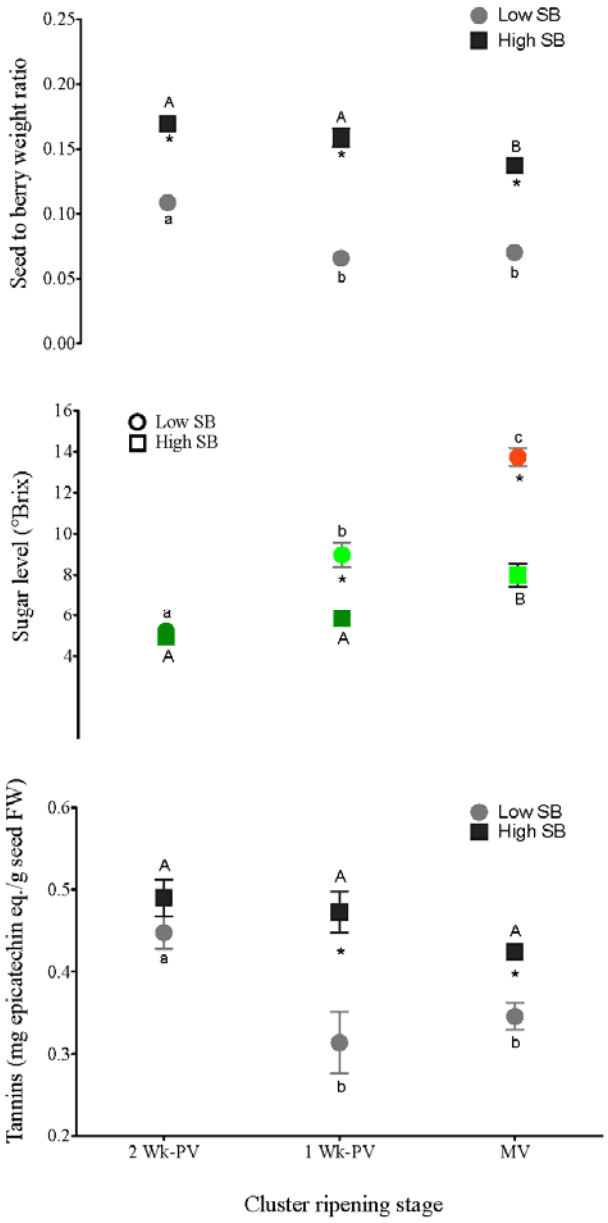


Figure 1. Percent of single-seeded green, pink and red berries in low and high seed weight groups within a grape cluster. Berries within 0.025-0.087 and 0.088-0.167 ranges were considered as low and high seed weight groups, respectively. Berries of four clusters from two plants were used for the analysis. Approximate test for equal proportions was used to identify differences in the distribution of ripening classes between the groups and significant differences were marked with asterisks ($p < 0.05$).

Figure 2. Differences between low and high SB berry groups in (A) seed weight-to-berry weight ratio (SB), (B) sugar level, and (C) seed tannin level at two- and one-week pre-véraison, and at mid-véraison (MV) cluster stages. Error bars are ±SEM (n = 5). In panel B, the ripening phenotype of the berries of low and high SB groups were indicated as dark green (green hard immature phase), light green (green soft phase with sugar increase), and red (red colored advanced ripening phase). Significant differences between low and high SB at each cluster stage are indicated by asterisks (Student's t-test, $p < 0.05$). Significant differences (Tukey's HSD, $p < 0.05$) of each SB group between the ripening stages are denoted by different letters (lower and upper case letters are used for low and high SB berries, respectively).



Next we examined emerging ripening characteristics between berries with low seed weight and berries with high seed weight in pre-véraison stages. Two weeks before mid-véraison, seed content in the group with a higher seed to berry weight ratio was 2-fold compared to the group with a lower seed to berry weight ratio.

Other than differences in seed content, the berries from the two groups were similar with respect to color and sugar level. Extractable tannin levels in the seeds were not significantly different between the groups, indicating that seeds of both groups were at a similar maturation stage. One week before mid-véraison and at mid-véraison, the differences in the seed to berry weight ratio between the two groups increased 3-fold and 8-fold, respectively (Figure 2).

