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Development of Viticultural Practices to Improve Winegrape Performance

Experiment II: Effect of Crop Level on Fruit Composition of Pinot noir Grapes

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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 (13,17). Moreover, of all factors affecting fruit ripening, crop level is the most important one which growers can manipulate (17). Many experiments have been conducted to determine the ideal crop load of several varieties grown in various climates (1,2,3,6,7,8,9,10,11,12,13,14,15,17). Results from these studies showed that the vines exhibited yield compensation, producing larger clusters with bigger berries, a trait not necessarily desirable to wine makers. To avoid yield compensation, clusters should be thinned at veraison (Candolfi-Vasconcelos, 1998. Personal communication), 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.

Another process occurring simultaneously with fruit ripening is the replenishment of carbohydrate reserves in the permanent structure, crucial for plant survival and yield stability (4). Heavy or unbalanced crop loads affect the level of reserves available in the spring.

To study the effect of cluster thinning on fruit yield, yield components, and fruit composition, the following criteria were observed:

- Fruit composition: soluble solids, pH, titratable acidity, and anthocyanins
- Fruit yield and yield components: cluster weight, berry weight, berries per cluster, and clusters per shoot
- Carbohydrate content of permanent structure (this phase of the project to be completed after pruning)

MATERIALS AND METHODS

This experiment was replicated at two commercial vineyards, including Temperance Hill Vineyard (site #1) and Stafford Vineyard (site #2). The Temperance Hill vines are head-trained, cane-pruned Pinot noir clones (Pomard), with downward growing shoots planted on their own roots. The vines were planted in 1981 with a 12 x 8 ft. spacing on a Nekia silty, clay loam soil. The Stafford vines are Pinot noir clones (Dijon 115), trained as traditional Guyot planted on their own roots. The vines were planted in 1990 with a 5 x 6 spacing on an Aloha silt loam soil.

Plot Design

Site #I- A layout of seven treatment levels x ten single vine replicates were used. 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.

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

The fruit was harvested on September 10, 1998 for site #1 and September 15, 1998 for site #2 (at maturity). Mean cluster weight was determined individually from the harvested crop of each vine. A randomly selected sub-sample of one hundred berries from five clusters was used to calculate the mean berry weight. The number of berries per cluster was calculated from the cluster weight to berry weight ratio. After weighing the harvested crop, the berries from a randomly selected ten cluster sample were crushed to determine °Brix, titratable acidity, and pH. The 100 berry samples were used for anthocyanin analysis. Analysis was performed at the viticulture laboratory using standard methods.

Carbohydrate content of permanent structure

During pruning, wood samples from the trunk will be collected and carbohydrates will be extracted and analyzed using the method described by Candolfi-Vasconcelos and Koblet (1990).

RESULTS:

SITE #1

Fruit composition

Regression analysis shows that 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 3.5 to 1.5 tons/acre (Table 3).

As predicted by the regression model, pH decreased by 0.02 per 0.5 tons/acre increase of yield (Table 3). The effect of yield on titratable acids and anthocyanins was not significant.

Site #1: Temperance Hill Vineyard

Table 1: Relationship between yield (x = Tons/Acre) and fruit composition

	Type of Regression	Regression Equation	R	R^2	p-value
°Brix	Non linear	y = -0.7291*LN (x) + 20.808	0.360	0.130	***
pH	Linear	y = -0.0488x + 3.1488	0.408	0.167	***
TA	Linear	y = 0.3054x + 7.5379	0.177	0.031	ns
Anthocyanins	Linear	y = -0.0072x + 1.2156	0.024	0.0006	ns

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 3: Relationship between fruit yield and fruit composition based on regression analysis.

yield T/Ac	°Brix	Change in °Brix	% Change	pH	Change in pH	% Change
0.5	21.3			3.12		
1	20.8	-0.5	-2.4	3.10	-0.02	-0.8
1.5	20.5	-0.3	-1.4	3.08	-0.02	-0.8
2	20.3	-0.2	-1.0	3.05	-0.02	-0.8
2.5	20.1	-0.2	-0.8	3.03	-0.02	-0.8
3	20.0	-0.1	-0.7	3.00	-0.02	-0.8
3.5	19.9	-0.1	-0.6	2.98	-0.02	-0.8
4	19.8	-0.1	-0.5	2.95	-0.02	-0.8

Yield components

Table 2 illustrates how yield components increased linearly with increasing yield. Contrary to what was expected, cluster weight increased 6.9 grams per 0.5 tons/acre increase in yield. It is unclear why the number of berries per cluster would increase with increasing yield being that the treatment levels were applied long after berry number per cluster was determined. An increase of 5 berries/cluster corresponds to an increase in yield of 0.5 tons/acre. 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 0.5 tons/acre. The degrees of change in these parameters are outlined in Table 4.

