Defining Crop Load Metrics for Quality Pinot Noir Production in Oregon

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Interim Report Summary

A three year study was conducted from 2013-2015 to determine the impact of varying crop levels on vine growth and balance. The project involved two components: 1) development of a large grower collaborator crop load study and 2) a more detailed physiological assessment of vine growth and nutrition within four sites from the larger study. A total of 14 companies implemented the project in 16 vineyards in 2015. Collaborators participated in the research by adjusting vines to two or more crop levels based on lag-phase cluster thinning following research protocols outlined by OSU, and they have completed three full growing seasons of data collection and wine production for the funding period. Results from the large grower collaborative study in 2013-2015 show no differences in vine size based on dormant pruning weight or vine nutrient status. Even after the two high yield years of 2014 and 2015, full crop vines did not have reduced pruning weights or vine macronutrients (N, P or K) compared to vines that had crop thinned to 1 cluster/shoot or fewer. In most sites within the project, crop level led to differences in fruit composition at harvest. However, there was not consistency in how crop level effected fruit composition across all sites or years. There were more vineyards showing differences in TSS (Brix) in 2015 than any other year, possibly due higher yields and greater magnitude of difference from high and low crop levels at those sites. Although only 23% of the vineyards had a difference in anthocyanin with crop level treatments in 2015, 31% had a significant yield – anthocyanin relationship (total or polymeric anthocyanins based on regression analyses. Anthocyanin has been one of the few consistent relationships found with yield found across the three-year period.

Data obtained from the four sites (study 2) during 2013-2015 show few differences in vine growth and fruit composition when comparing full crop (non-thinned vines) with those cluster-thinned to one cluster/shoot. There were no differences in tissue nutrients in 2013 or 2014, but 2015 data show lower leaf blade and petiole phosphorous in non-thinned vines at both bloom and véraison. Crop level did not result in differences in fruitfulness, vine leaf area and shoot length at bloom, vine leaf area at véraison, or leaf photoassimilation rates during ripening at any site during 2015. Dormant pruning weights were not different by crop level in any of the four sites following the 2015 season with the exception of one site which had lower cane weights in full crop vines but did not differ for whole vine pruning weight.

The past three years of data collected across more than 15 vineyards suggest that crop level is not limiting vine growth nor consistently impacting fruit composition of Pinot noir at harvest. However, further statistical analyses across sites and across years will help us develop more appropriate crop load metrics that can guide Oregon producers to optimized fruit composition and long-term vine productivity while maintaining economic viability for vineyards and wineries.

Unified Grant Management for Viticulture and Enology

INTERIM REPORT (Year 3) – MAY 2016

Project Title and UGMVE proposal number: Defining Crop Load Metrics for Quality Pinot Noir Production in Oregon, #2015-1512

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Cooperators: Project cooperators during 2015 included 14 commercial vineyards and/or winery businesses in Oregon: Adelsheim Vineyard, Airlie Winery, A to Z Wineworks, Bethel Heights Vineyard, Chehalem Winery, Dion Vineyard, Domaine Drouhin-Oregon, Domaine Serene, Ken Wright Cellars, Stoller Family Estate Vineyard, Van Duzer Vineyards, Willakenzie Estate, Winemakers Investment Properties, and Winter's Hill Winery.

Objectives and Experiments Conducted to Meet Stated Objectives

Objective 1: Develop the statewide research effort to implement and conduct research trials in commercial vineyards and wineries to address vine growth, fruit and wine quality as a result of yield management.

The statewide research program was initiated in 2012 with the recruitment of the first set of ten collaborators who successfully implemented the project. A recruitment call was released each April 2012-2015 to increase project participation. The application process requires the completion of an application form and review by the PI. Only businesses that meet the following criteria were approved to join the study: a healthy, uniform Pinot noir vineyard of >5 years of age and at least 1 to 1.5 acres in size to use for the trial, enough acreage to support involvement in a trial of this size without compromising their overall production, ability to conduct the research for at least three years in the same vineyard block, willingness to follow project protocols for experimental design and ability to collect data required according to project protocols. Since all new collaborators to date are from the Willamette Valley and in close proximity to OSU, they were trained through one-on-one meetings in the vineyard. The PI made initial site visits to each vineyard to check the suitability of the research block for use in the project and provided training on experimental design and layout for the project. Follow-up visits were conducted by the PI and faculty research assistant (FRA) as needed to ensure collaborator confidence in taking part in the study. Continued support to collaborators is provided by the PI and FRA on an on-going basis throughout the season.

