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Development of Viticultural Practices to Improve Winegrape performance:

Effect of Crop Level on Fruit Composition of Pinot noir Grapes Grown in the Northern and Central Willamette Valley, Oregon

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Introduction

A broad range of factors influence wine grape quality and manipulation of these factors has stimulated interest among grape growers, wine makers, and research scientists alike. One such factor affecting wine grape quality is crop level, particularly for Pinot noir. Since the capacity of a vine to ripen fruit depends largely on the rate of photosynthesis and accumulation of carbohydrates, it follows that a quantitative crop level may be related qualitatively to fruit composition. Heat summation plays an important role in the accumulation of sugar and the rate of other metabolic processes occurring during ripening. In cooler climate regions, some cultivars are slow to ripen and cluster thinning may be employed to advance ripening (14,22). Moreover, of all factors affecting fruit ripening, crop level is the most important one which growers can manipulate (22). Many experiments have been conducted to determine the ideal crop load of several varieties grown in various climates (1,2,3,6,7,8,9,10,11,12,14,15,16,22). Results from these studies showed that the vines exhibited yield compensation, producing larger clusters with larger berries, a trait not necessarily desirable to wine makers. To avoid yield compensation, clusters should be thinned at veraison, after the final number of cells per berry has been established. At this point, further growth is by cell enlargement due to the import of sugars and water. This growth is accompanied by other changes in fruit composition such as a decrease in acid levels, an increase in anthocyanin levels, and changes in aroma and flavor compounds, each contributing to the quality of the grape (Candolfi-Vasconcelos, 1998. Personal communication).

Justification and Significance of Project

Still in its first generation of owners, the Oregon wine industry is relatively young. In the last ten years however, the number of winegrape hectares in production has increased by 208 percent, and sales have increased by 269 percent, contributing more than $115 million to the State's economy (in 1997). Of the hectares planted, Pinot noir now accounts for more than 40 percent (17).

Among the wine-grape varieties, Pinot noir has the reputation of being one of the most challenging, both for the grape grower and the wine maker. Little dispute may be offered that Burgundian Pinot noir are among the best wines in the world. It is not uncommon however, for the Pinot noir of Oregon to rival those of the Burgundy region. The state of New York in 1985, hosted a blind comparative tasting in which wine industry experts placed the five best 1983 Pinot noir wines from Oregon (20).

It is also not uncommon for the quality of these wines to vary with each vintage, as an additional factor influential to ripening is temperature. In cooler climate regions with cold, rainy harvest seasons, where fungus infestation threatens the crop (e.g. the Willamette Valley), cluster thinning is a common practice. This allows the fruit to be harvested before it rots on the vines, while still providing the winemakers with fruit that are worthy for wine production.

Most Oregon wineries prefer to buy grapes from vineyards yielding under 5500 kg per hectare (1.5 to 2.5 tons per acre), encouraging growers to thin their crop to these levels. The inherent trouble with this practice in some cases is too low of a crop level, which may equate with too little revenue for the grower. While this practice is acceptable, an optimal yield for quality and maximum varietal character has yet to be determined, warranting further investigation in this area.

Objectives

To determine the relationship between yield components and fruit composition in Pinot noir.

Materials and Methods

Plot location:

This experiment was replicated at two commercial vineyards, including Temperance Hill Vineyard of Salem (site #1), and Stafford Vineyard of Wilsonville (site #2). The Temperance Hill vines were non-grafted, and were head-trained, cane-pruned Pinot noir (Pomard), with downward growing shoots. The vines were planted in 1981 with a 3.66 x 2.44 meter spacing (12 x 8 ft.) on a Nekia silty, clay loam soil.

At site #2, vines were Pinot noir (Dijon 115), Non-grafted, and trained as a traditional double Guyot. The vines were planted in 1990 with a 1.52 x 1.83 meter spacing (5 x 6 ft.) on an Aloha silt loam soil.

