Understanding vine balance and cropping levels in Oregon Vineyards

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Summary

Two vine balance studies are being conducted during 2011-2013 to determine the impact of vine vigor, N status, and crop level on fruit composition of Pinot noir in Oregon. A split plot trial is being conducted 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 early season shoot growth, leaf area, photosynthetic assimilation, and pruning weight but led to increases in fruit set, and canopy sunlight infiltration. Differences in vine vigor are attributed to differences in tissue nitrogen status. Both vigor and crop level influenced vine growth and fruit composition in 2012. Leaf area at bloom and véraison were reduced by both main plot and split-plot factors. The Full Crop treatment had reduced early season growth, and the Half Crop vines had increased lateral shoot growth. Fruit ripening was influenced by crop level and vigor. Grass treatments had lower Brix at harvest suggesting an impact on carbohydrate allocation during 2012. Results indicate that there is a curvilinear relationship between vine leaf area/yield and total soluble solids at harvest, with greatest soluble solids being achieved between 2.5 and 3.0 m^2 leaf area per kg fruit. Anthocyanins were influenced by crop level but not vigor level during 2012 as observed in 2011. Despite having increased sunlight infiltration in the canopies of Grass, there was no increase in berry anthocyanins with this main plot factor. A second study was conducted in southern Oregon with two crop thinning levels thinned 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, YANs, or polyphenols. Crop thinning fruit 50% increased SS by 1.4°Brix, increased pH, YAN concentration and decreased TA. Timing had a larger effect on YAN than on any other parameter measured in 2012. These data suggests that reducing yields by more than 50% does not increase Pinot noir ripening and composition of SS, pH, TA, anthocyanins, phenolics or tannins based on results from southern Oregon in 2012. Data analysis is still in progress, and this report provides details on progress to date.

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Objectives and Experiments Conducted to Meet Stated Objectives

Objective 1. Determine impact of crop 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 again rototilled 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 2 PM during bloom, bunch close, and véraison during 2012. 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, 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 tissue nutrient status was assessed by collecting tissue samples at bloom and véraison. A sample of 20 petioles and leaf blades (opposite a cluster) was collected at bloom and

20 leaf blades and petioles were collected at véraison (from leaves opposite a cluster and the most recently expanded leaves) for each plot. Samples collected, rinsed in distilled water and oven dried at 60°C for 48 hours, ground and submitted to Oregon State University's Central Analytical Lab for nutrient analysis (C, N, P, K, Ca, Mn, Mg, Cu, Fe, B, Zn). Funds were requested for only 60 samples per the original proposal, but we wanted to monitor total vine nutrients at both time points and both tissues, increasing total sample number to 120 in 2012, and the extra charge for nutrient analysis was covered by the PI's startup funds. This will allow analysis of the role of crop level and vine vigor level on nutrient status across this and other crop level experiments being conducted.

Fruit was harvested on 10/2/2012 to obtain whole vine yields from each treatment replicate. 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 processed immediately after harvest was frozen and stored at -20°F until analysis for yeast assimilable nitrogen 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 crop 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 (own-rooted) 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 completely unthinned). Each treatment plot consisted of six vines, replicated across five blocks. The two thinning intensity treatments included moderate thinning (1 cluster per shoot, MT) and severe thinning (1 cluster per two shoots, ST). 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.

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 nutrient samples were collected (petioles and leaf blades) at véraison using the same protocols as outlined in Objective 1 and used for analysis of macro and micronutrients. Funds were not originally requested for these analyses in the 2012 proposal, but based on preliminary findings from 2011 and other crop load research being conducted by the PI, we decided to gather this data to complete the crop load data set to compare the potential impact of crop load on nutrient reserves across regions. The funds used to analyze 100 samples in 2012 ($3500) were covered by startup funds of the PI.

Fruit was harvested on 9/30/2012, 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.

Shoot growth was reduced in vines grown with Grass compared to Alternate and Tilled treatments ($p \leq 0.0005$) starting as early as 5/17/2012 and continuing until hedging commenced in mid-July 2012 (Figure 1). Prior to 5/17/2012, differences in shoot length were not due to vineyard floor treatments but due to thinning imposed the following season. Half Crop vines had longer shoots than Full Crop vines post-bud break until 5/28/2012 ($p \leq 0.0040$). This growth response during early season suggests that the tillage and crop level treatments have an influence on stored reserves (carbohydrates and nutrients) which influences early season growth.

This early season growth response was quantified at bloom and véraison. Whole vine leaf areas at bloom differed with vineyard floor treatments ($p<0.0001$) as a result of differences in shoot length ($p<0.0001$), number of leaves, and number of laterals ($p<0.0001$). Differences were not due to shoot number per vine. Grass treatment vines had fewer leaves and 30% smaller leaf size than Tilled treatment vines ($p<0.0001$). Grass vines had 37% lower primary leaf area ($p<0.0001$) and 89% lower lateral leaf area as Tilled vines ($p=0.0011$). Cumulatively, this resulted in Grass and Alternate treatment vines having 40% and 16% less total leaf area than Tilled vines. Vines that had a Full Crop in 2011 had a 10% reduction in the amount of leaf area at bloom compared to Half Crop vines ($p=0.0246$). These data indicate that the 2011 crop levels, which were higher than normal, played an important role in vine growth during 2012.