Collaborators in the study continue to implement the same crop levels each year. Most have two to three crop levels implemented in their research vineyard block. The majority chose to implement 1 cluster/shoot, 2 clusters/shoot, or no thinning. Because Pinot noir fruitfulness rarely exceeds 2 clusters/shoot, cluster thinning was easily managed on a larger scale by using these two thinning treatments. All collaborators developed their vineyard experiment using the same randomized complete block design with whole row plots and at least three field replicates.

Collaborators followed specific protocols developed by the PI for data collection. All data were collected from 10-vine reference plots within three replicates of each treatment. Data collection included fruitfulness counts in spring, shoot and cluster counts pre- and post-thinning, yield weights at harvest and dormant pruning weights. All field data are collected by staff of the commercial vineyard following the project protocols. Data sheets were provided to the collaborators for all data collection protocols. A members-only website was developed in 2012 and continues to serve as a central hub for collaborators to locate protocols, data sheets, data entry files for the project. For weights, each collaborator was provided a calibrated hanging scale.

Vine nutrition samples (leaf blade and petiole) were collected from two treatments (1 cluster/shoot and either no-thinning or 2 clusters/shoot) per site at véraison each year. Grower collaborators collected the samples and submitted them to Precision Agri-Labs for analysis of macro- and micro-nutrients. Crop Production Services (CPS) volunteered to arrange for sample coordination and delivery from the collaborator to the commercial lab and coordinating data delivery to the PI. Collaborators covered the cost of their own tissue nutrient analysis and results were reported directly to the PI by Precision Agri-Labs.

Fruit samples were collected at least two time points prior to harvest to monitor ripening progression. These samples were gathered across the entire project (each treatment replicate, but avoiding the reference vines). At harvest, a 20-cluster fruit sample was collected from the reference vines in each plot, weighed and measured for cluster weight by the grower, and picked up by OSU for processing and shipping to ETS Labs. Fruit was analyzed using ETS Lab's basic ripening panel and rapid phenolic panel (total soluble solids, pH, TA, L-malic acid, tartaric acid, glucose + fructose, ammonia, alpha-amino acids, YAN, K, catechin, quercetin glycosides, tannins, polymeric anthocyanins, total anthocyanins, catechin/tannin index, and polymeric anthocyanin/tannin index). This service was donated by ETS Labs in 2013-2015. Their donation of services was critical to obtaining more data than is possible through this funding.

At harvest, the majority of collaborators produced wines from the trial each year. Only 1-2 collaborators are taking part in the vineyard/fruit analysis part of the project only and did not carry the project to wine production. All treatment plots were bulked for wine production in a minimum of 1.5 ton fermentations under each cropping level. Wines were produced to winery collaborator's commercial standard but using the same method for all of their treatment wines in the study. Wines were stored under temperature controlled conditions at each winery until they were picked up by OSU and stored on campus under temperature controlled conditions until analysis. Sensory analysis of wines began in 2014 with the 2012 vintage, and the 2013 wines evaluated in 2015. All wines were bottle-aged two years before they entered into sensory evaluation by the trained winemaker panel.

Significant effort was placed on coordinating this group of industry researchers. Regular reminders for data collection and coordination were sent out monthly per the next task to be

implemented. The PI and FRA frequently communicated with the project collaborators to ensure project success. A collaborator meeting was held each year in spring/summer to discuss protocols, project results and next steps in the research.

Objective 2: Evaluate vine growth and nutrient status data with fruit/wine composition data to develop better vine balance metrics for Oregon Pinot noir.