Plot Design:

Site #1- A layout of seven treatment levels x ten single vine replicates was used in a completely randomized design. Seven crop level treatments (25, 30, 35, 40, 45, 50, and 55 clusters per vine) were established by cluster thinning at veraison. Thinning criteria included number of colored berries, cluster structure, and size of the fruit-bearing shoot. Clusters with poor fruit-set and those that were further behind in the ripening process were preferentially removed, as were the clusters hanging from weaker shoots. The treatment level with the maximum number of clusters pre vine (55) was assigned based on the vineyard average of clusters per vine. The average number of clusters per vine was obtained by following a standard cluster count sampling protocol commonly used by viticulturist (23). Minimum treatment level was set at the lower limit of what is an economically feasible crop level, by converting estimated final average cluster weight, to clusters per vine. Final average cluster weight was estimated using a yield prediction method by Price (13) for the Willamette Valley.

Site #2- A layout of five treatment levels x ten single vine replicates was used. Five crop level treatments (15, 20, 25, 30, and 35 clusters per vine) were established by cluster thinning at veraison. Thinning criteria and treatment level determination were identical to procedures outlined for Site #1.

Note: The final cluster count at harvest, which differed slightly from the intended treatment levels, was used in the regression analysis, as this was the most appropriate technique for comparing several levels of a quantitative factor (5).

Yield Components:

The fruit were harvested at maturity, on 15 September, 1998 for site #2, while an unfortunate fungal infestation at site #1 forced an earlier harvest on 10

September, 1998. Maturity can be described as the time when the average berry content of sugar, titratable acids, pH, and other components reach a balance that is appropriate for the style of wine that is to be made (21). To determine this, daily field samples were taken when the berries approached maturity.

At harvest, the remaining clusters were removed from the treatment vines, and were placed into buckets. Mean cluster weight was determined by counting all the clusters and weighing the total harvested crop of each vine using a digital balance (*Acculab® SV-30,* New Town, PA.) in the vineyard. From each vine, randomly selected sub-samples of five and ten clusters were labeled and set aside.

A randomly selected sub-sample of 100 berries from the five-cluster sub-sample was used to calculate the mean berry weight. In order that all the berries could be removed without sustaining any structural damage, the clusters were frozen at -38 °C. Once the berries were removed from the rachis, they were mixed together in a population from which 100 berries were randomly drawn. These berries were weighed and then divided by 100 to obtain the mean berry weight per vine.

The number of berries per cluster was calculated from the cluster weight to berry weight ratio.

A measure of clusters per shoot was calculated from the number of clusters per vine divided by the number of shoots per vine, which were counted and recorded in the field.

Fruit Composition:

After weighing the harvested crop, the berries from the ten cluster sub-samples were crushed to determine °Brix, titratable acidity, and pH of the juice. The berries were crushed in food-grade, 12-L plastic bags. To ensure that each berry was crushed without breaking any seeds, the berries were crushed by hand. The resulting juice was sieved through a Mira Cloth® filter (Calbiochem, La Jolla, CA.) into 120-ml polypropylene containers, and immediately refrigerated to delay oxidation of the juice and allow the precipitation of solids in suspension.

A one-ml sub-sample of the juice was used to obtain values of °Brix. Samples were measured at room temperature using a digital refractometer (*Atago® PR-100,* Tokyo, Japan).

A fifty-ml sub-sample of the juice was used to obtain titratable acids and pH. The samples were measured with an automatic titrator (*Mettler® DL21* , Herisau, Switzerland) to an end-point of 8.2 pH, using 0.92 M NaOH. Values are expressed as mg of tartaric acid per liter of juice.

The previously frozen 100 berry samples were used for anthocyanin analysis. This process involved removing the skin completely from the flesh and pulp of the fruit, and was conducted as outlined by Candolfi-Vasconcelos and Koblet (1990) (4). Samples were measured using spectrophotometry

(*Shimadzu® UV 1601,* Tokyo, Japan). Anthocyanins were determined at an absorbance of 530 nm and concentration was calculated using an extinction coefficient of E 1% = 380 (19).