At one week before mid-véraison, berries with a lower seed to berry weight ratio were less green, softer, and had higher sugar levels. By mid-véraison, these berries showed further sugar accumulation and red-ripe phenotype (Figure 2). In contrast, the shift from green to pink and the beginning of sugar accumulation in berries with a higher seed to berry weight ratio was observed at mid-véraison. From these obeservations, we concluded that the emergence of ripening-related changes in the berries of a cluster is dependent on the relative seed weight.

In addition, we observed differences in auxin levels between the pericarp tissues (pulp and skin) of low and high SB ratio berries during the pre-ripening stages and at ripening onset. Auxin level in the pericarp of berries with a lower seed weight declined earlier (by one week before mid-véraison) whereas berries with a higher ratio of seeds maintained a higher auxin level until mid-véraison (Figure 3A).

Interestingly, gene activity associated with local synthesis of auxin in the pericarp of both berry groups was not significantly different. This suggests that the observed auxin level difference between the two groups might be due to a transport of auxin from the seed. So, higher seed weight per berry would result in higher and lasting auxin presence in the surrounding fruit tissues. Further, the level of abscisic acid, which is a hormone that promotes ripening and plays a role in sugar and pigment accumulation, increased earlier in

the pericarp of low SB berries (Figure 3B). Together, our experiments indicate that the difference in the dynamics of auxin decline in pericarp of low and high seed weight berries resulted in differences in the dynamics of abscisic acid accumulation.

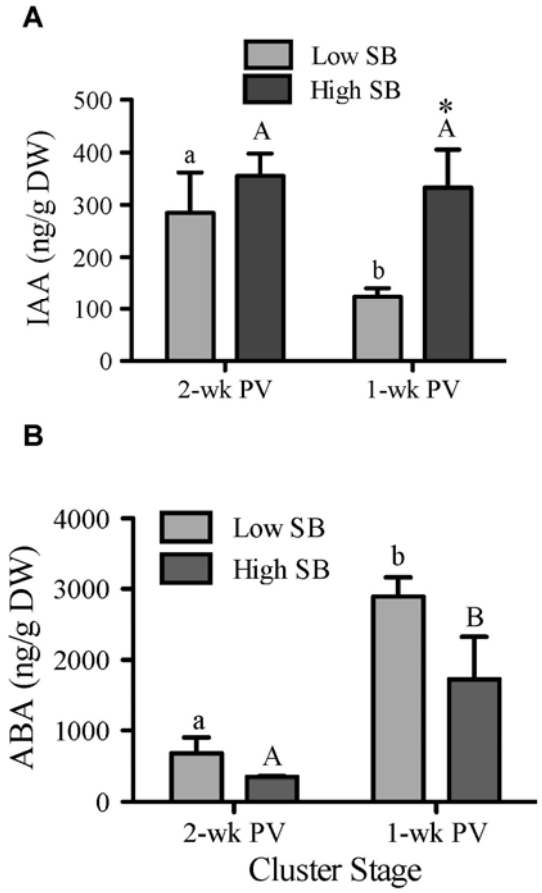


Figure 3. Levels of indole-3-acetic acid (IAA) (A) and abscisic acid (ABA) (B) in the pericarp of low and high seed weight-to-berry weight (SB) berries. Pre-véraison cluster stages were two- and one-week before véraison (2-wk PV and 1-wk PV). IAA and ABA levels were quantified by LC-MS/MS using four replicates (Gouthu et al., 2012). Significant differences between low and high SB at each cluster stage are indicated by asterisks (Student's t-test, $p < 0.05$). Significant differences (Student's t-test, $p < 0.05$) of each SB group between the ripening stages are denoted by different letters (lower and upper case letters are used for low and high SB berries, respectively).

From the perspective of the seed, the transport of auxin to pericarp promotes fruit growth and also inhibits premature ripening of fruit to ensure sufficient time for seed maturation. Once seed matures, the transport of auxin would stop, which allows the fruit to ripen. From these experiments we show that differences in the ripening between the berries of the asynchronous cluster originate from the differences in seed content that, in turn, results in different auxin dynamics.