Four sites were selected from the project outlined in Objective 1 based on the level of vine vigor, elevation and location across two different AVAs. More detailed data collection occurred during 2013-2015. The four vineyards were monitored for shoot length and shoot leaf area at bloom and véraison. Leaf area and vine canopy measures were determined with various techniques, several of which are under development as potential new methods for field researchers to more efficiently measure leaf area. All measures were done in-field using non-destructive methods. Leaf assimilation and stomatal conductance was measured using a LICOR 6400 XT (LI-COR Biosciences, Lincoln, NE) during early ripening at all four sites. Leaf water potential measures were taken on the same leaves as the gas exchange measures to compare pressure chamber results to gas exchange measures. Leaf greenness (an estimate of chlorophyll) was measured with a SPAD-502 meter (Konica-Minolta, Ramsey, NJ) during bloom and véraison, and these measures were made on leaves selected for nutrient analysis at each time point. Vine nutrient status was monitored by collecting leaf blade and petiole samples at bloom and véraison. Samples were collected by the Skinkis and Schreiner labs, cleaned, dried, ground and analyzed for macro- and micronutrients at the USDA-ARS HCRL, Corvallis. Dormant pruning weights were measured during January 2014, 2015, and 2016, and those data were collated with other vine growth data, nutrient data, and pending carbohydrates for statistical analysis at the end of the field component of this trial (2016). Vine nutrient and non-structural carbohydrate (sugars and starch) reserves will be measured in these dormant cane tissues. Currently, those tissues have been collected, dried, and stored under cool, dry conditions until analysis.

The data collected in this Objective have been analyzed to determine vine productivity and how it relates canopy leaf area, yield, pruning weight and crop load (Ravaz; yield/pruning weight). The detailed measures obtained in this objective allows us to draw more conclusions for vine physiological response to crop level than is possible from the project in Objective 1. Additionally, the use of sites with varying vigor helps us evaluate crop load impacts and develop better guidelines for a broader range of vineyards.

Summary of Major Research Accomplishments and Results by Objective

Objective 1: Develop the statewide research effort to implement and conduct research trials in commercial vineyards and wineries to address vine growth and fruit and wine quality as a result of yield management.

As of this reporting, a total of 14 companies are collaborating in this research project. Ten companies joined in 2012, and an additional five companies joined the project since that time. As expected, a few collaborators had to leave the study within the first year or two, and this was mostly due to factors outside of our control. All collaborators are from the Willamette

Valley, but they span across six AVAs (Chehalem Mountain, Dundee Hills, Eola-Amity Hills, Ribbon-Ridge, Willamette Valley, and Yamhill-Carlton). The composition of the collaborators also spans across a diversity of site characteristics that allow for a greater ability to assess vine balance across the region. Collaborators also represent a diversity of different production goals and wine markets. During 2015, we recruited and trained one new collaborator.

The results included in this grant report show 2012 through 2015, which is the full duration of the project to date. However, grant support from the Oregon Wine Board was not obtained until the 2013 season.

The 2015 season was the highest yielding year of the project (Figure 1), with 25% greater yield across all treatments and a 42% increase in yield in non-thinned treatments compared to 2014. This was likely due to greater fruitfulness (number of clusters per shoot) and excellent fruit set compared to prior years. Cluster weight mean across all sites in 2015 was 136 g ($\pm$38 g) which was the highest mean across the four year period with means of 82, 92, 108 g per cluster for 2012, 2013 and 2014, respectively. Pruning weights were not largely different in 2015 than prior years, despite the high crop level.

Despite greater base yields and yield differences by crop level treatments in 2015, only one vineyard had a difference in pruning weight with crop level treatment. However, the change in pruning weight could not be explained by higher yield. No vineyard trial had a reduction in pruning weight with an increase in yield, even with most vineyards being in the trial for three or more years. Furthermore, only two vineyards in 2015 had lower N or K as a result of higher crop level. This suggests that sustained high crop level in non-thinned vines is not compromising vine growth or nutrient status.