RESULTS

For practical purposes, parameters from both sites are reported as a function of yield, not number of clusters per vine, as crop is sold by mass, and not cluster number. Figures 1 and 2 illustrate how yield decreased linearly with decreasing clusters per vine. The linear relationships validate the use of yield in place of the treatment levels, by employing a simple linear conversion. In addition, figures 1 and 2 support our hypothesis that yield compensation would not occur if the clusters were thinned after veraison.

Site #1

Fruit composition:

Must soluble solids and pH decreased with increasing yield (Table 1). Soluble solids decreased non-linearly with yield, while the corresponding decrease in pH was linear. The regression model predicts an increase of 0.6 °Brix when yield decreased from 7875 kg/ha to 3375 kg/ha (Table 1). This roughly corresponds to a decrease from 3.5 to 1.5 t/ac, which represents the region's average maximum yield and lower limits on yield respectively. As predicted by the regression model, pH decreased inversely to yield by 0.02 units per 1000-kg/ha increment (Table 1). The effect of yield on titratable acids and anthocyanins was not significant.

Yield components:

Yield components increased linearly with increasing yield. Contrary to what was expected, cluster weight increased 7.1 g per 1000-kg/ha increase in yield (Table 2). While this is not an indication of yield compensation, it does indicate a relationship between yield and cluster weight, even when adjusted after veraison. An increment of 5 berries/cluster corresponds to an increment in yield of 1000 kg/ha (Table 2). The number of clusters per shoot would naturally increase with the corresponding treatment levels, or in this case 0.2 clusters/shoot per increase of 1000 kg/ha (Table 2). No effect of yield on berry weight was observed at site #2.

Correlation of yield components:

In Table 3, the yield component with the strongest correlation to °Brix was yield/vine, closely followed by clusters/shoot. Yield/vine also had the strongest correlation for juice pH. The number of clusters per vine was the largest factor contributing to yield per vine (Table 3). The number of berries per cluster was most strongly correlated to cluster weight (Table 3).

Site #2

Fruit composition:

Must soluble solids and pH decreased with increasing yield (Table 4). Soluble solids decreased non-linearly with yield. The regression model predicts an increase of 1.5 °Brix when yield decreases from 7875 kg/ha to 3375 kg/ha (Table 4). Juice pH decreased non-linearly with yield. An increase in pH of 0.17 was predicted using the regression model when yield was decreased from 7875 kg/ha to 3375 kg/ha (Table 4). Titratable acids increased non-linearly with yield (Table 4). A decrease 0.61 mg/L titratable acid corresponds to a decrease from 7875 kg/ha to 3375 kg/ha (Table 4). There was no correlation between anthocyanins and yield (Table 4). The data in Table 4 indicate a delay in ripening at higher crop levels.

Yield components:

Table 5 illustrates how yield components increased linearly with increasing yield. Again, cluster weight and berry weight unexpectedly increased with yield. The model predicted an increase in cluster weight and berry weight of 4.6 and 0.01 g respectively, per 1000-kg/ha increase of yield. As in site #1, a minimal increase of 3 berries/cluster corresponded to an increase in yield of 1000 kg/ha. A decrease of 0.6 clusters/shoot corresponded to a decrease in yield from 7875 kg/ha to 3375 kg/ha.

Correlation of yield components:

Of the yield components from site #2, cluster weight was most strongly correlated to °Brix and pH, while yield/vine was the largest factor affecting titratable acidity (Table 6). As in site #1, the number of clusters per vine was the largest factor contributing to yield per vine (Table 6) and the number of berries per cluster was more strongly correlated to cluster weight than was berry weight (Table 6).

DISCUSSION

It may be noted that at both sites, change in °Brix was only significant at uneconomical crop levels (≈1125 – 2250 kg/ha or 0.5 – 1 t/ac). At site #2, changes in pH and titratable acids, similarly, were significant only at crop levels considered uneconomical. Although changes in pH at site #1 were linear, they were relatively minimal when compared to loss of revenue due to crop thinning.