Vine leaf areas at véraison differed with vineyard floor management. The difference in whole canopy leaf area was due to primary shoot length ($p<0.0001$), primary leaf size ($p<0.0001$), primary leaf area ($p<0.0001$), lateral length ($p<0.0001$), lateral leaf area (<0.0001), and lateral leaf size ($p=0.0002$), number of lateral leaves ($p=0.0004$), and number of laterals per shoot ($p=0.0006$). Crop level did not result in difference in total leaf area per vine at véraison; however there was a difference in lateral growth with Half Crop vines having 19% longer laterals, 20% more laterals per shoot, 11% larger lateral leaves, and consequently 7% more lateral leaf area per vine than Full Crop vines.

Soil moisture was measured during 12 time points in 2012, from 5/25/2012 to 10/10/2012. The only differences were found between thinning level where Half Crop showed higher volumetric soil moisture than Full Crop on 8/6/2012 and 8/29/2012 ($p=0.0460$ and 0.0500 respectively). Stem water potential measured at solar noon throughout the season, showed differences between the vineyard floor management treatments by the end of the season: August 30 ($p=0.0112$) and September 14 ($p= 0.0470$). However, the lowest mean stem water potential

measured was -8.91 bars in Tilled, which is not considered stressed for vineyard production standards. Interestingly, Grass treatment vines had the higher stem water potential readings (lower stress) on these same dates, which is likely due to reduced leaf area in Grass compared to Tilled. No differences were found between treatments when water status was measured at pre-dawn during mid-August; which indicates that water is not the limiting factor causing vine size reduction in Grass treatment vines.

Plant tissue analysis and other measures indicate that nitrogen (N) is the primary factor limiting canopy growth in Grass treatments. Both leaf blade and petiole samples collected at bloom and véraison were lower in Grass treatments than Tilled. Grass results were 0.38%N (petioles) and 2.04%N (leaf blade) at bloom and 0.30%N (petioles) and 1.57%N (leaf blade) at véraison. These N values are considered deficient for grapes, and these findings are in alignment with the reduced canopy size that was observed, reduced YAN, and lower photosynthetic assimilation rates.

Dormant season pruning weights are an important measure of vine vigor that adequately estimate vine size differences between treatments. As expected based on larger canopy size for Tilled vines during the season, Tilled vines had greater pruning weights than Grass vines at 1.99 and 0.96 kg, respectively ($p<0.0001$). Ravaz, a measure of vine balance defined as yield/pruning weight indicates that Tilled has a much lower Ravaz Index (1.27) compared to Grass (2.64) ($p<0.0001$). All vine size measurements show that grass cover can effectively reduce vine vigor and moderate canopy density over time by creating nitrogen competition.

Other interesting vine growth responses were observed with vineyard floor management treatments. There was a reduction in the number of flowers per inflorescence and number of inflorescences per shoot in Grass (Table 1). However, Grass vines had higher percent fruit set compared to Tilled vines (Table 1). At harvest, there were no differences in the number of berries per cluster or weight of clusters, but Grass treatment berries were 0.12 grams lighter than Tilled ($p=0.0201$). Grass and Tilled vines had very similar yields however, 2.473 and 2.476 kg/vine respectively ($p=0.1688$). The only differences in cluster architecture between thinning treatments was a 14% increase in cluster weights of thinned vines ($p=0.0312$) and a 37% decrease in yield ($p<0.0001$).

Three ripening measurements were taken prior to harvest to track soluble solids (SS) accumulation between treatments. During ripening, fruit from the Grass treatment lagged behind other treatments by 0.2-0.9 °Brix, but followed the same ripening curve, suggesting they were accumulating sugars at a comparable rate. Lower SS were found at harvest for the following combinations: Grass vs. Tilled and Full Crop vs. Half Crop vines (Table 2). When the leaf area to yield ratio is compared to SS in 2012, there is a point at which increasing leaf area results in higher SS; however, there is an inflection point in the curve where beyond which there is no increase in SS with reduced yield or increased leaf area. This relationship indicates that ~ 3 m^2 of leaf area per kilogram of fruit was the balance needed for maximum sugar accumulation in this trial (Figure 2). Both pH and titratable acidity (TA) were affected by thinning and TA and malic acid were affected by vineyard floor management. Malic acid was higher for Tilled vines and generally higher malic acid concentrations have been found in more shaded conditions which was observed in the Tilled treatments based on incident PAR received within the canopy and by the cluster zone.

Yeast Assimilable Nitrogen (YAN) was influenced by tillage ($p<0.0001$) and to a lesser extent by thinning ($p=0.0024$). YANs were the lowest in the Grass treatment (58.7 mg/L) as expected given the lower vine tissue N. The Half Crop treatment had 24% greater YAN concentration compared to unthinned vines. The YANs values from this research are much lower than the suggested threshold of 140 mg/L for healthy fermentations. However, stuck fermentations have not been observed in our small lot research fermentations. Regression analysis of YAN and leaf blade %N indicate a strong linear relationship where with increasing tissue N there we can expect increased YAN in fruit at harvest (Figure 3).

