Understanding vine balance and cropping levels in Oregon Vineyards

Patricia A. Skinkis, Jungmin Lee, and Julie Tarara

Summary

Two vine balance studies were conducted from 2011 to 2013 to determine the impact of vine vigor, nitrogen (N) status, and crop level on fruit composition of Pinot noir in Oregon. This included a split plot trial in the North Willamette Valley with three main-plot vineyard floor management treatments (Grass, Alternate, and Tilled; used to alter vine vigor) and two cropping levels (Full Crop and Half Crop) imposed as sub-plots. Vineyard floor treatments effectively altered vine vigor with Grass having reduced fruitfulness, early season shoot growth, and vine leaf area in 2013. Similar findings were reported for 2011 and 2012. The altered vigor of Grass vines allowed for greater canopy solar radiation. Differences in vine vigor are attributed to differences in tissue N status as measured in prior years. Vigor level influenced vine growth more than crop level (yield) in 2013. Leaf area at bloom and véraison were reduced in Grass vines, and they had fruit 0.4°Brix lower at harvest. There was relationship between leaf area: yield and total soluble solids at harvest in 2013, likely due to the uniform leaf area: yield ratio per each treatment, leading the vine to adjust the crop level accordingly in the smaller vine in the Grass treatment. Despite having increased sunlight infiltration in the canopies of the lower vigor Grass vines, there was no increase in berry anthocyanins. Also, there were no major differences in fruit composition and ripeness as a result of either crop reduction or vine vigor. A second crop level study was conducted in southern Oregon with two crop levels applied at four different time points from pre-bloom to véraison. In this trial, the two thinning treatments did not differ from each other in grape maturity (TSS, pH, and TA), yeast assimilable nitrogen (YAN), anthocyanins, phenolics, or tannins in 2013. Timing of cluster thinning did not influence YAN concentration as in other years. These data suggests that reducing yields in a warmer year when vines are at low Ravaz indices (low yield relative to canopy size) does not increase the concentration of key "quality" compounds or indicators such as sugars, anthocyanins, and tannins in Pinot noir. Maintaining higher yields did not decrease vine leaf area across the three years; however, the first difference in pruning weights were observed in 2013 with the earliest time points and lowest crop levels having higher pruning weights than the higher yielding vines. Lab analysis and statistical analyses are still in progress for both experiments in the final year of the study. This report provides details on progress to date from the 2013 season.

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Principal Investigator:
Patricia A. Skinkis, Ph.D., Associate Professor & Viticulture Extension Specialist, Oregon State University, Department of Horticulture, 4017 ALS Bldg., Corvallis, OR 97331-7304; ph: 541-737-1411, fax: 541-737-3479, e-mail: Patricia.Skinkis@oregonstate.edu

Co-PIs:
Jungmin Lee, Ph.D., Research Food Technologist, USDA-ARS HCRL, 29630 U of I Lane, Parma, ID, 83660. Phone: 208-722-6701, email: Jungmin.Lee@ars.usda.gov
Julie Tarara, Ph.D., Research Horticulturist, USDA-ARS HCRL, 24106 N Bunn Road, Prosser, WA, 99350. Phone: 509-786-9392, email: Julie.Tarara@ars.usda.gov

Cooperators:
Rob Schultz, Vineyard Manager, Stoller Family Estate Vineyards, 15151 NE Stoller Road, Dayton, OR 97114. ph: 503-583-1794, email: Robert.Schultz@StollerVineyards.com.
Bill Wendover, Viticulturist, Foris Winery/Stonefield Vineyard, 1628 Dick George Rd, Cave Junction, OR, 97523. Ph: 541-592-2985, e-mail: stonefield@frontiernet.net.

Objectives and Experiments Conducted to Meet Stated Objectives

Objective 1. Determine impact of cluster thinning on vine growth and fruit composition of vines with varying vine vigor and tissue nitrogen status.

This three year trial was established in 2011 in a mature Pinot noir block at Stoller Vineyards, in Dayton, OR. The block, planted in 1998, consists of clone 115 Pinot noir grafted to 101-14 rootstock with 5' row and 7' row spacing and trained to a bilateral Guyot system. This block was chosen for the study as three different vineyard floor management practices had been used in the block for a separate study (2007-2010) and resulted in three levels of vine vegetative vigor. The vineyard floor management treatments include the following: 1) perennial grass mix of red fescue, *Festuca rubra* spp. *Rubra* grown in both alleys between vine rows (Grass), 2) alternating alleys of perennial grass and cultivation (Alternate), and 3) cultivated alleyways between vine rows (Tilled). These vineyard floor treatments were applied in a completely randomized design across the vineyard block with five replicates of 16 vines each. Within each main plot, two crop levels were applied in a split plot design with eight vines per crop level. The two crop levels include 1) no clusters removed which is approximately two clusters/shoot (full crop), and 2) one cluster per shoot (half crop). Plots were tilled in main plot treatments shortly after bud break. Tilled areas were roto-tilled in spring and summer to keep weed vegetation from growing. The vineyard was managed per the regular maintenance regime including fungicide

applications, mowing, herbicide application, hedging and leaf pulling. No irrigation or soil fertilizers were added for the duration of this trial.