In Oregon, Pinot noir sells for $1500 per ton on average, or $1.65 per kg. At site #1, thinning 4500 kg of fruit per hectare corresponded to an increase of 0.6 °Brix and 0.09 pH, for an economic loss of over $7400.00 per hectare. The 4500 kg of fruit represents the total fruit thinned per hectare, from maximum yield, to the "break-even" point for the vineyard. The "break-even" point can be described as the point where it is costing the vineyard more to maintain operations, than it is earning in revenue. In Oregon, this is roughly $5600.00 per hectare (Candolfi-Vasconcelos, 1998, personal communications) At site #2, thinning the fruit down to the "break-even" point would equate with a loss of 6400 kg of fruit per hectare, valued at $10,560.00. In this case, °Brix was increased by 2.0, and pH by 0.2, while titratable acidity decreased by 0.76 mg per liter. While even subtle differences are important to wine quality, they may not justify the loss of over $10,000.00 per hectare.

Similar studies showed mixed results. In a span of over 4 years, one study reported that pH increased minimally with decreasing crop levels, and titratable acidity decreased. In this same study however, soluble solids were shown to decrease with decreasing crop levels, although again, to a minimal degree (3). Another study reported results of increased titratable acidity and pH with decreasing crop levels (16), while still another studied linked increases in soluble solids and titratable acidity, and decreases in pH, to decreases in crop level (14). The underlying similarity in all of these studies suggest that no matter the effect, changes were minimal.

Yield was strongly related to the number of clusters per shoot, but also to the number of berries per cluster. Several studies reported an overall increase in yield components with decreasing crop levels (1, 3, 14, 16, 22), and contributed this phenomenon to yield compensation. The increase in number of berries per cluster with increasing yield may be a result of the increased cluster weight, or biased sampling of berry weight. This statement is most probable for several reasons. First, the number of berries per cluster was calculated by the cluster weight to berry weight ratio. In addition, the number of berries per cluster explains most of the variation in cluster weight at both sites. Moreover, the treatment levels were applied long after berry number per cluster was determined by fruit-set. An increase in cluster weight in this case, would effectively increase the number of berries per cluster. In reality, this is not possible, but an error in sampling might have caused this. Since the clusters were weighed directly, biased or error in sampling may be ruled out for this variable. The only remaining factor used to determine the number of berries per clusters was berry weight. It is possible that biased sampling occurred in the selection of berries used for weight determination. Fewer people worked on this phase of the project and the samples were organized and measured by treatment level, making it the most probable source of error.

Further interest may be taken in the uncharacteristically low values (for Pinot noir) of cluster weight and berries/cluster at site #2. It has been shown that downward growing shoots are less vigorous compared to upward growing shoots (18). Site #1 had downward growing shoots and almost normal cluster weights, while site #2 had extremely loose clusters weighing no more than 40 to 70 grams maximum. Additionally, it was observed during thinning that both sites had the largest clusters on the weakest shoots. Moreover, the first clusters on each shoot were much smaller than the second clusters of the same shoot. These two observations may be related to the timing of bloom and the rate of vegetative growth at this time. Vigorously growing shoots tend to set fruit poorly (Candolfi-Vasconcelos, 1998. Personal communication). Winemakers may ask grapegrowers to thin their vines, sometimes to as low as one cluster per shoot. In a year of poor fruit set such as 1998, this practice would be highly uneconomical.

Due to limited time and funding, no attempt was made to statistically compare the two sites. However, obvious differences in the data raise additional justifications for expanding this study. One such difference would be the increased response in the percent-change for both °Brix and pH at site #2. The percent-change in these parameters at site #1 was half what was observed for site #2. Two factors that may contribute to the large discrepancies between the sites are the age and the spacing of the vines. Not only were the vines at site #2 half as old as those at site #1, they were planted at nearly twice the density as those at site #1. Some further differences that could be studied would include clonal selection and trellis type. Additionally, the soil types vary and may have contributed to measurable differences.