With the high yields in 2015, it is no surprise that crop load, as measured by the Ravaz Index, reached its highest over the four-year period with a mean of 3.9 for all treatments (Table 1 and 2). Non-thinned treatments had an average of 5.4, which reached the minimum threshold of acceptable Ravaz Index for quality wine production that is often cited in literature (5-10). Over the course of the four-year period, obtaining a Ravaz Index of this magnitude is not a common occurrence, and the realistic realm of crop load for quality wine production is within the 2-4 range. We will explore the proper crop load metric with fruit quality and wine sensory impacts as we continue with the project.

Fruit composition at harvest was quantified in 2015 across 13 Pinot noir sites and three Chardonnay sites. There were no differences in basic ripeness of the three Chardonnay vineyards in the project, as there were no differences found for TSS, pH, TA, malate, tartrate, glucose + fructose, ammonia N, alpha amino acid N or total YAN with varying crop levels.

There were more differences found in fruit composition of the Pinot noir, but there were no consistent differences across all vineyard sites in 2015 nor across all four years of the project . There were more vineyards showing differences in TSS (Brix) in 2015 than any other year, possibly due higher yields and greater magnitude of difference from high and low crop levels at those sites. Although only 23% of the vineyards had a difference in anthocyanin with crop level treatments in 2015, 31% had a significant yield – anthocyanin relationship (total or polymeric anthocyanin) based on regression analyses. Anthocyanin has been one of the few consistent relationships found with yield found across the four-year period.

Objective 2: Evaluate vine growth and nutrient status data with fruit/wine composition data to develop better vine balance metrics for Oregon Pinot noir.

The four sites selected from the larger project outlined in Objective 1 were monitored for vine physiological measurements during 2013, 2014 and 2015. All four sites had implemented crop level treatments since 2012. Two of the sites (BH and RR) are located within the Eola-Amity Hills AVA, and the other two are located in Yamhill-Carlton AVA (MC and WKE). Focus of this Objective was placed on only two treatments across all sites: a) 1 cluster/shoot and b) no thinning.

Vine leaf area measured at bloom and véraison did not differ by crop level in 2015 (Table 3). There also was no difference in shoot length at bloom. The lack of difference in growth between the two crop levels in 2015 suggests that the vines that held a full crop in 2014 (a high yield year) had sufficient nutrient reserves to allow early season growth. Furthermore, there was no difference in fruitfulness (number of inflorescences per shoot) between crop levels at any site in spring 2015. Again, this suggests that full crop vines had sufficient nutrient status to support good floral primordia development in the buds during 2014.

Vine nutrient samples were collected at bloom and véraison each year to monitor the impact that heavier yields may have on vine health long-term. Bloom and véraison data were analyzed separately. Crop level did not have an effect on any leaf blade or petiole nutrient concentrations measured at bloom or véraison until 2015, when phosphorus was found to be lower in the full crop (non-thinned) vines for both leaf and petiole tissues at bloom and véraison. With high baseline yields in 2014, it was anticipated that there would be greater differences in 2015; however, no differences were found for the key nutrients that are typically impacted by crop level, namely potassium (K). These data suggest that the vines have sufficient resources from reserves and/or the vineyard environment to maintain a healthy canopy and significant fruit yields.

Single leaf gas exchange was measured during ripening in all four sites in September each year. We anticipated greater differences in 2015 due to the higher crop level and the warmer season. However, there were no differences found by crop level for photosynthetic assimilation or stomatal conductance at any of locations in any year measured.

Yields varied by crop level, as expected, since cluster thinning was employed at each site. Approximately 40% of clusters were removed across the four sites to obtain the 1 cluster/shoot treatment. Yields at harvest in 2015 (Table 3) were similar to 2014 in one site and higher in two of the three sites.