There is an increasing interest in manipulating the timing of ripening because it will impact the harvest date and the crop quality composition, allowing growers more adaptability to adjust to varying growing conditions. Understanding the molecular mechanism of ripening differences in a grape cluster is a significant step towards achieving that goal. While controlling the berry seed is an alluring yet difficult task, with our current knowledge, seed to berry weight ratio may be manipulated. For instance, berry growth rapidly responds to many viticulture practices (regulated deficit irrigation, cluster thinning, hormone sprays) that are used to manipulate source-sink ratio. On the other hand, the seed growth development is more or less unaltered even during water deficit condition, thereby offering several means of altering seed content relative to berry in the cluster.

References

Coombe, B.G, and M.G. McCarthy. 2000. Dynamics of grape berry growth and physiology of ripening. *Australian J. Grape Wine Res.* 6:131-135.

Friend, A.P., M.C.T. Trought, and G. Creasy. 2009. The influence of seed weight on the development and growth of berries and live green ovaries in Vitis vinifera L. cvs. Pinot Noir and Cabernet Sauvignon. *Australian J. Grape Wine Res.* 15:166-174.

Gouthu S., J. Morré, C.S. Maier, and L.G. Deluc. 2012. An analytical method to quantify three plant hormone families in grape berry using liquid chromatography and multiple reaction monitoring mass spectrometry. *In Recent Advances in Phytochemistry.* D. Gang (ed.), 42 pp 19-35. Springer Publication , NY USA.

Gouthu, S., and L.G. Deluc. 2015. Timing of ripening initiation in grape berries and its relationship to seed content and pericarp auxin levels. *BMC Plant Biol*. 15:46

McAtee, P., S. Karim, R. Schaffer, and K. David. 2013. A dynamic interplay between phytohormones is required for fruit development, maturation, and ripening. *Front. Plant Sci.* 4:1-7.

Nitsch, J.P. 1950. Growth and morphogenesis of the strawberry as related to auxin. *Am. J. Bot*. 37:211-215.

Ozga, JA, R. Van Huizen, and D.M. Reinecke. 2002. Hormone and seed-specific regulation of pea fruit growth. *Plant Physiol.* 128:1379-1389.

Ristic, R., and P.G. Iland. 2005. Relationships between seed and berry development of Vitis Vinifera L. cv Shiraz: Developmental changes in seed morphology and phenolic composition. *Australian J. Grape Wine Res*. 11:43-58.

Zhang, X., G. Luo, R. Wang, J. Wang, and G.H. Himelrick. 2003. Growth and developmental responses of seeded and seedless grape berries to shoot girdling. *J. Am. Soc. Hort. Sci.* 128:316-323.

Building Models for Decision Support

Walt Mahaffee, Research Plant Pathologist, USDA-ARS

Don't you think it would be great to get real-time information delivered to your mobile device or a screen on your tractor? What if you could see a pest risk predication that looks like a weather radar image for a vineyard block? Better yet, would you like a sprayer that adjusts the fungicide volume, rate, or mixture based on that risk prediction as you drive through the vineyard? Or a leaf-puller that adjusts the degree of leaf removal based on a prediction of how much the microclimate needs to be altered to reduce disease or pest development?

This vision of the future rests on developing better models for predicting pest and disease development, and how they spread. It also requires understanding how to downscale weather predictions to the plant level, and predict how plant canopy architecture and terrain impact vine microclimate. The Foliar Pathology Lab at the USDA-ARS Horticulture Crops Research Unit in Corvallis, Oregon in collaboration with numerous other groups have been envisioning this future and working in this direction since 1996.

Over the years we have developed several mathematical equations that describe pathogen development. Some give us a better understanding of the probability of spore germination or infection, where and when spores move, or the rate of spore development. We have used these equations to develop and improve forecasting models to better describe the observed biology. However, at the very heart of modeling is a simple truth, models are just an approximation of reality and therefore technically wrong. The question is not whether they are right or wrong but are they *useful* - "does the model improve my ability to make a decision?" Something that can happen when building forecaster models is that you can make them a lot more complex (requiring more inputs) to more accurately describe the precise biology, but the added complexity may not change the management decision from the simpler model. The model is better but it does not change management decisions, so why use it?