An appropriate factor to consider, if future research is to be conducted, would be to expand the study to include grafted vines. With the discovery of grape phylloxera (*Daktulosphaira vitifoliae*, (Fitch)) throughout the grape-growing appellations of Oregon, the practice of planting on grafted vines is eminent.

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Figure 1: Yield as a function of clusters/vine at Temperance Hill Vineyard

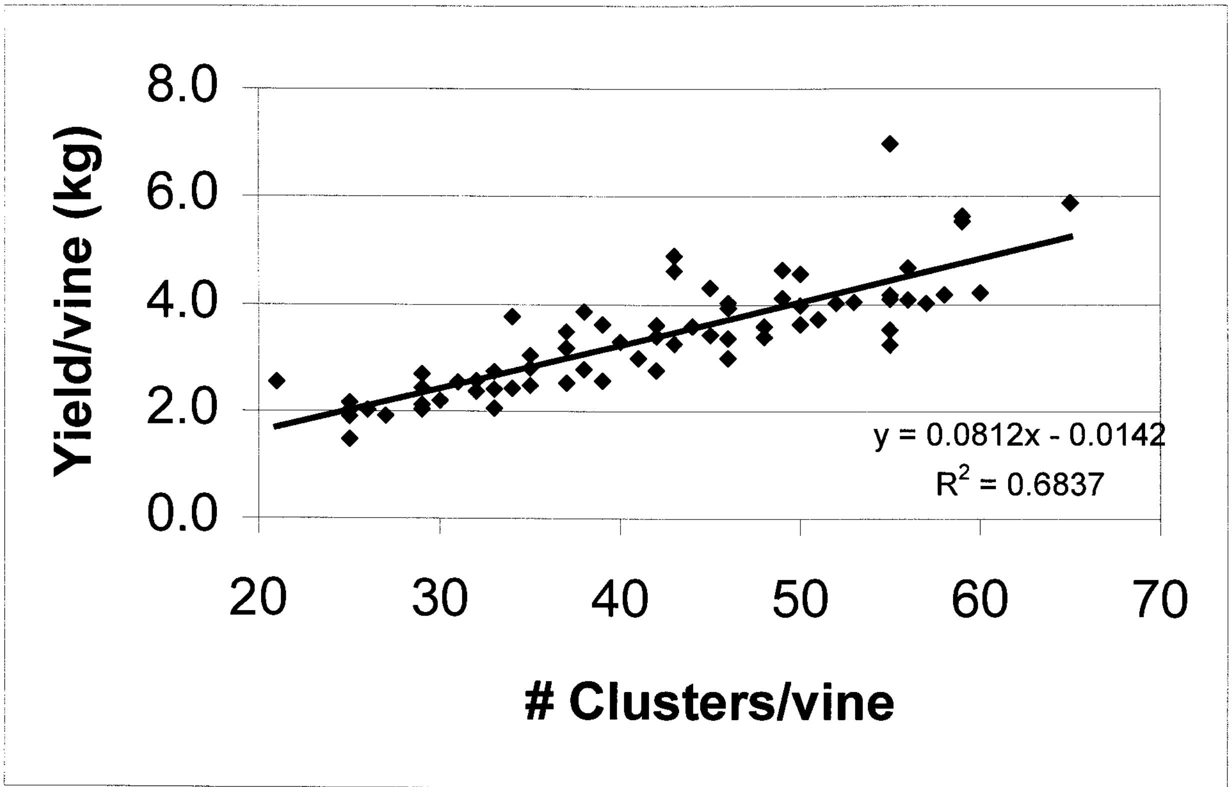
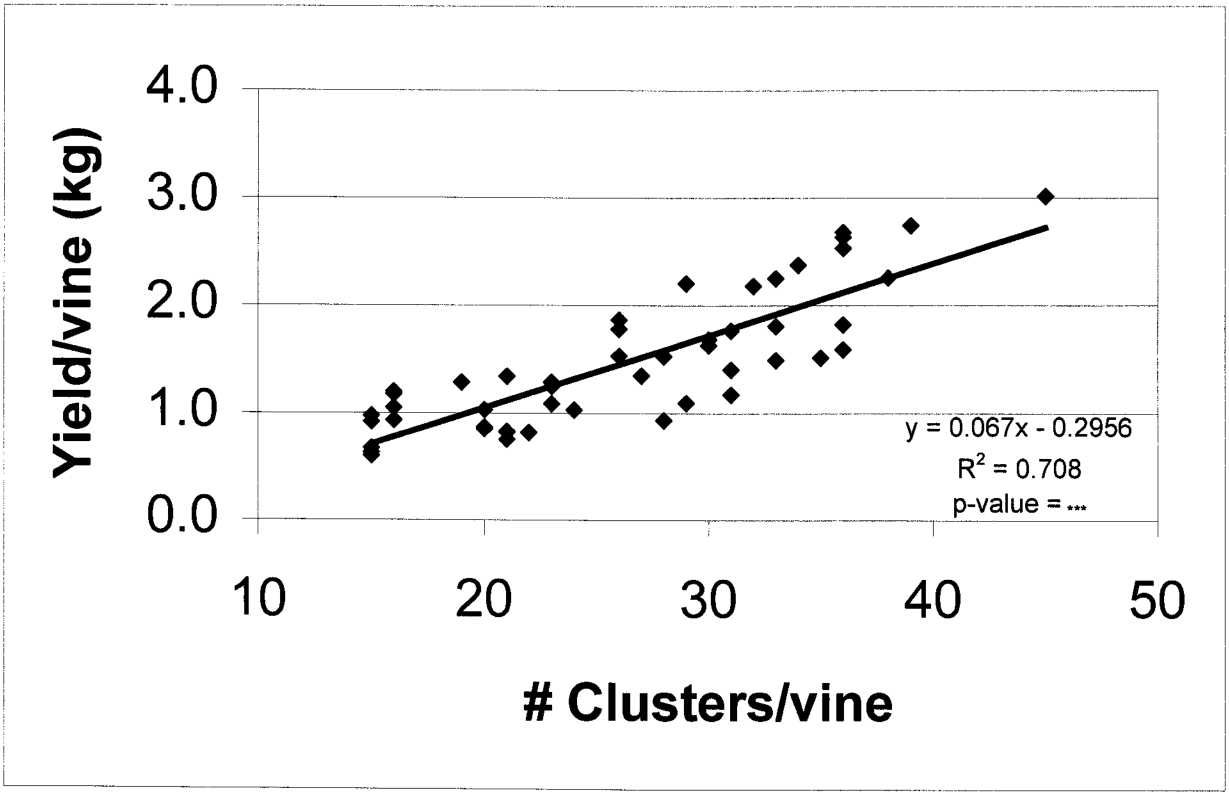