The influences of both main plot and sub-plot factors on vine growth were evaluated by shoot growth rate, leaf area, canopy density, secondary crop weight, harvest yield, dormant pruning weight, and cane weight. Shoot lengths were measured weekly on eight tagged shoots per plot beginning shortly after bud break and carried out until hedging commenced to determine impacts on reduced vine reserves and tissue N on vine growth. Vine leaf area was measured non-destructively in the vineyard during bloom and véraison on five vines per plot using a calibrated template method. Primary leaf area, lateral leaf area, lateral number, and lateral length were measured to determine the differences in vine canopy structure between the treatments. To partner canopy density and leaf area measures, incident sunlight and LAI (leaf area index) was measured using a ceptometer (LP-80, Decagon Devices, Pullman, WA). Measures were taken at 10 AM, solar noon, and 3 PM during bloom, bunch close, and véraison during 2013. Data were gathered in several configurations within the canopy to determine how to best estimate canopy architecture and microclimate within the canopy using the ceptometer. Shoot number per vine, inflorescences per shoot, and cluster per shoot were recorded during the growing season to calculate differences in canopy size, fruitfulness per shoot, and percent crop by cluster number to compare between thinned and full crop treatments, respectively. Leaf chlorophyll was measured using a chlorophyll meter (Minolta SPAD 502, Konica Minolta, USA) during bloom, mid-season, and véraison, pairing measures with tissue sampling for nutrient analysis. Because significant second crop began to form from laterals in 2012 and 2013, all second crop fruit was removed from vines prior to véraison and weighed per plot. Whole vine yield was measured per vine at harvest, and these data will be combined with pruning weight collected in winter following harvest to determine crop load (Ravaz index).

Because declining tissue nitrogen (N) can lead to changes in fruitfulness and flowering, both vine fruitfulness (inflorescences/shoot) and fruit set were quantified. Percent fruit set was determined using digital images of tagged inflorescences before bloom as outlined by Poni et al. 2006 but modified to include images taken post-set to quantify the percent fruit set during the season. In addition, berries per cluster and berry weights were quantified at harvest. These data helped us determine shifts in fruitfulness, flowers/inflorescences, and fruit set with changes in vine N status.

Midday stem and leaf water potential was measured in each plot every 7 to 10 days from early June through the end of September on clear, cloudless days using a pressure chamber (PMS Instruments, Albany, OR). Soil moisture was monitored in the vine row using capacitance probes (AquaPro Sensors, Ducor, CA) concurrently with stem water potential measurements. Leaf gas exchange of four treatments (Grass-Full Crop, Grass-Half Crop, Till-Full Crop, and Till-Half Crop) was measured during five time points in 2012 (early bloom, full bloom, pea-size, 50% véraison, ripening) with measures at 10 AM, solar noon, and 2 PM using a LI-COR 6400 XT (LI-COR Biosciences, Lincoln, NE). Focus was placed on these treatments because of the physiological importance between growth differences but also to allow efficient data collection within an appropriate window of time to allow data collection before changing environmental conditions (~1 hour).

Vine nutrient status was assessed by tissue samples collected and analyzed at bloom and véraison. Samples of 20 petioles and leaf blades (opposite a cluster) were collected at bloom and

véraison (from leaves opposite a cluster and the most recently expanded leaves) for each plot. Samples were collected, rinsed in distilled water and oven-dried at 60°C for 48 hours, ground to pass through a fine mesh, and were submitted to Oregon State University's Central Analytical Lab for nutrient analysis (P, K, Ca, Mn, Mg, Cu, Fe, B, and Zn). Analysis was supposed to be conducted on samples for C and N also; however, those data are still pending as the OSU lab that conducts the analyses had their C&N analyzer fail during summer 2013 and the replacement unit is expected to be ready to run samples in summer of 2014. Funds were requested for only 60 samples in the original proposal, but we wanted to monitor total vine nutrients at both time points and both tissues, thereby increasing total sample number to 120 in 2013. The extra charge for nutrient analysis was covered by the PI's startup funds. This allows us to further analyze the impact of yield and vine vigor level on nutrient status.

Fruit was harvested on 18 September 2013 to obtain whole vine yields and gather fruit for compositional analyses. A seven cluster sample was randomly collected for each treatment, measured for cluster weight, berries per cluster, berry weight, and processed to juice for analysis of total soluble solids (°Brix), pH, and titratable acidity. A second seven cluster sample was harvested and frozen at -80 °C until analysis for total anthocyanins, phenolics and tannins. Juice was processed immediately after harvest and frozen at -20°F until analysis for YAN using an enzymatic assay for ammonia (r-Biopharm, Germany), and the NOPA assay for primary amines (Dukes and Butzke 1998), and L-malic acid enzyme assay (Megazyme). Total anthocyanins, phenolics, and tannins of homogenized whole berries were determined using the pH-differential method (Lee et al. 2005), Folin-Ciocalteau colorimetric assay (Waterhouse 2002), and the methyl cellulose precipitation assay (Mercurio et al. 2007), respectively.