Anthocyanins were influenced only by crop level during 2012 whereas both crop level and vine vigor influenced anthocyanins in 2011. Research suggests that anthocyanins are increased with greater sunlight exposure, but despite differences in microclimate with the different canopy sizes in Grass, Alternate, and Tilled, the anthocyanins were not different. Conversely, phenolics and tannins were affected by the main plot vineyard floor management factor (Table 3). For other variables that are influenced by sunlight/shading, such as malic acid, there were differences with canopy shading. Malic acid was highest in the most vigorous treatment (Tilled) and lowest in the least vigorous treatment (Grass), likely due to differences in both canopy and fruit exposure. Fruit from the Grass treatments resulted in higher levels of phenolics and tannins than Alternate or Tilled treatments per gram of homogenate (Table 3). Differences observed for phenolics and tannins may also be due to differences in the number of seeds.

Based on the data from 2012, anthocyanins seem to be less affected by sunlight as we had previously thought (Figure 4). With decreasing vine vigor with the main plot treatments, we had reduced leaf area and increased canopy sunlight infiltration to both the canopy and fruit zone. We hypothesized an increase of anthocyanin concentration due to increased sunlight. Further analyses of archived 2012 fruit by co-PI Lee for detailed polyphenolic analysis will help determine any differences that may be masked in our global whole berry assays. However, we will explore this in more detail from our data sets and our 2013 season to determine if allocations of carbon and/or nitrogen affect polyphenolic levels. Some research suggests that plants "starved" of nitrogen reallocate carbon to produce new roots to acquire more nitrogen rather than investing the resource into secondary metabolites. If this is the case, the Grass treatment vines may be reallocating carbon or N to roots and may explain the impact we see in slightly reduced soluble solids in fruit at harvest.

Fruit samples from the 2011 and 2012 season are currently stored at -80° for analysis by co-PI 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 in 2011 and 2012 by bulking all fruit from the various treatments. These wine samples are currently stored at OSU under controlled conditions and will be used for sensory analysis by a trained panel and used for compositional analysis by Dr. Jungmin Lee. 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 2012 season had lower base yields and smaller cluster weight than 2011. As expected, there were differences in vine yields and total clusters per vine with crop thinning treatments (Table 5). The MT and ST treatments had 49% and 26% of full crop level, respectively. However, there were no differences observed with cluster weight, berries per cluster, or berry weight by harvest between any of the thinning levels (Table 6). Some literature suggests that there is a berry size increase (compensation effect) with early crop thinning; however based on data from 2011 and 2012, there was no influence of timing of thinning on berry size. Despite crop yield differences, there were no differences in pruning weight or cane weight in 2012 (Table 5). This suggests that higher yields did not inhibit or slow vine growth which is in agreement with what was observed in this trial during 2011. There may be differences in vine leaf area; however, those data are still under analysis as of this reporting.

Within the full crop treatments, we assessed whether the presence or absence of wings on clusters had an effect on fruit composition. This work was conducted because the majority of winegrape growers in Oregon remove wings from Pinot noir while crop thinning. Results indicate no differences in fruit composition between clusters with or without wings. There were no differences in basic maturity (SS, pH, and TA), YANs, total anthocyanins, phenolics, or tannins. In addition, we did not find any differences in cluster weight, berries per cluster, or berry weight. The lack of differences observed in 2011 and 2012 for +/- wings may be due to the fact that wing size is highly variable for this clone of Pinot noir, and most wings on clusters are quite small. Due to the lack of statistical differences found between Control and No-wing Control treatments, all data for these "full crop" treatments was pooled for comparison with the thinning treatments.

All treatments were harvested on the same date in 2012 (9/30/2012), within 24-48 hours of commercial harvest. Fruit composition analysis indicates that the intensity of crop thinning was most important when compared to the Full Crop treatment. There were no differences found for fruit composition (SS, pH, TA, YAN, anthocyanins, phenolics, or tannins) between MT and ST treatments which represented 49% and 26% of full crop, respectively (Tables 6 and 7). This indicates that reducing crop levels by more than 50% did not increase fruit quality. However, all thinned treatments show differences when compared to Full Crop treatments, indicating a benefit of crop thinning. The Full Crop treatment had lower total soluble solids (1.4 °Brix), pH and YAN but higher TA (Table 6). There were no differences found for anthocyanin, phenolics or tannin between thinned treatments and Full Crop (Table 7).

Regression analysis was conducted to determine the impact of vine growth, such as yield, pruning weight, and crop load (Ravaz; yield/pruning wt) on various components of fruit composition. With the span in crop level created in the treatments, we were able to identify important relationships. Analysis of total soluble solids indicates a linear relationship with vine yield ($p=0.0005$, Figure 5) and Ravaz ($p=0.002$). With increasing vine yield and increasing Ravaz, there is a decline in Brix. Despite differences observed between treatments, there was a significant relationship for fruit anthocyanin concentration with yield ($p=0.0140$, Figure 6) and Ravaz ($p=0.0133$).