Let's take the example of how heat impacts spore germination and infection. We conducted a series of experiments in controlled environments and discovered that when leaf temperature exceeded 98°F (which is quite

common in the bright sun), spores and young mildew colonies died. We made a series of mathematical equations that were used to develop rules for a disease forecasting model. We then conducted five years of field experiments in Oregon, but the temperature never remained consistently high enough to cause a shift in management decisions. However, when Doug Gubler's group in California applied our model to vineyards in Southern California, they cut two fungicide applications with no increase in disease. These results indicated that the disease forecasting model is useful for Southern California but not the Willamette Valley – at least not yet. The predictions are that this will be changing in the coming decades due to climate change. This model may also be useful in warmer wine regions of southern or eastern Oregon. We had the right idea about the effects of high temperature but it applied to a different climate. These results and our spore trapping data indicate that we need to shift our focus to understanding how temperatures below 50°F impact disease development.

So, what goes into building a model? First, you need a large dataset that is specific to what you are interested in modeling. For example, the twelve years of data collected on powdery mildew ascospore release after bud-break does not help us to understand how grape powdery mildew over-wintering structures mature during the fall and winter. It only allows us to examine what conditions are associated with their post bud break release. The dataset must capture a wide range of conditions; which can only be achieved through research over multiple years and locations. At a minimum, you need three years of data, but greater than five is more likely to obtain the needed variability. Having multiple locations with climatic differences would shorten the time frame for data collection, but at least three years are usually necessary at each location. Without a robust dataset, you run the risk of developing a model specific only to the location where data were collected. The dataset needs to have independent variables (e.g. weather data) and response variables (e.g. disease or pest levels, spore release, etc). Increasing the number of independent varia-bles or even the frequency of their measurement provides more options to find relationships to the response variables. Unfortunately, we are often guessing which parameters need to be measured and we don't always get it right or are limited by the equipment available. A good bit of time and money is required to accomplish step one of building a model, creating a robust and useful dataset.

Once you have a dataset, you begin to analyze it using various techniques looking for correlations between environment and the response(s) you are trying to model. This often requires a broadening of one's statistical expertise, which is not a painless exercise. Sometimes you are lucky and find a collaborator. Part of this analysis also requires you to make assumptions and leaps in logic; basically, to apply your intuition. Yes, there is a great deal of intuition in science. You usually end up with a few equations that reasonably explain the collected data and make biological sense. Sometimes nothing shows a relationship because you did not take the response data frequently enough or measured the wrong aspect of the disease or pest epidemic. Either way, you have learned a lot, but do not yet have a forecasting model. If you end up with no workable equations, you have to start back at step one, data collection, using what you have learned from your first failed attempt.

Once you have a group of equations explaining the observed biology, you have the modeling equivalent of a lump of clay in front of you with all the potential to be a work of art. However, there is still the tough job of deciding how to shape it into something that works. Often, the equations you developed have numerous parameters of varying importance. To make the parameters useful, you have to sort through them and figure out which are critical in relation to the cost to measure them, and remove those that are not cost effective. You're trying to apply the KISS (keep it simple, stupid) principle to both the forecasting model and equipment required to run it. You also have to watch out for making it too simple. This often results in the forecasting model being too conservative and not reducing costs. This process is often highly iterative based on the field testing results.

Once you have a forecasting model, you have to test it in the field and compare management decisions to the currently accepted practice. This is best done by using multiple locations and years, which requires more time and money. The initial testing will most likely be done in small research plots at a single location because of costs. After two to three years of successful small plot testing, you probably have enough data to convince a few growers to test your model in their fields on a limited scale. If the demonstrates promise after two years, a grower might expand the area they are willing to risk to a commercial scale (i.e. whole block). It will likely take three to five

years before you are testing a forecasting model at a commercial scale at multiple locations. The real cost of commercial vineyard trials is that you can expect at least 50% of your plots to not have been treated according to the fore-casting model. Cooperating growers have many competing interests during the season and your experiment can fall through the cracks despite the best of intentions.

All of this effort requires a great deal of time and money and before you know it, ten to fifteen years have passed before you have a validated model ready for commercial use. It sure felt like you were breaking your back trying to move as fast as you could, but like a fine wine, it takes time to make a useful model.