Objective 2. Determine impacts of timing and intensity of cluster thinning on fruit composition and vine balance in Pinot noir produced in southern Oregon.

A separate trial was conducted in a mature Pinot noir (clone 115, own-rooted) vineyard (Maple Ranch Vineyard) in Cave Junction, OR. Vines were planted in 1989 at 6' vine and 9' row spacing and trained to a bilateral Guyot system. Treatments were applied in a randomized complete block design with a 2 x 4 factorial (2 thinning levels and 4 time points of crop thinning) and compared to full crop control treatments (one with wings removed from all clusters and another left without any thinning). Each treatment plot consisted of six vines, replicated across five blocks. The two thinning intensities included moderate thinning (MT = 1 cluster per shoot) and severe thinning (ST = 1 cluster per two shoots). The non-thinned treatments had no clusters removed, which left approximately two clusters per shoot. All thinning treatments were implemented by the collaborator, Bill Wendover, and staff of Foris Winery.

Vine growth measures were collected at véraison by the Skinkis Lab. Measures included vine leaf area, shoots per vine, clusters per vine, leaf area index and incident sunlight using protocols as outlined in Objective 1. Tissue samples were collected (petioles and leaf blades) at véraison using the protocols outlined in Objective 1 and used for macro- and micronutrient analysis. Funds were not originally requested for these analyses in the 2013 proposal, but this data was analyzed to complete the crop load data set to compare the potential impact of crop load on nutrient reserves across regions. Funds used to analyze 100 samples in 2013 ($3500) were covered by startup funds of the PI.

Fruit was harvested on 14 September 2013, and whole vine yields and clusters per vine were measured. A seven cluster sample was randomly selected from vines and measured immediately for cluster weight, berries/cluster, berry weight, and processed to juice to measure total soluble solids, pH and titratable acidity. An aliquot of juice was collected and frozen at -20°C until analysis for YAN, as outlined in Objective 1. A second seven cluster sample was frozen immediately at -20°C until processing for analysis of total anthocyanins, phenolics and tannins as outlined in Objective 1.

Summary of Major Research Accomplishments and Results by Objective

Objective 1. Determine impact of crop thinning on vine growth and fruit composition of vines with varying vine vigor and tissue nitrogen status.

Vine growth measures during 2013 continued to show the reduced growth based on vine vigor and nitrogen (N) status. The Grass treatment which has been grown with a perennial cover since 2007 continued to show the most reduced growth compared to Tilled and Alternate. Shoot length was shorter in the Grass treatments from 6 May 2013 to the first hedging. Shoot growth rate was reduced in Grass treatments during five of the seven sampling time points (Figure 1). This led to a reduced canopy size by bloom-time in Grass treatments as shoot length was 25% shorter, average leaf size was 18% smaller, and total vine leaf area was 27% smaller compared to the Tilled treatment. Crop level (Full or Half Crop) the prior year did not affect canopy leaf area by bloom in 2013 ($p=0.1772$). By véraison there was no difference in shoot length between treatments ($p=0.1191$). The Grass treatment had less leaf area per vine by véraison; there was 30% less leaf area compared to the Tilled treatment ($p=0.0055$). The reduced leaf area in the Grass treatment was due to a smaller size of primary leaves ($p=0.0003$). Lateral shoot leaf area was reduced in the Grass treatment as well ($p=0.0054$), as there were shorter lateral shoots ($p=0.0128$). It is likely that vine N status or carbohydrate status as a result of main plot treatments had the most effect on this growth as crop level did not influence the total vine leaf area within the main plots ($p=0.50247$).

Solar radiation within the canopy differed depending on the time of day and the position within the canopy. Measurements made at full canopy showed a strong bimodal curve in the fruit zone (Figure 2) with the lowest readings observed around solar noon when the sun was highest in the sky. There were no differences in fruit zone PAR in the morning as vines had leave removed in the cluster zone on the eastern exposure of all treatments per normal production practices. By afternoon, solar radiation reaching the cluster zone was higher in the Grass vines as the vines had less leaf area shading clusters compared to Tilled. Solar radiation reaching the mid-canopy was higher in the Grass vines during the hours of 10 am, 12 pm, 1 pm, and 5 pm. Grass vines had the highest percent of ambient solar radiation in the morning from 9 am to 12 pm. The reduced amounts of solar radiation reaching the inside of Tilled canopies especially in the mid-canopy, can potentially reduce the amount of photosynthesis in the interior leaves. Since Tilled vines have a larger amount of leaf area in the same space within the vine row, more leaves are shaded and under lower light conditions than Grass, likely making a larger percentage of leaves per canopy less productive overall. Leaf gas exchange measures were collected during three time points during the day on five dates from bloom to ripening. These measures were taken to