Dormant pruning weights are typically one of the first vine growth parameters that changes when conducting research to adjust vine vigor, whether it is with vineyard floor management, irrigation, or fertilization. After all three seasons, dormant pruning weights (kg/vine) did not differ by crop level at any of the four vineyards, suggesting that the full crop vines had sufficient resources for vine growth (Table 3). However, one vineyard showed differences in cane weights, and it had the greatest difference in crop level based on pounds per linear foot. Analysis of carbohydrates of the dormant canes collected in winters following the 2013, 2014, and 2015 growing season will provide insight into potential nutrient reserve limitations. Carbohydrate analyses are planned for summer 2016 so that the 3-years of samples can be run at the same time to avoid any issues with the assay used. So far we have completed

ICP analysis of the dormant cane tissues from 2015, and the results show no differences in any macro- or micronutrients based on crop level used at any of the four sites (Figure 2, %N shown). The dormant bud wood samples reflect lack of nutrient differences as found in the 2015 véraison tissue samples. However, there was some reduced P with lower crop level found in the véraison samples that are not showing up in the dormant budwood samples.

The four sites used for Objective two differ in vine vigor and productivity, and this is valuable in understanding how crop load may be influencing fruit composition and quality in vineyards with different yield capacity. The data obtained from these sites where more detailed data are collected will help us further evaluate the impact of leaf area (canopy size) on fruit composition, and those analyses are under further statistical anlaysis as of this reporting.

Outside Presentations of Research

The results from the project outlined in Objective 1 have been presented by the PI to peers and industry at various venues during 2014 and 2015. Results were shared at the annual collaborator meetings held on 1 July 2014, 1 July 2015, and 25 April 2016. Presentations on the first few years of research results have been shared with the Oregon industry through 6 seminars and 3 field days over 2014 and 2015. Canopy quantification work from Objective 2 was part of a student MS thesis (Alejandra Navarrete in March 2015; note student was not supported by OWB funds from this grant). Information from the large collaborative study was presented as an oral presentation at the 2015 OWRI Grape Day at OSU and an OWRI Seminar in December 2015. The PI will be giving an oral presentation on this project at the American Society for Horticulture Sciences (ASHS) Annual Conference in Atlanta, Georgia in August 2016.

Research Success Statements

There has been strong grower collaboration in this study because they are seeking to understand how yield relates to wine quality. Currently the majority of industry uses a yield standard between 2.0 to 2.75 T/A for Pinot noir, and this comes at a significant cost. The goal to develop suitable Oregon-based vine balance metrics is important to Oregon's wine industry as they begin to apply the best management practices to different sites with different yield capacity, rather than subscribing to target yields that have become the status quo. Collaborators and the broader industry have reaffirmed that reducing canopy management (crop thinning) costs and increasing yields without compromising fruit quality is of paramount importance to economic viability of vineyard and winery companies but the overall Oregon winegrape industry. This large research project will help expand crop load research to different Oregon production regions and help develop better metrics that allow a flexible approach to managing vine balance and fruit quality rather than applying a standard target yield without regard to vine vigor, growing region, and season.

With labor becoming scarce for intensive canopy management, and the increasing costs of production, growers are more inclined to experiment with new ideas directly to help make future management decisions for their companies. Conducting this research by engaging grape growers and winemakers is beneficial for their understanding of the effects of yield management on their own vineyards and the resulting wine characteristics. As active participants in the

research, they also learn how to design on-farm studies to help address questions in a systematic way and think differently about their management decisions.

Fund Status

The project outlined in Objective 1 was initiated in 2012 and funded by the Oregon Wine Research Institute through a pilot project program until 2015. The funding provided by the Oregon Wine Board from 2013/14 to 2015/16 allowed for expansion of Objective 1 to new data collection and to begin investigating physiological responses of higher crop levels on vine health and productivity through Objective 2. Funds were used to support half of a full-time faculty research assistant (Michael Kennedy) who works in the Skinkis Lab and assists in the communication and coordination of information between the PI, co-PI and industry collaborators. This large of a project would not be possible without this type of staff support. Funding for Objective 2 was used to travel to four research sites and collect data, including vine nutrient sampling, leaf area quantification, canopy metrics, shoot lengths, leaf gas exchange, etc. We will continue to use funds through August 2016 to finalize data analysis from the 2015 season of the project.

The research team thanks the Oregon Wine Board for the financial support of this research project and for their continued support of other research within the program of the PI.