To understand how crop level may be influencing vine nitrogen (N) use, we compared measures from various components of the vine, including leaf area, pruning weight, yield, leaf chlorophyll, tissue N, and fruit YAN. Multiple regression analysis of YAN indicates that pruning weight ($p < 0.0001$) and yield ($p = 0.0005$) had the greatest impact on YAN while leaf blade %N and leaf chlorophyll were not found to impact YAN in the model. This is to be expected in part because yield and pruning weight are whole vine measures while the %N and chlorophyll were measured on the leaf level. However, all components interact in whole plant N use and partitioning. The thinning treatments further describe the impact of crop level on N use. With greater crop level, we would expect a decrease in N components in the vine, and potentially in the fruit. Crop thinning increased YAN compared to full crop (Table 6), and the earliest thinning treatments had 51% greater YAN concentration compared to Full Crop (Figure 7). This suggests a potential benefit of earlier thinning on increased N availability to fruit. This will be further explored through tissue nutrient analysis this winter as it plays a role in fruit N, canopy size, pruning weights, and yields (data not shown, in progress).

Wines were produced by collaborator, Bill Wendover, in fall 2012. The wines will be bottled in winter/spring 2013, and stored under appropriate conditions until they are ready for chemical and sensory analysis. Sensory analysis will be conducted through a trained panel of industry/academics within the Oregon Wine Research Institute.

Fruit samples are archived from the 2012 season 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 2011 and 2012 for volatile aroma compounds.

Data analysis is not yet complete as of this reporting, but the work will continue to identify growth response curves for vine growth parameters and fruit composition.

Outside Presentations of Research

The first results from the research have been presented by the PI to peers and industry as a research seminar in the Oregon State University Department of Horticulture/Crop & Soil Sciences webinar series, three seminars presented to industry during regional meetings throughout the state, and in three regional technical group meetings (consisting of industry members) during 2012. 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 2012 American Society for Enology and Research National Conference in Portland, OR. The PI is scheduled to present this work to peers and industry at the *Wineries Unlimited* conference in Richmond, VA in March 2013.

Research Success Statements

This research has been of great importance to Oregon vineyards and wineries as crop thinning, canopy management and vigor control come at a significant expense to producing high quality Pinot noir. There is little scientific data to support the extent to which crop thinning should be practiced for this region. Metrics currently published for “balanced vines” that correlate to good fruit and wine quality include 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 two growing seasons (2011 and 2012) proved to be highly beneficial seasons to conduct this type of work since growers were trying to address the questions of *how much* and *when* to crop thin, and there were very different fruit set and base yields observed in those years. This work suggests that crop thinning does increase basic fruit ripening as measured by our preliminary metrics of global anthocyanins, tannins, phenolics and basic maturity. However, the effect of crop thinning is realized by only a small reduction in yield, and further reducing crop to very low levels does not linearly increase fruit ripeness.

Fund Status

This study was funded by the Oregon Wine Board for two seasons so far, starting from August 2011–August 2013. The funds were used toward the research beginning in the 2011 season. The project was implemented in 2011 and two years of data have been gathered. Funds for 2012 were used to fund Alison Reeve, graduate research assistant working on this project for her MS thesis, lab consumables, data collection, and fruit analyses, as outlined in the original proposal. We intend to conduct this research for the 2013 growing season, and will continue to seek funding in this funding cycle and the next.

We want to thank 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.

Literature Cited

Dukes, B.C., and C. Butzke. 1998. Rapid determination of primary amino acids in grape juice using an o-phthaldialdehyde/N-acetyl-L-cyseine spectophotometric assay. Am. J. Enol. Vitic. 49:125-134.

Lee, J., R.W. Durst, R.E. Wrolstad. 2005. Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: Collaborative study. J. AOAC International. 88: 1269-1278.

Mercurio, M.D., R.D. Dambergs, M.J. Herderich and P.A. Smith. 2007. High throughput analysis of red wine and grape phenolics—adaptation and validation of methyl cellulose precipitable tannin assay and modified Somers color assay to a rapid 96 well plate format. J. Agric. Food Chem. 55: 4651-4657.

Poni, S.F., L. Casalini, F. Bernizzoni, S. Civardi, C. Intrieri. 2006. Effects of early defoliation on shoot photosynthesis, yield components and grape composition. Am. J. Enol. Vitic. 57:397-407.

Skinkis, P.A.and M. Qian 201X. Vineyard floor management influences vine vegetative vigor and fruit composition of Pinot noir in Western Oregon. *(in progress)*

Vance, A.J. 2012. Impacts of crop level and vine vigor on vine balance and fruit composition in Oregon Pinot noir. MS Thesis. Oregon State University, Corvallis, OR.

Waterhouse A.L. 2002. Determination of total phenolics. *In* Current protocols in food analytical chemistry*;* R.E. Wrolstad (ed.), pp. 461-470. John Wiley & Sons, New York, NY.

Zoecklein B.W., K.C. Fugelsang, B.H. Gump, and F.S. Nury. 1999. *In* Wine Analysis and Production, pp. 511. Gaithersburg, Maryland: Aspen Publication.