determine stomatal conductance and photosynthetic assimilation. There were no differences in leaf gas exchange (photosynethic productivity) between crop thinning or tillage treatments for four of the five dates. During one post-véraison measurement, Tilled had greater photoassimilation than Grass in mid-afternoon (2:30-3:00 PM). Measures were taken on fully exposed leaves in the exterior of the canopy, it is assumed that our photosynethic efficiency was greater in the exterior leaves only for the Tilled vines and does not reflect whole vine photosynthetic efficiency. The larger percentage of shaded canopy within Tilled vines are likely less productive compared to leaves in the Grass canopy which was less dense and better exposed to sunlight. The impact of the shade-carbohydrate-nitrogen dynamic is being explored further with respect to bud fruitfulness in a new grant proposed in 2014.

There were differences in actual fruitfulness (number of inflorescences per shoot in spring) based on the vineyard floor management. Shoot number per vine did not differ by treatment, but there were differences in the number of inflorescences per vine ($p<0.0001$) and clusters per vine at harvest ($p=0.0016$). Vines in the Grass treatment had 24% fewer and smaller inflorescences ($p=0.0042$) per vine compared to those vines in the Tilled treatment. The number of florets per inflorescence was decreased 22% in the Grass treatment ($p<0.0001$) compared to the Tilled. The percent of florets that became berries was similar in all main plot treatments, so the effect of having a reduced number of florets per inflorescence was seen as a reduction in the number of berries per cluster at set ($p=0.0023$). Although these differences were observed at fruit set, there were not differences in berry number per cluster by harvest. During the past three years of this research, we have found this phenomenon of reduced florets per inflorescence, and this suggests that vine N or carbohydrates may be playing a role in inflorescence development as the vines shift in vigor and vine N status.

We anticipate differences in vine nitrogen status in 2013 given that lower %N was found in tissues of Grass compared to Alternate and Tilled in Years 1 and 2 of this study. However, nitrogen analysis has not been conducted as of this reporting since the OSU Central Analytical Lab that analyzes the samples had equipment failure, and they will have a new LECO TruSpec CN Analyzer available for analyses in 2014. Coincident with nutrient sampling, we collected vine greenness data (SPAD), which correlates well with nitrogen data based on our prior research. The SPAD data provides an estimate of chlorophyll concentration by measuring greenness, and this is related to nitrogen present in chlorophyll molecules. In 2013, SPAD readings were lowest in the Grass treatments in leaves opposite the basal cluster at bloom ($p<0.0001$), bunch closure ($p=0.0020$), and at véraison ($p=0.0003$). Grass also had lower SPAD readings of apical leaves at both bunch closure ($p=0.0145$) and véraison ($p=0.0004$). It is interesting that SPAD readings decreased in basal leaves from bunch closure to véraison in the Grass treatment only (Figure 3). By the end of the season, grass vines had lost nearly all their leaves (31 October 2013), while Tilled vines had many leaves still attached, some of which were still light green. This early senescence of leaves in the Grass treatment may affect photosynthetic ability and carbohydrate accumulation post-harvest, but was not measured here. This is a component that we are studying further with respect to fruitfulness as a new grant proposal submitted to the Oregon Wine Board was selected for funding in 2014-2015.

Other vine nutrient data were analyzed from bloom and véraison tissues in 2013. There were differences that varied with mineral nutrient, but no clear patterns were found between

main plot vineyard floor treatment and crop level. The most important differences found to date are in the vine tissue N.

Soil moisture was measured at six depths in the soil profile biweekly from 6 May to 11 September 2013. Although there were no differences statistically, there was a trend of less soil moisture in the Full Crop compared to Half Crop treatment, and the difference was more pronounced at depths of 30, 45, and 60 cm. During the period encompassing 7 August to 11 September, vines that were crop thinned had higher soil moisture at the 45 cm depth. Differences were not found among vineyard floor treatments at any depth on any of the 16 dates measured throughout the 2013 season. This is similar to our findings in Years 1 and 2 of this project. There was a significant interaction between the vineyard floor and thinning treatments at 75 cm during 20 May to 24 June 2013. On these dates, the soil moisture readings were higher in the Tilled (Half Crop) than the Tilled (Full Crop) treatments.

Stem water potential (SWP) was measured on the same days as soil moisture, but stem water potential was started later in the season (3 July 2013). There was no difference between vineyard floor treatments on any of the days measured, and the lowest stem water potential was -0.7 MPA during the whole season, indicating that vines were not under significant water stress. Based on these data, the grass cover crop did not compete significantly with the vines for water through this season compared to tilled treatments. There were also no differences in SWP with different crop levels. These results are similar to our findings in prior years of this project (2011 and 2012). Since vine water status and soil moisture were not impacted by the vineyard floor management methods, we attribute our vine vigor differences to vine nitrogen status, resulting in Grass vines having lower N status due to reduced N availability in competition with the grass cover.