Tables

The results included in this grant report show 2012 through 2015, which is the full duration of the project to date. However, grant support from the Oregon Wine Board was not obtained until the 2013 season.

Table 1. Mean yields (per linear length of canopy) and crop load (Ravaz Index= yield/pruning weight) obtained from all Pinot noir vineyards during 2015 (n=11 sites of 13 Pinot noir vineyards). Standard deviations of the mean are shown in grey to reflect the amount of spread in the data across all sites with a given crop thinning treatment.

		Means			Standard Deviation		
Treatment	# sites	Yield (kg/m)	Yield (lb/ft)	Ravaz	Yield (kg/m)	Yield (lb/ft)	Ravaz
0.5 cluster/shoot	3	0.84	0.44	2.1	0.30	0.20	1.0
1 cluster/shoot	11	1.45	0.91	2.9	0.62	0.45	0.9
1.5 clusters/shoot	6	2.33	1.43	4.2	0.48	0.50	1.5
2 clusters/shoot	4	2.28	1.53	4.3	1.01	0.68	1.2
No thinning	8	2.68	1.80	5.4	1.26	0.84	1.4
All treatments	11	1.87	1.21	3.9	0.94	0.67	1.6

Table 2. Range of crop load (Ravaz Index) achieved in trial vineyards from 2012 to 2015.

Ravaz	2012	2013	2014	2015
Mean (all treatments)	2.7	2.7	3.1	3.9
Minimum (all treatments)	0.9	0.8	1.2	0.9
Maximum (all treatments)	6.0	5.9	5.0	7.6
No Thinning treatments only	3.5	3.4	3.7	5.4

Table 3. Yield, pruning weight, leaf area and vine balance of vines in 2015 from four vineyards where cluster thinning (1 cluster/shoot) was compared to vines that were not cluster thinned.

Vineyard	Treatment	Yield (kg/vine)	Yield (lb/ft)	Vine leaf area (m^2)	Leaf area:Yield (m^2/kg)	Pruning wt (kg/vine)	Cane wt (g)	Ravaz
BH	1 cluster/shoot	1.06 b	0.78 b	2.54	2.43	0.40	55	2.7 b
	No Thin	1.60 a	1.18 a	2.77	1.74	0.43	57	3.8 a
	p-value	0.0186	0.0196	n.s.	n.s.	n.s.	n.s.	0.0277
MC	1 cluster/shoot	n.d.	n.d.	1.81	n.d.	0.50	56	n.d.
	No Thin	n.d.	n.d.	1.98	n.d.	0.46	59	n.d.
	p-value	n.d.	n.d.	n.s.	n.d.	n.s.	n.s.	n.d.
RR	1 cluster/shoot	1.33 b	0.89 b	2.88	2.17 a	0.45	49	3.0 b
	No Thin	3.12 a	2.10 a	2.92	0.93 b	0.42	38	7.6 a
	p-value	0.0008	0.0008	n.s.	0.0020	n.s.	0.0194[a]	<0.0001
WKE	1 cluster/shoot	2.63 b	1.16 b	4.69	1.81 a	1.03	60	2.5 b
	No Thin	6.48 a	2.86 a	4.71	0.73 b	1.14	62	5.7 a
	p-value	0.0148	0.0149	n.s.	0.0129	n.s.	n.s.	0.0015

Where there were no statistical differences in data, n.s. (not significant) is indicated. For those with differences between treatments based on statistical analysis, the p-value is shown and means separation denoted by a different letter behind the means of each treatment (Tukeys HSD test, $p<0.05$). [a]Kruskal Wallis non-parametric statistics run for non-normal data. Ravaz is the yield divided by pruning weight to give a unitless number to indicate vine balance. n.d. is not determined due to missing data.

Figures

The results included in this grant report show 2012 through 2015, which is the full duration of the project to date. However, grant support from the Oregon Wine Board was not obtained until the 2013 season.