OWRI Winemaker Panel Update

Dr. Elizabeth Tomasino, Assistant Professor of Enology, OSU

Industry members involved in the OWRI winemaker panel have been busy, parcipating in wine sensory evaluations in December, February, May, and once more in July. Due to a generous gift from the Erath Family Foundation, we have streamlined collection of sensory data, using Chromebooks (computer tablets) and other sensory equipment and supplies we purchased.

In December, winemakers evaluated wines made with collaborators in the Statewide Crop Load Project, conducting descriptive analysis of 12 wines previously evaluated by consumers in November. Following a conventional sensory analysis method, winemakers ranked intensity of appearance, aroma and taste/mouth feel descriptors. These results were presented at the OWRI Grape Day in March, and further informaton was presented to project collaborators in July.

In February, a winemaker panel consisting of 27 winemakers evaluated Pinot noir wines from AVA's throughout the Willamette Valley to help determine sub-regional styles. A total of 36 wines were evaluated, including four to five wines from each sub-region within the Dundee Hills, Yamhill-Carlton, Chehalem Mountains, McMinnville, Eola-Amity Hills, Southern Willamette Valley, Ribbon Ridge and the overall Willamette Valley region. Winemakers used a citation by frequency method to evaluate the wines, choosing five attributes that best described 22 randomly selected wines. The initial results of this panel will be released to industry members participating in this project, and disseminated to the entire industry after the 2015 vintage.

We also expanded on previous sensory work done by the OWRI winemaker panel by conducting a trained panel evaluation at Oregon State University. Last year, the OWRI winemaker panel evaluated wines from Dr. Paul Schreiner's research on optimum levels of nitrogen, phosphorus and potassium (NPK) in Pinot noir. The winemaker panel evaluated wines to determine if differences existed between treatments and to describe those differences. The results from the panel were used to train 18 individuals to evaluate aroma differences and overall preferences of different NPK treatments of wines from the 2012 and 2013 vintages. Dr. Schreiner presented the results of this study at the ASEV International Nitrogen Symposium in June. The winemaker panel also evaluated wines from Dr. James Osborne's study investigating the impact of yeast on Pinot noir aroma during cold soak.

The May sensory panel investigated the impact of two aroma compounds, β-damascenone and β-ionone, on Pinot noir quality. In addition to the winemaker evaluation, consumer panels were held to determine whether or not wines with different concentrations of these two compounds were perceived as different. The winemaker panel then conducted descriptive sensory analysis on the wines consumers considered different. Additionally, three different "wine bases" (two Oregon and one New Zealand pinot noirs) were used to investigate the effect on perception of additional compounds. Results from this study were presented at the ASEV National Conference in June.

I would like to thank all the participants who regularly attend OWRI winemaker panels. You provide important feedback and information to OWRI research projects. This information would be very difficult to obtain otherwise. In the future, we will be conducting additional red wine and white wine sensory panels. If you would like to be included in the mailing list please send your contact information to Elizabeth.tomasino@oregonstate.edu.

I look forward to seeing you at future OWRI winemaker sensory panels.

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.

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

The highly anticipated Compendium of Grape Diseases, Disorders, and Pests, Second Edition is now available. This book contains valuable information for growers and vineyard managers. Broken into four parts, this comprehensive guide provides information on grape diseases, disorders, and pests ranging from biotic factors, to mites and insects, abiotic factors, and lastly, tips that help managers save money and minimize pesticide use. Edited by Wayne Wilcox, Walter Gubler, and Jerry Uyemoto , this book is available for purchase through the *American Phytopathological Society* here: http://www.apsnet.org/apsstore/shopapspress/Pages/44792.aspx

Dealing with Compromised Fruit in the Winery

An article written by Dr. James Osborne, OSU Enology Extension Specialist, assessing how to best handle compromised fruit in the winery. *Practical Winery and Vineyard*. August 2014. http://www.winesandvines.com/

Distribution and monitoring of grape mealybug: A Key Vector of Grapevine Leafroll Disease in Oregon