Vine yields were influenced by both our main plot and sub-plot treatments (vineyard floor and crop thinning). Grass vines had the lowest yields at 1.68 kg per vine (2.3 T/A) while Tilled vines had the highest yields at 2.06 kg/vine (2.8 T/A) ($p=0.0230$) in 2013. Thinning resulted in a 42% decrease in yield across all main plots. Cluster weights did not differ between treatments and were on average 73.9 g. The number of berries per cluster and berry weight also did not differ between main plot treatments or thinning treatments, indicating that crop thinning did not lead to berry size compensation. The ratio of leaf area to yield was similar across vineyard floor treatments ($p= 0.1812$), suggesting that the vines may have regulated its yield to match the amount of canopy. The amount of leaf area relative to yield was much higher in the thinned treatments as a result of cluster removal. In cool climates, it is suggested that the amount of leaf area relative to yield should be higher than in warmer climates where sun intensity during the season and heat allows for a smaller canopy to ripen the same amount of crop as photosynthesis is increased under those conditions. There was increased TSS ($p=0.0216$) in the Half Crop vines that had 5.22 m^2 of leaf area/kg of fruit compared to the Full Crop vines which had 2.79 m^2 of leaf area/kg of fruit. The difference in TSS between these two treatments was only 0.4 °Brix, and suggests that vines did not require the full 5.22 m^2/kg of leaf area in Tilled vines to fully ripen the fruit. The shading quantified in the Tilled vines may be resulting in a less efficient total leaf area. Grape maturity at harvest did not differ by main plot vineyard floor management for TSS or in pH. Full crop vines had lower pH (3.18) than Half Crop vines (pH=3.23). There were no differences in titratable acidity at harvest across any treatments.

As anticipated, differences in Yeast Assimilable Nitrogen (YANs) were found among main plot treatments as in 2011 and 2012. Both N from primary amino acids and ammonia were significantly reduced in the Grass treatment ($p<0.0001$ for both). The YAN concentrations for fruit from Grass was 75 mg/L, while Alternate and Tilled had 141 and 195 mg/L, respectively. Although the levels of YAN are getting progressively lower in the Grass treatment, they have been able to complete fermentation successfully in our trial winemaking. Crop level also influenced YAN, as there was a slight decrease in N from primary amino acids in the Full Crop treatments ($p=0.0369$), but this did not result in differences in total YANs ($p=0.0847$). In monitoring the evolution of YANs, measured three times during ripening and before harvest, we observed that YANs decreased slightly from ripening to harvest due to a decrease in ammonia.

Polyphenolic compounds were quantified from berries at harvest, and there were some differences found based on main plot treatments and crop level. There were more tannins in the Grass vines when expressed as mg epicatechin equivalents per gram of homogenized berry ($p=0.0428$). However, Half Crop treatments had decreased tannins when expressed in mg/g homogenate and as mg per berry ($p=0.0070$ and 0.0268, respectively). There were only differences in anthocyanins when comparing crop thinning within the Tilled vines: Half Crop fruit had higher anthocyanins (mg/berry) than Full Crop fruit ($p=0.0105$). Total phenolics analysis is still planned for 2013 fruit, but it will be analyzed this winter 2014.

Fruit samples from all three years of this research (2011 to 2013) are currently stored at -80° for analysis by Dr. Jungmin Lee after the completion of the field component of this study. The analyses to be conducted will include detailed polyphenolic compositional analysis, amino acids, and organic acids. Wines were produced after harvest each year from 2011 to 2013 by bulking fruit by treatment. The wine samples are currently stored at OSU under controlled conditions and will be used for sensory analysis by a trained panel. When these data are made available, we will statistically analyze the entire data set to determine impact of the vine balance curve on these fruit and wine characteristics.

Objective 2. Determine impacts of timing and intensity of crop thinning on fruit composition and vine balance in Pinot Noir produced in southern Oregon.

The 2013 season had lower base yields (2.6 T/A) than both 2011 and 2012, but cluster size was larger than 2012. As expected, there were differences in vine yields ($p<0.0001$) and total clusters per vine with cluster thinning treatments (MT and ST). The MT and ST treatments had 73% and 42% of full crop level, respectively in 2013. However, there were no differences observed with cluster weight, berries per cluster, or berry weight by harvest between any of the crop level treatments in 2013. Some research suggests that berry size increases (compensation effect) with early crop thinning; however, based on data from 2011 to 2013, timing of thinning did not influence berry size.

Crop level influenced canopy size in some years. The earlier cluster thinning resulted in slightly higher shoot leaf areas compared to late-season cluster thinning and the non-thinned vines in 2012; however, there were no differences found in vine leaf area or lateral leaf area in 2013 (Table 1). There were no differences in vine pruning weight following 2011 and 2012 seasons; however, we found that the earliest timepoint (flower and fruit set) and most severe cluster thinning treatments resulted in higher pruning weights when compared to full crop vines

(Table 1). These data suggests that higher yields did not inhibit or slow vine growth despite three consecutive years of full crop level or crop reduction. However, with earlier and more aggressive cluster thinning, we are starting to see our first increase in vine size after three years.