Figure 2: Yield as a function of clusters/vine at Stafford Vineyard



Site #1: Temperance Hill Vineyard

Table 1: Relationship between yield (x = kg/ha) and fruit composition

	Type of Regression	Regression Equation	r^2	p-value
°Brix	Non linear	$y = -0.762*\text{Ln}(x) + 26.694$	0.130	***
pH	Linear	$y = -0.00002(x) + 3.1434$	0.134	***
TA	Linear	$y = 0.0001(x) + 7.5405$	0.028	ns
Anthocyanins	Linear	$y = -0.00001(x) + 1.2492$	0.0102	ns

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.

Table 2: Relationship between yield (x = kg/ha) and yield components

	Type of Regression	Regression equation	r^2	p-value
Cluster weight	Linear	$y = 0.0063(x) + 57.263$	0.276	***
Berry weight	Linear	$y = 0.00001(x) + 1.219$	0.009	ns
Berries/Cluster	Linear	$y = 0.0044(x) + 48.096$	0.169	***
Clusters/Shoot	Linear	$y = 0.0002(x) + 0.4506$	0.567	***

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.

Table 3: Correlation matrix between yield components and fruit composition descriptors of Pinot noir grapevines submitted to varying levels of crop thinning. Data from Temperance Hill Vineyard.