This guide provides a practical overview of the grape mealybug and its role as a key vector in the spread of Grapevine Leafroll Virus. This publication was released in April 2014 by *Oregon State University Extension Publishing* (EM 9092) by authors K. Daane, C., Kaiser, R. Hilton, D.T. Dalton, V.M. Walton, and L.J. Brewer. It is available online. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/47545/em9092.pdf

Establishing a Vineyard in Oregon: A Quick-start Resource Guide

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. This publication was released in September 2014 by *Oregon State University Extension Publishing* (EM 8973) and was published by Dr. Patty Skinkis, Viticulture Extension Specialist. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/52092/em8973.pdf

Field Guide for Integrated Pest Management in Pacific Northwest Vineyards

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. This guide was published in June 2013 by Washington State University, Oregon State University, and University of Idaho through *Pacific Northwest Extension Publishing* (PNW 644). Edited by M.M. Moyer and S.D. O'Neal, this book is available for purchase online at http://cru.cahe.wsu.edu/CEPublications/PNW644/PNW644.pdf

Improving Management of Grape Powdery Mildew with New Tools and Knowledge

Walter Mahaffee, Seth Schwebs, Francesca Hand, Doug Gubler, Brian Baily and Rob Stoll provide growers with practical tools to help fight Powdery Mildew in this article in *Practical Winery and Vineyard*. April 2014. http://www.practicalwinery.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 Dave Stone, Associate Professor and Director, National Pesticide Information Center at OSU (Dave.Stone@oregonstate.edu, 541-737-4433).

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. This online handbook is edited by E. Peachey and available through *Pacific Northwest Extension Publishing*. It is updated quarterly, and the most recent revision was published in June 2015. http://pnwhandbooks.org/weed/

2015 Pest Management Guide for Wine Grapes
This publication is updated annually by Extension experts at Oregon State University and scientists at the USDA-ARS. Of particular interest is the update on fungicide efficacy provided by Dr. Jay Pscheidt, OSU Extension Plant Pathologist. Published by *Oregon State University Extension Publishing* (EM8413), this document was revised in March 2015. Authors: P. Skinkis, J. Pscheidt, A. Dreves, V. Walton, E. Peachey, I. Zasada, R. Martin, D. Sanchez, and C. Kaiser The document may be downloaded online here: https://catalog.extension.oregonstate.edu/em8413

Preventing Herbicide Drift and Injury to Grapes
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. This document was released in February 2014 by *Oregon State University Extension Publishing* (EM 8860) and was published by authors D.A. Ball, M. Corp, and I. Dami. https://catalog.extension.oregonstate.edu/files/project/pdf/em8860.pdf

Scouting for Grape Powdery Mildew
This publication provides vineyard owners with approaches for finding the first occurrence of grape powdery 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. This document was released in May 2013 by *Oregon State University Extension Publishing* (EM 9067) and authored by Jay W. Pscheidt. https://catalog.extension.oregonstate.edu/files/project/pdf/em9067.pdf

Soil Acidity in Oregon: Understanding and Using Concepts for Crop Production
This guide provides information on how to manage soil pH for various crops. While grapes are not specifically mentioned in this publication, the concepts for testing, interpreting and managing soil pH for nutrient management are discussed. It also provides helpful information that may be used when considering cover cropping in the vineyard. This publication was released in July 2013 by *Oregon State University Extension Publishing* (EM 9061) by authors J.M. Hart, D.M. Sullivan, N.P. Anderson, A.G. Hulting, D.A. Horneck, and N.W. Christensen. It is available online. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/41199/em9061.pdf

Spotted Wing Drosophila Identification and Testing
These two documents, developed by Amy J. Dreves, Adam Cave, and Jana Lee were developed in October 2014 to assist growers in detecting and identifying Spotted Wing Drosophila larvae in fruit. These publications provide information on proper supplies, collection methods, detection parameters and more.