The lack of differences found in 2013 may be due to the low base yields of Pinot noir, low Ravaz Index, and the greater degree of ripening that resulted in that season. Based on the yield data across the three years, full crop yields were at 4.4, 3.2 and 2.6 T/A for 2011, 2012, and 2013, respectively. Crop reduction resulted in concomitant reduced yields (Table 1) that resulted in even lower Ravaz indices, suggesting that cluster thinning is not required to attain optimum fruit quality based on the suggested Ravaz for Oregon (3-6).

All treatments were harvested on the same date in 2013 (9/14/2013), within 24 to 48 hours of commercial harvest. Fruit composition analysis indicates that the intensity of cluster thinning was generally more important than the timing. Comparisons were made for both timing and intensity of cluster thinning and compared them to the Full Crop treatment. There were no differences found for fruit composition in 2013, including TSS, pH, TA, YAN, anthocyanins, phenolics, or tannins (Table 2). In other seasons, we found a difference in fruit TSS at harvest when comparing cluster-thinned to full crop (1.4°Brix in 2012). These differences were not found in 2013 possibly due to the warmer season allowing the fruit to ripen further than in other seasons. Some of our prior research and other crop load studies indicate an increase in anthocyanin with a small reduction of yield prior to véraison; however, this was not found in this study during 2013.

Regression analysis was conducted to determine the relationship of vine growth, such as yield, pruning weight, and crop load (Ravaz=yield/pruning weight) on various components of fruit composition. During 2011 and 2012, lower yields and lower Ravaz (lower crop load) led to increased Brix and fruit anthocyanins. However, these same patterns were not observed in 2013. Lack of differences is likely due to greater fruit ripening being achieved prior to harvest than in previous years, and yields were lower than in 2011 and 2012.

To understand how crop level may be influencing vine nitrogen (N) use, we collected measures from various components of the vine, including leaf area, pruning weight, yield, leaf chlorophyll estimation (SPAD), tissue N, and fruit YAN. Tissue N data is currently not available for 2013 as it is pending analysis in summer 2014. However, fruit YAN were able to be compared to vine leaf area, pruning weight, and yield through multiple regressions. The 2013 YAN data indicates that pruning weight ($p < 0.0001$) had the greatest impact on YAN, and there was no influence of crop level (yield/vine) or leaf area. As we obtain the vine tissue N data for 2013, we will be able to investigate this relationship further with the combine vine growth and fruit composition data. Other macro- and micronutrients were analyzed by ICP in 2013, and there were no clear differences found with respect to yield on vine nutrient status. At this point, these nutrition status data suggest that the vines were able to support a full crop to maturity.

Wines were produced by our collaborator, Bill Wendover, after harvest each year. The wines from 2011 and 2012 are currently stored at Oregon State University's research wine cellar under appropriate conditions until they are ready sensory analysis, and the 2013 vintage has been produced and is currently stored at Foris Winery. Sensory analysis has been conducted on the 2011 vintage wines by Dr. Elizabeth Tomasino using a trained panel within the Oregon Wine Research Institute during 2013. The 2012 and 2013 wines will be analyzed after two years of bottle aging for analysis in 2014 and 2015, respectively.

Fruit samples are archived from the 2011-2013 seasons for future analysis (pending funding) by Dr. Michael Qian, professor, OSU Department of Food Science and Technology. The goal is to identify any differences in volatile aroma compounds with changes in yield and/or crop load. The Qian Lab will also analyze wines produced from the three vintages for volatile aroma compounds, again pending funding.

Outside Presentations of Research

The first results from the research have been presented by the PI to peers and industry as research seminars within various events/venues from 2012 and 2013. During 2013, results of the first two years of the study were presented to the Oregon industry at the Oregon Wine Research Institute's Grape Day in April 2013. Presentations were also made at the Wineries Unlimited conference in Richmond, Virginia in March 2013. Seminars were presented to industry during regional meetings throughout the state, and in regional technical group meetings (consisting of industry members) during 2013. Results have been shared with an industry advisory group who has been a part of developing this and other related research projects. Portions of this work were presented at the 2013 American Society for Enology and Viticulture National Conference in Monterey, CA and the 2013 American Society for Horticultural Sciences National Conference in Palm Desert, CA. The PI and PhD student, Alison Reeve, are scheduled to present results from Objective 1 at the American Society for Enology and Viticulture National Conference in Austin, TX in June 2014.