Figures and Tables

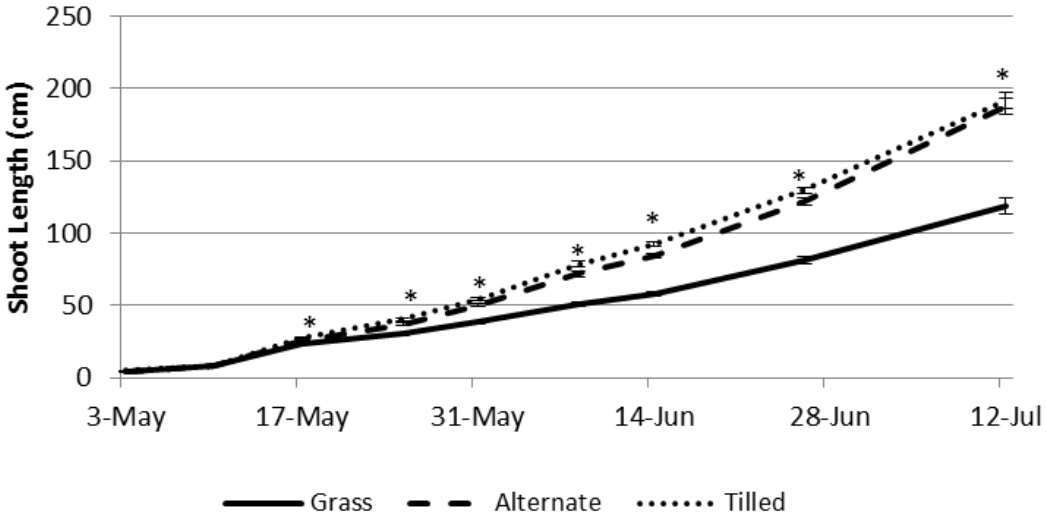

Figure 1. Shoot growth from bud break to first hedging of vines under different vineyard floor management treatments, Stoller Vineyard (Dayton, OR) during 2012. Dates with a * indicate a significant difference between main plot treatments shown at α=0.05. Error bars show standard error.

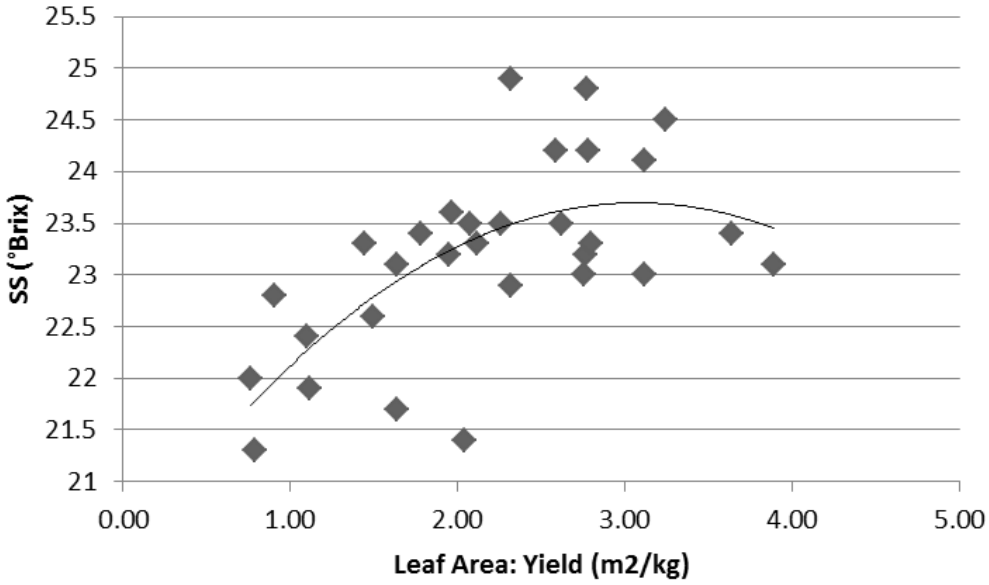

Figure 2. Relationship between leaf area: yield and soluble solids of fruit from different vine size and crop levels at Stoller Vineyard (Dayton, OR) at harvest, 2012. Quadratic regression equation is $y=-0.3673x^2+2.2557x+20.234$, $r^2=0.4378$, p=0.0004.