A Detailed Guide for Testing Fruit for the Presence of Spotted Wing Drosophila (SWD) Larvae (EM 9096) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/52502/em9096.pdf

Spotted Wing Drosophila (SWD): A quick, 7-step guide for detecting SWD larvae in fruit (EM 9097) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/52501/em9097.pdf

Vineyard Canopy Management Publication Series
A series of four articles were published by Dr. Patty Skinkis, Viticulture Extension Specialist, in collaboration with co-authors Amanda Vance and Alison Reeve (graduate research assistants) and research colleague Dr. Paul Schreiner. These publications provide information on components of canopy management including the concepts and applications of vine balance, how vine balance is altered by canopy management practices, and two protocols developed for use by industry with information about using these data for decision-making. All articles were published by *Oregon State University Extension Publishing* in June 2013 and are available online through links provided below:

Understanding Vine Balance (EM 9068) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/39883/EM%209068.pdf

The Role of Canopy Management in Vine Balance (EM 9071) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/39968/EM9071.pdf

How to Measure Dormant Pruning Weight of Grapevines (EM 9069) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/39902/em9069.pdf

How to Measure Grapevine Leaf Area (EM 9070) http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/39969/EM%209070.pdf

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 were released in 2014 and describe research conducted by members of the Oregon Wine Research Institute at Oregon State University.

Viticulture

Feng H, F. Yuan, P.A. Skinkis, and M.C. Qian. 2015. 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

Gouthu S., S.T. O'Neil, Y. Di, M. Ansarolia, M. Megraw, and L.G. Deluc. 2014. A comparative study of ripening among berries of the grape cluster reveals an altered transcriptional programme and enhanced ripening rate in delayed berries. *J. Exp. Bot.* 65: 5889-5902. http://www.ncbi.nlm.nih.gov/pubmed/25135520

Schreiner, R. P., C.F. Scagel, and J. Lee. 2014. N, P, and K supply to Pinot noir grapevines: Impact on berry phenolics and free amino acids. *Am. J. Enol. Vitic.*65:43-49. http://www.ars.usda.gov/SP2UserFiles/person/5018/PDF/2013/2013%20AJEV%2064-26-38.pdf

Schreiner, R. P., P.A. Skinkis, and A.J. Dreves. 2014. A rapid method to assess grape rust mites on leaves and observations from case studies in western Oregon vineyards. *HortTechnology* 24:38-47. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/47976/SkinkisPatriciaHorticultureRapidMethodAssess.pdf

Song, J., R. Smart, H. Wang, B. Dambergs, A. Sparrow and M.C. Qian. 2015. 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

Insect, Disease, and Pest Management

Bailey, B. N., R. Stoll, E.R. Pardyjak, and W.F. Mahaffee. 2014. Effect of vegetative canopy architecture on vertical transport of massless particles. *Atmospheric Environment* 95: 480–489. http://www.sciencedirect.com/science/article/pii/S1352231014005135

Mahaffee, W.F. 2014. Use of airborne inoculum detection for disease management decisions. Pp, 39-54. Detection and Diagnostics of Plant Pathogens, M. L. Gullino and P. Bonants, Eds. Springer Verlag, NY. http://link.springer.com/chapter/10.1007/978-94-017-9020-8_3

Enology

Chescheir, S.C., D. Philbin, and J.P. Osborne. 2015. Impact of *Oenococcus oeni* on wine hydroxycinnamic acids and volatile phenol production by *Brettanomyces bruxellensis*. *Am. J. Enol. Vitic*. (In press) doi: 10.5344/ajev.2015.14108. http://ajevonline.org/content/early/2015/04/24/ajev.2015.14108.abstract?sid=a103592c-67cd-4498-9b57-d2cab01c1ccd

Burns, T.R., and J.P. Osborne. 2015. Loss of Pinot noir Wine Color and Polymeric Pigment after Malolactic Fermentation and Potential Causes. *Am. J. Enol. Vitic.* (In press) doi: 10.5344/ajev.2014.14061. http://ajevonline.org/content/early/2014/10/22/ajev.2014.14061.abstract?sid=a103592c-67cd-4498-9b57-d2cab01c1ccd

Schopp, L.M., J. Lee, J.P. Osborne, S.C. Chescheir, and C.G. Edwards. 2013. Metabolism of nonesterified and esterified hydroxycinnamic acids in red wines by *Brettanomyces bruxellensis*. *J. Agric. Food Chem*. 61: 11610–17. http://pubs.acs.org/doi/abs/10.1021/jf403440k

Song, M., Y. Xia and E. Tomasino. 2015. 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

Thesis

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