Research Success Statements

This research has been of great importance to Oregon vineyards and wineries as cluster thinning, canopy management, and vigor control are a significant expense to high quality Pinot noir production. There is little scientific data to support the extent to which crop thinning should be practiced for this region. Metrics currently published for vine balance related to good fruit and wine quality include certain ranges of "optimum" leaf area: yield, pruning weight: yield, Ravaz Index, all of which do not fill well with what is observed for Oregon Pinot noir production. The past three growing seasons (2011-2013) proved to be beneficial seasons to conduct this type of work since growers were trying to address the questions of *how much* and *when* to adjust yields through cluster thinning, and there were very different fruit set and base yields observed in those years. This work suggests that cluster thinning can increase basic fruit ripening as measured by our preliminary metrics of global anthocyanins and basic maturity. However, the effect of is realized by only a small reduction in yield in certain years. A universal crop level was not found to be effective in obtaining "optimum" quality during all years of the study, suggesting a much more flexible approach to understanding vine balance rather than simply yield weight during a given growing season.

Fund Status

This study was funded by the Oregon Wine Board for three seasons, starting from August 2011 to August 2014. Funds were used for conducting the experiments during the full growing seasons of 2011, 2012 and 2013. Project objectives were achieved by funding a graduate research assistant to assist with data collection and analysis, purchase of lab supplies, conduct lab analyses, and travel to trial sites as outlined in the original proposal. We will continue to use

funds through August 2014 to finalize lab analysis, data analysis, and begin composition of manuscripts for publication in peer-refereed journal articles.

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Figures and Tables

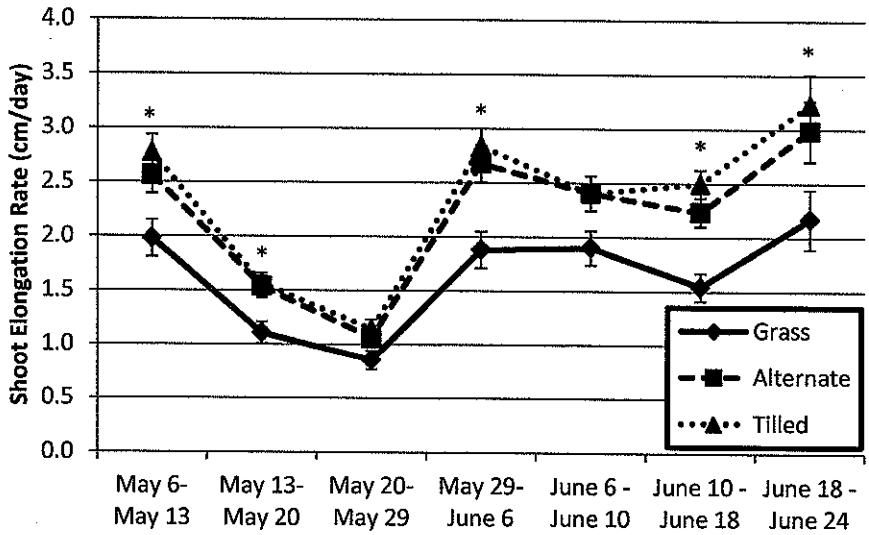

Figure 1. Shoot elongation rate (mean ±SE) measured two weeks post-bud break to the initiation of hedging in vines with different vine vigor levels as a result of vineyard floor management, 2013 (Dayton, OR).

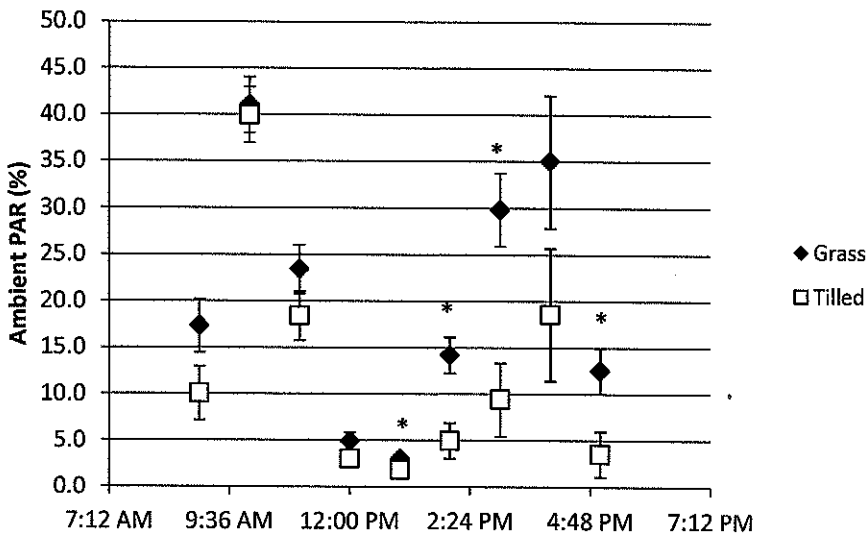

Figure 2. Solar radiation (mean ±SE) reaching the middle of the fruit zone of vines of different vigor levels on 12 September 2013. Values are expressed as percent of ambient PAR (photosynthetically active radiation). *Indicates a difference in means at $p<0.05$.