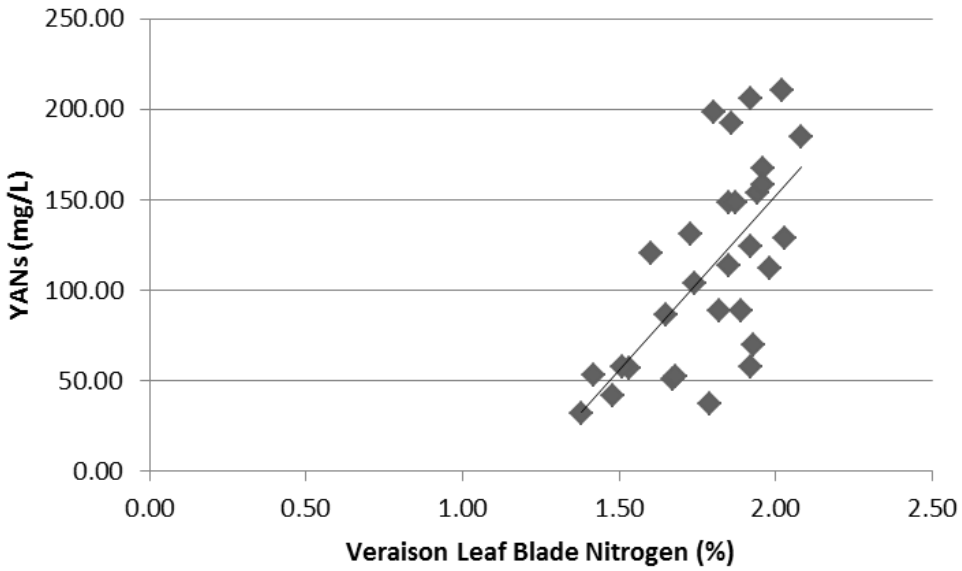

Figure 3. Relationship between leaf nitrogen concentration of apical and basal leaves at véraison and YANs (Yeast Assimilable Nitrogen concentration) at harvest 2012 (Stoller Vineyard, Dayton, OR). Linear regression equation is y=193.11x-233.81, r^2=0.4408, p=0.0001.

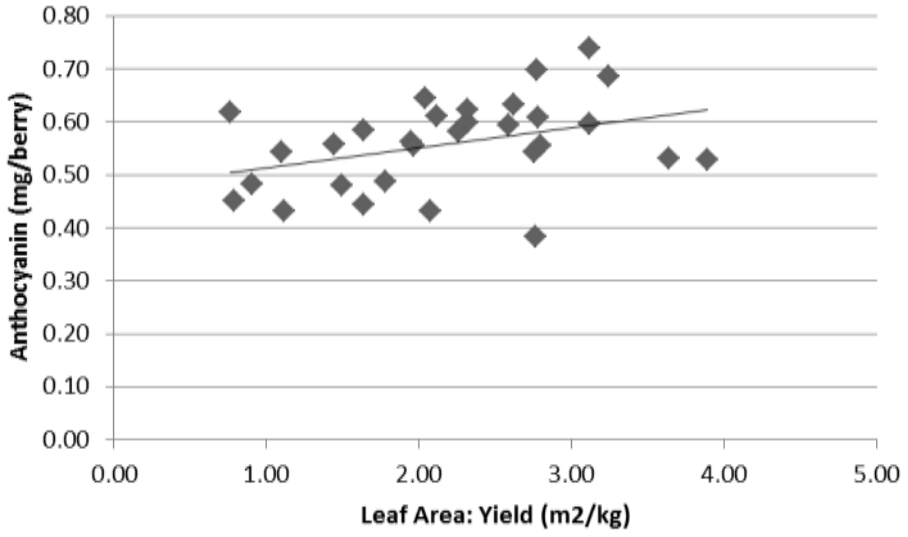

Figure 4.Relationship of leaf area: yield to total anthocyanin content of fruit at harvest 2012 (Stoller Vineyard, Dayton, OR). Linear regression equation is y=0.038x+0.4757, r^2=0.1383, p=0.0430.

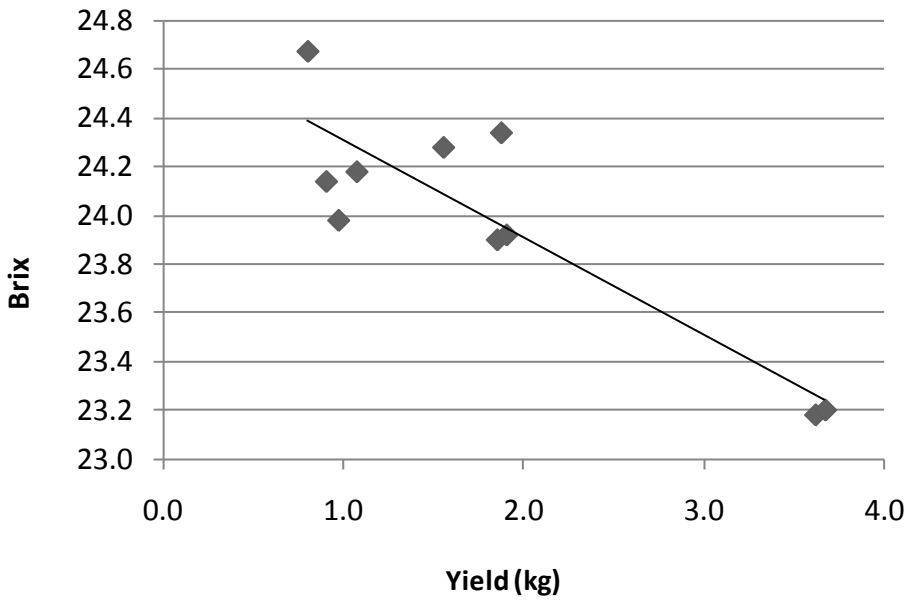

Figure 5. Relationship between vine yield and total soluble solids (Brix) in fruit at harvest (Maple Ranch, Cave Junction, OR). Linear regression equation is y= -0.3992 + 24.707, r^2 = 0.7796, p=0.0007.