	°Brix	pH	Titratable acidity	Anthocyanins (mg/berry)		Yield (kg/m2)	Cluster weight	Berry weight	Berries/ cluster	Clusters/ shoot
°Brix	1.000									
pH	0.423 ***	1.000								
Titratable acidity (g/L)	-0.361 **	-0.643 ***	1.000							
Anthocyanins (mg/berry)	ns	-0.380 **	0.374 **	1.000						
Anthocyanins (mg/g)	ns	-0.408 ***	0.271 *	0.432 ***	1.000					
Yield (kg/m^2)	-0.345 **	-0.408 ***	ns	ns	ns	1.000				
Cluster weight (g)	ns	-0.241 *	ns	ns	ns	0.531 **	1.000			
Berry weight (g)	ns	ns	ns	0.535 ***	-0.523 ***	ns	ns	1.000		
Berries/cluster	ns	ns	ns	-0.245 *	0.354 **	0.411 **	0.708 ***	-0.561 ***	1.000	
Clusters/shoot	-0.341 **	-0.309 **	ns	ns	ns	0.753 **	ns	ns	ns	1.000
Shoots/vine	ns	ns	ns	ns	ns	ns	ns	ns	ns	-0.308 **

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.

Site #2: Stafford Vineyards:

Table 4: Relationship between yield (x = kg/ha) and fruit composition

	Type of Regression	Regression equation	r^2	p value
°Brix	Non linear	$y = -1.8173*\mathrm{Ln}(x) + 38.338$	0.471	***
pH	Non linear	$y = -0.1949*\mathrm{Ln}(x) + 4.7995$	0.318	***
TA	Non linear	$y = 0.7176*\mathrm{Ln}(x) + 0.6221$	0.265	***
Anthocyanins	Linear	$y = 0.000004(x) + 0.9118$	0.0039	ns

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.

Table 5: Relationship between yield (x = kg/ha) and yield components

	Type of Regression	Regression equation	r^2	p value
Cluster weight	Linear	$y = 0.0041(x) + 33.907$	0.452	***
Berry weight	Linear	$y = 0.00001(x) + 1.1459$	0.047	*
Berries/Cluster	Linear	$y = 0.0028(x) + 30.735$	0.371	***
Clusters/Shoot	Non Linear	$y = 0.7596*\mathrm{Ln}(x) - 5.0861$	0.575	***

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.

Table 6: Correlation matrix between yield components and fruit composition descriptors of Pinot noir grapevines submitted to varying levels of crop thinning. Data from Stafford Vineyard.

	°Brix	pH	Titratable acidity	Anthocyanins (mg/berry)		Yield (kg/m2)	Cluster weight (g)	Berry weight (g)	Berries/ cluster	Clusters/ shoot
°Brix	1.000									
pH	0.698 ***	1.000								
Titratable acidity (g/L)	-0.321 *	-0.374 **	1.000							
Anthocyanins (mg/berry)	-0.366 **	-0.503 ***	ns	1.000						
Anthocyanins (mg/g)	-0.281 *	-0.350 *	ns	0.823 ***	1.000					
Yield (kg/m^2)	-0.622 ***	-0.544 ***	0.458 ***	ns	ns	1.000				
Cluster weight (g)	-0.761 ***	-0.643 ***	0.278 *	0.419 **	ns	0.670 **	1.000			
Berry weight (g)	ns	-0.348 *	ns	0.545 ***	ns	0.285 *	0.389 **	1.000		
Berries/cluster	-0.723 ***	-0.517 ***	ns	ns	ns	0.575 **	0.894 ***	ns	1.000	
Clusters/shoot	-0.314 *	ns	0.295 *	ns	ns	0.763 **	ns	ns	ns	1.000
Shoots/vine	ns	ns	0.279 *	ns	ns	ns	ns	ns	ns	-0.318 *

ns: not significant at the 5% level; *, **, ***: significant at the 5%, 1%, and 0.1% levels, respectively.