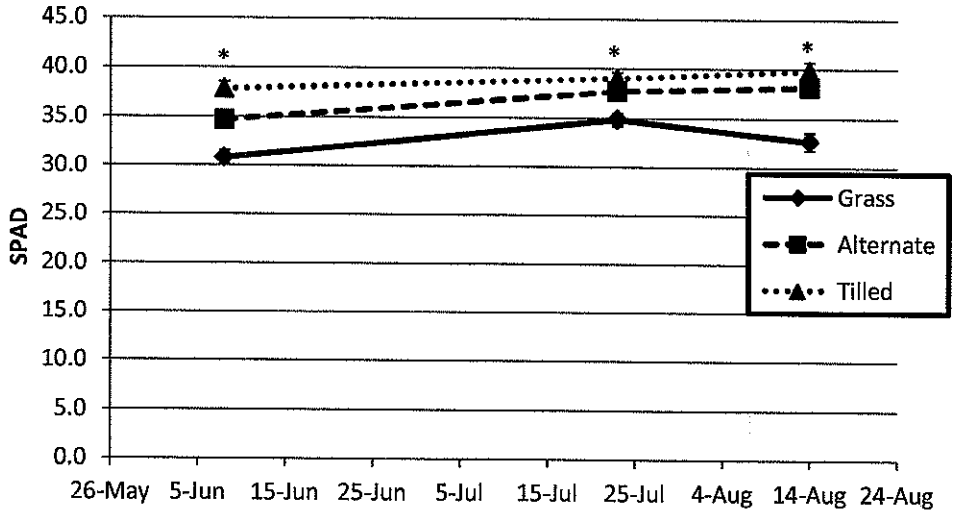

Figure 3. Leaf SPAD measurements (mean ±SE) taken on leaves opposite the basal cluster at bloom, bunch closure, and véraison on vines with different vine vigor levels as a result of vineyard floor management, 2013 (Dayton, OR).

Table 1. Vine yield, leaf area, pruning weight and balance metrics measured from a crop thinning trial conducted in Cave Junction, OR in 2013.

Crop Thinning Treatment	Yield (kg/vine)	Leaf area (m^2/vine)	Pruning weight (kg/vine)	Ravaz
Moderate	2.15	3.6	0.63	3.8
Severe	1.22	3.8	0.68	2.1
Intensity	*<0.0001*	n.s.	n.s.	<0.0001
Pre-bloom	1.68	3.9	0.78	3.0
Fruit set	1.87	3.8	0.64	3.1
Lag phase	1.51	3.5	0.61	2.7
Véraison	1.67	3.5	0.61	3.1
Timing	<0.0001	n.s.	0.0030	n.s.
I x T	ns	n.s.	0.0031	n.s.
Full Crop	2.93	3.7	0.53	6.1
Intensity	<0.0001	n.s.	n.s.	<0.0001
Timing	<0.0001	n.s.	0.0091	n.s.

Crop thinning was conducted at two crop levels (moderate and severe cluster thinning) and four time points (pre-bloom, fruit set, lag phase, and véraison). These were compared to full crop vines. Analysis of variance was conducted using mixed procedures in SAS for a 2 x 4 + 2 factorial design. n.s. indicates no significance ($p>0.05$), and p-values are shown for statistical comparisons where differences were found. The shaded area shows stats where the timing and intensity of crop thinning treatments were compared to Full Crop.

Table 2. Harvest yield and fruit composition from the crop thinning trial conducted with two crop thinning levels and four time points in Cave Junction, OR, 2013

Thinning Group	yield (kg)	TSS (°Brix)	pH	TA (g/L)	YAN (mg/L)	Anthocyanins (mg/berry)	Phenolics (mg/berry)	Tannins (mg/berry)
Moderate	2.15	24.9	3.33	7.1	128	0.52	7.49	7.37
Severe	1.22	24.6	3.35	6.8	135	0.50	7.64	7.25
Intensity	*<0.0001*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pre-bloom	1.68	22.3	3.02	6.6	142	0.51	7.34	6.90
Fruit set	1.87	24.4	3.34	7.2	134	0.52	7.01	7.73
Lag phase	1.51	25.0	3.39	6.7	133	0.50	7.32	7.07
Véraison	1.67	25.1	3.32	6.8	117	0.52	7.83	7.63
Timing	<0.0001	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
I x T	ns	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Controls	2.93	24.0	3.27	7.3	128	0.48	7.90	7.44
Intensity	<0.0001	n.s.	0.0112	n.s.	n.s.	n.s.	n.s.	n.s.
Timing	<0.0001	n.s.	0.0412	n.s.	n.s.	n.s.	n.s.	n.s.

Crop thinning was conducted at two crop levels (moderate and severe cluster thinning) and four time points (pre-bloom, fruit set, lag phase, and véraison). These were compared to full crop vines. Analysis of variance was conducted using mixed procedures in SAS for a 2 x 4 + 2 factorial design. n.s. indicates no significance ($p>0.05$), and p-values are shown for statistical comparisons where differences were found. The shaded area shows stats where the timing and intensity of crop thinning treatments were compared to Full Crop.