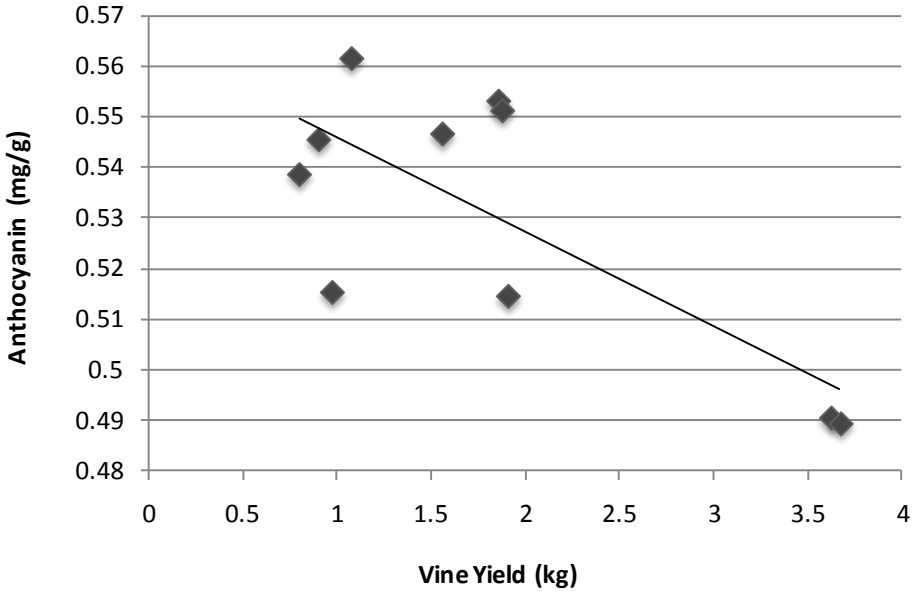

Figure 6. Relationship between vine yield and berry anthocyanin content at harvest 2012 (Maple Ranch, Cave Junction, OR). Linear regression equation is y= -0.0186x + 0.5646, r^2=0.5504, p=0.0140.

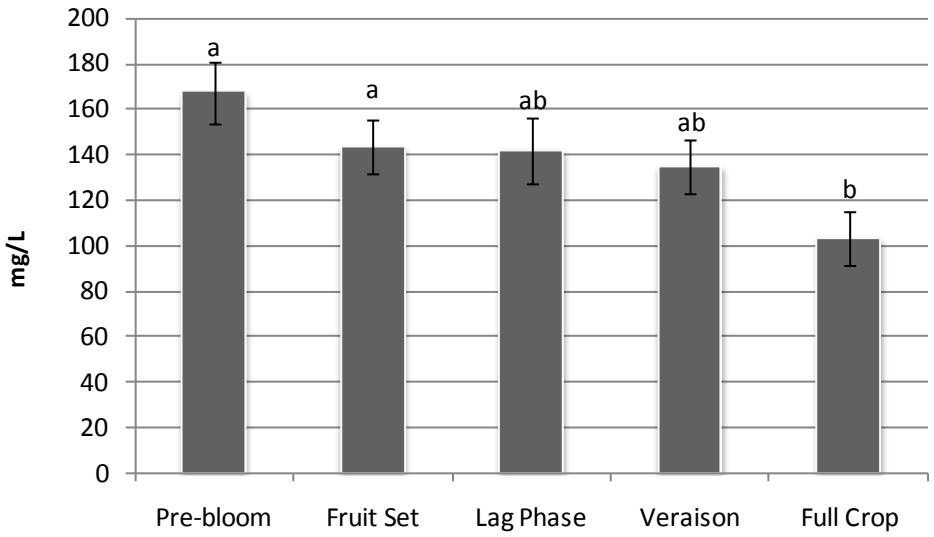

Figure 7. Mean (± SE) yeast assimilable nitrogen concentration (YAN) in fruit at harvest, 2012 (Maple Ranch, Cave Junction, OR). Different letters indicate differences in means (P=0.0353, Tukey). Pre-bloom, fruit set, lag phase and véraison refer to the time at which crop was thinned. Full Crop vines were not crop thinned during the season.

Table 1. Fruitfulness of Pinot Noir clusters with vineyard floor management and crop thinning treatments (Stoller Vineyard, Dayton, OR), 2012.

Factor	Treatment	Flowers/ Inflorescence	Berries/ Cluster	Fruit Set (%)	Shoots/ Vine	Inflorescences/ Shoot
Management between rows	Grass	247 b	109	46 a	22	1.5 b
	Alternate	258 ab	108	48 a	21	1.6 a
	Tilled	275 a	101	39 b	22	1.7 a
Crop Level	Full Crop	256	107	45	22	1.6
	Half Crop	265	105	44	21	1.6
Influence of treatment effects (p)	Tillage	*0.0263*	*ns*	*0.0132*	*ns*	*0.0267*
	Thinning	*ns*	*ns*	*ns*	*ns*	*ns*
	Interaction	*ns*	*ns*	*ns*	*ns*	*ns*

Means followed by different letters are significant at the 0.05 level by LSD. Not significant (*ns*) at α =0.05. Full crop has all clusters remaining; half crop has 1 cluster per shoot remaining.

Table 2. Berry maturity measures at harvest (10/2/2012) for vineyard floor and crop level treatments (Stoller Vineyard, Dayton, OR).