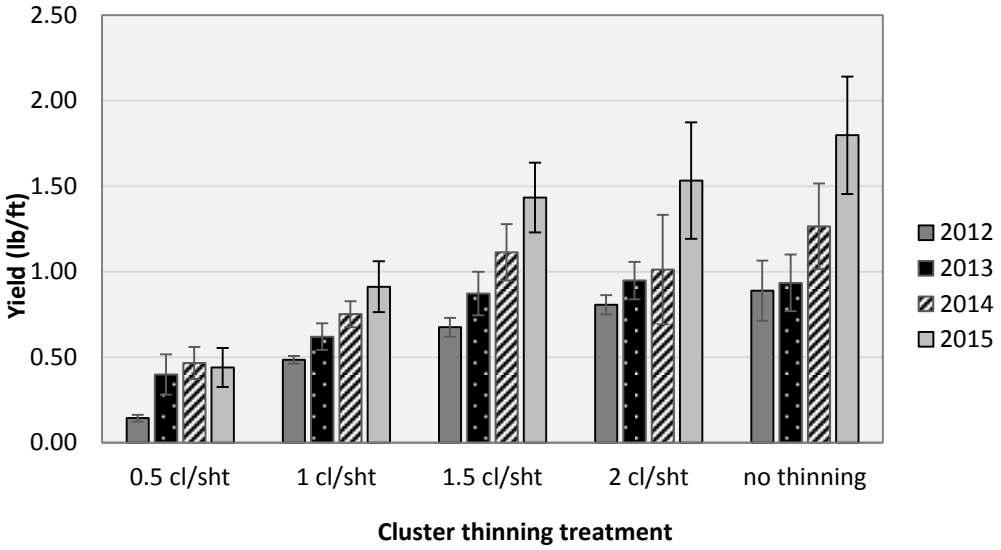

Figure 1. Mean (±standard error) yield obtained at harvest across all Pinot noir vineyard sites from 2012 to 2015. The treatments include 0.5 clusters/shoot, 1 cluster/shoot, 1.5 clusters/shoot, 2 clusters/shoot and no thinning. Those sites with target yield treatments (n=2) were not summarized in these data.

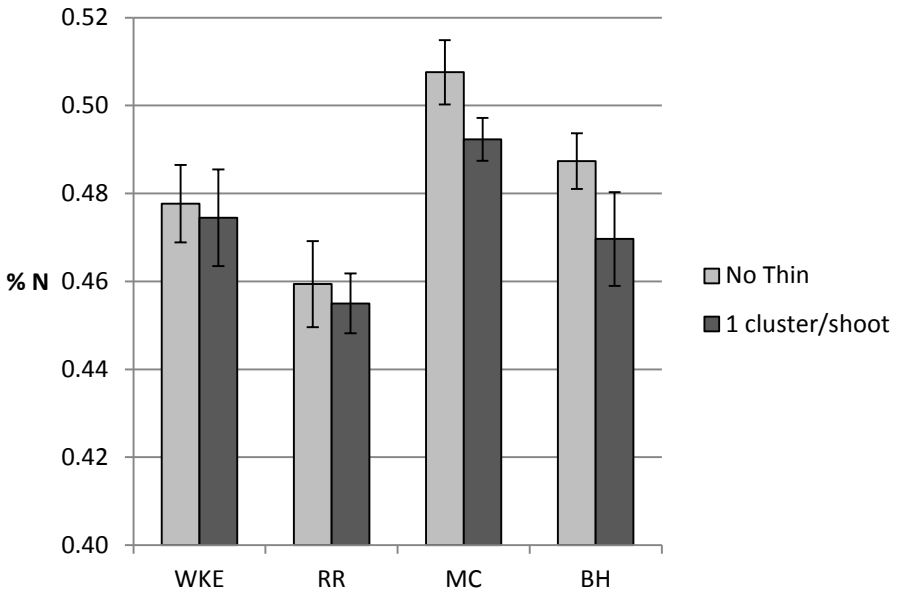

Figure 2. Mean (+SE) nitrogen of budwood samples collected during dormancy following the 2015 growing season at four different sites (listed on x-axis). There were no differences in %N found in tissues between crop levels within any of the four vineyard sites.