Factor	Treatment	SS (°Brix)	pH	TA (g/L)	Malic Acid (g/L)
Management between rows	Grass	22.7 b	3.26	8.6 b	3.254 b
	Alternate	23.3 ab	3.26	9.4 a	4.020 a
	Tilled	23.6 a	3.31	9.6 a	4.121 a
Thinning	Full Crop	22.6 a	3.24 b	9.4 a	3.830
	Half Crop	23.7 b	3.32 a	9.1 b	3.767
Influence of treatment effects	Tillage	*0.0185*	*ns*	*0.0091*	*0.0052*
	Thinning	*<0.0001*	*0.0003*	*0.0361*	*ns*
	Interaction	*ns*	*ns*	*ns*	*ns*

Means followed by different letters are significant at the 0.05 level by LSD. Not significant (*ns*) at α =0.05. Full crop has all clusters remaining; half crop has 1 cluster per shoot remaining.

Table 3. Total anthocyanins, tannins, and phenolics from fruit at harvest (10/2/2012, Stoller Vineyard, Dayton, OR).

Factor	Treatment	Anthocyanins (mg/g)	Tannins (mg/g)	Phenolics (mg/g)
Management between rows	Grass	0.51	5.84 a	6.91 a
	Alternate	0.48	5.05 b	6.35 b
	Tilled	0.49	4.75 b	6.16 b
Thinning Level	Full Crop	0.47 b	5.14	6.31
	Half Crop	0.53 a	5.28	6.64
Influence of treatment effects	Tillage	ns	*0.0025*	*0.0267*
	Thinning	*0.0398*	ns	ns
	Interaction	ns	ns	ns

Means followed by different letters are significant at the 0.05 level by LSD. Not significant (*ns*) at α =0.05.Means reported in mg/g homogenate as Malvidin equivalents for anthocyanins, -Epicatechin equivalents for tannins, and Gallic Acid equivalents for phenolics. Full crop has all clusters remaining; half crop has 1 cluster per shoot remaining.

Table 5. Vine yield, pruning weight and crop load measures of Pinot noir under different crop levels, 2012 (Maple Ranch, Cave Junction, OR)

	Clusters/ vine	Vine yield (kg)	Vine pruning wt (kg)	Cane wt (g)	Ravaz Index[a]
Moderate	20	1.79	0.58	26.8	3.44
Severe	11	0.94	0.61	28.1	1.68
Intensity	*<0.0001*	*<0.0001*	*ns*	*ns*	<0.0001
Pre-bloom	16	1.41	0.68	30.8	2.46
Fruit set	16	1.49	0.60	26.9	2.64
Lag phase	14	1.23	0.60	27.9	2.41
Véraison	15	1.34	0.51	24.2	2.72
Timing	ns	<0.0001	*0.0121*	*ns*	*ns*
I x T	ns	ns	*ns*	*ns*	*ns*
Full Crop	41	3.65	0.50	20.3	8.24
Intensity	<0.0001	<0.0001	*ns*	*ns*	*<0.0001*
Timing	ns	<0.0001	*ns*	*0.0170*	*ns*

[a]Ravaz = yield (kg)/ pruning weight (kg). P-values are shown in italics. *ns*-not significant at α=0.05.

Table 6. Cluster and berry size and fruit composition of Pinot noir at harvest, 2012 (Maple Ranch, Cave Junction, OR).

	Cluster wt (g)	Berries/ cluster	Berry wt (g)	SS (°Brix)	pH	TA (g/L)	YAN (mg/L)
Moderate	89.9	109	0.99	24.2	3.19	8.0	141
Severe	88.6	112	0.96	24.3	3.22	7.6	153
Intensity	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Pre-bloom	86.8	107	0.97	23.9	3.21	7.9	168
Fruit set	94.9	108	1.00	24.1	3.21	7.8	143
Lag phase	85.7	111	0.97	24.2	3.19	7.9	142
Véraison	89.6	117	0.96	24.5	3.20	7.5	135
Timing	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
I x T	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Full Crop	89.3	116	0.96	23.2	3.10	8.2	103
Intensity	*ns*	*ns*	*ns*	*0.0035*	*<0.0001*	*0.0040*	*0.0278*
Timing	*ns*	*ns*	*ns*	*0.0019*	*0.0049*	*ns*	*0.0353*

P-values are shown in italics. *ns* - not significant at α=0.05.

Table 7. The concentration of total anthocyanins, phenolics and tannins in whole berry homogenates of Pinot noir at harvest, 2012 (Maple Ranch, Cave Junction, OR).

	Wt of 50 berries (g)	Total Anthocyanin (mg/g)	Total Phenolics (mg/g)	Total Tannin (mg/g)
Moderate	51.5	0.54	7.82	2.91
Severe	51.6	0.54	7.66	2.84
Intensity	*ns*	*ns*	*ns*	*ns*
Pre-bloom	51.5	0.53	7.61	2.72
Fruit set	54.0	0.54	7.78	3.03
Lag phase	49.9	0.55	7.88	2.98
Véraison	50.6	0.55	7.67	2.77
Timing	*0.0366*	*ns*	*ns*	*0.0287*
T x I	*ns*	*ns*	*ns*	*ns*
Full Crop	50.8	0.49	7.45	2.86
Intensity	*ns*	*ns*	*ns*	*ns*
Timing	*ns*	*ns*	*ns*	*ns*

P-values are shown in italics. *ns* - not significant at α=0.05.