Table 2: Relationship between yield (x = Tons/Acre) and yield components

	Type of Regressio	Regression equation	R	R^2	p-value
Cluster weight	Linear	y = 13.803x + 57.58	0.531	0.282	***
Berry weight	Linear	y = 0.0298x + 1.2243	0.089	0.008	ns
Berries/Cluster	Linear	y = 9.6617x + 48.083	0.411	0.169	***
Clusters/Shoot	Linear	y = 0.4513x + 0.4526	0.753	0.567	***

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 4: Relationship between fruit yield and yield components based on regression analysis.

yield T/Ac	Cluster weight (g)	Change in Cluster weight (g)	% Change	Berries per Cluster	Change in Berries/Clstr	% Change	Cluster per Shoot	Change in Clstrs/Shoot	% Change
0.5	64.5			53			0.7		
1	71.4	6.9	10.7	58	5	9.1	0.9	0.2	33.3
1.5	78.3	6.9	9.7	63	5	8.4	1.1	0.2	25.0
2	85.2	6.9	8.8	67	5	7.7	1.4	0.2	20.0
2.5	92.1	6.9	8.1	72	5	7.2	1.6	0.2	16.7
3	99.0	6.9	7.5	77	5	6.7	1.8	0.2	14.3
3.5	105.9	6.9	7.0	82	5	6.3	2.0	0.2	12.5
4	112.8	6.9	6.5	87	5	5.9	2.3	0.2	11.1

Correlation of yield components

In Table 5, the yield component with the strongest correlation to Brix is 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 6). The number of berries per cluster was more strongly correlated to cluster weight than was berry weight (Table 7).

Table 5: Correaltion coefficients of fruit composition to yield components

	Brix		pH		TA	
	Correlation	p-value	Correlation	p-value	Correlation	p-value
Yield/Vine (kg)	-0.345	**	-0.408	***		ns
Clusters/Shoot	-0.341	**	-0.309	**		ns
Clusters/Vine	-0.300	*	-0.304	*		ns
Cluster weight (g)		ns	-0.241	*		ns
Berry weight (g)		ns		ns		ns
Shoots/Vine		ns		ns		ns
Berries/Cluster		ns		ns		ns

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 6: Correlation coefficients of yield components to yield

	Yield/Vine (kg)	
	Correlation	p-value
Clusters/Vine	0.827	***
Clusters/Shoot	0.753	***
Cluster weight (g)	0.531	***
Berries/Cluster	0.411	***
Berry weight (g)		ns
Shoots/Vine		ns

Table 7: Correlation coefficients of berry number and berry weight, to final cluster weight.

	Cluster weight (g)	
	Correlation	p-value
Berries/Cluster	0.708	***
Berry weight (g)	0.171	ns

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

SITE #2

Fruit composition

Similar to site #1, must soluble solids and pH decreased with increasing yield (Table 8). Soluble solids decreased non-linearly with yield. The regression model predicts an increase of 1.5 °Brix when yield decreases from 3.5 to 1.5 tons/acre (Table 10). Juice pH decreased non-linearly with yield. An increase in pH of 0. 16 was predicted using the regression model when yield was decreased from 3.5 to 1. 5 tons/acre (Table 10). Titratable acids increased non-linearly with yield (Table 8). A decrease 0.56 g/L titratable acids corresponds to a decrease from 3.5 to 1.5 tons/acre (Table 10). There was no correlation between anthocyanins and yield (Table 8). The data in Tables 8 and 10 indicate a delay in ripening at higher crop levels.

Site #2: Stafford Vineyards:

Table 8: Relationship between yield and fruit composition

	Type of Regression	Regression equation	R	R2	p value
°Brix	Non linear	y = -1.6991*LN (x) + 24.251	0.668	0.446	***
pH	Non linear	y = -0.1884*LN (x) + 3.2927	0.565	0.319	***
TA	Non linear	y = 0.6668*LN (x) + 6.1871	0.498	0.248	***
Anthocyanins	Linear	y = 0.0061x + 0.919	0.042	0.0018	ns

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 10: Relationship between fruit yield and fruit composition based on regression analysis

Yield T/Ac	°Brix	Change in °Brix	% Change	pH	Change in pH	% Change	TA (g/L)	Change in TA (g/L)	% Change
0.5	25.4			3.42			5.7		
1	24.3	-1.2	-4.6	3.29	-0.13	-3.8	6.2	0.5	8.1
1.5	23.6	-0.7	-2.8	3.22	-0.08	-2.3	6.5	0.3	4.4
2	23.1	-0.5	-2.1	3.16	-0.05	-1.7	6.6	0.2	3.0
2.5	22.7	-0.4	-1.6	3.12	-0.04	-1.3	6.8	0.1	2.2
3	22.4	-0.3	-1.4	3.09	-0.03	-1.1	6.9	0.1	1.8
3.5	22.1	-0.3	-1.2	3.06	-0.03	-0.9	7.0	0.1	1.5
4	21.9	-0.2	-1.0	3.03	-0.03	-0.8	7.1	0.1	1.3
4.5	21.7	-0.2	-0.9	3.01	-0.02	-0.7	7.2	0.1	1.1
5	21.5	-0.2	-0.8	2.99	-0.02	-0.7	7.3	0.1	1.0
5.5	21.4	-0.2	-0.8	2.97	-0.02	-0.6	7.3	0.1	0.9

Yield components

As with site #1, Table 9 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 4.3 and 0.02 grams respectively, per 0.5 tons/acre increase of yield. As in site #1, a minimal increase of 3 berries/cluster corresponded to an increase in yield of 0.5 tons/acre. The number of clusters per shoot increased 0.2 clusters/shoot per 0.5 tons/acre. Tables 11 and 12 delineate the degree of change in these parameters.

Table 9: Relationship between yield (x = Tons/Acre) and yield components

	Type of Regression	Regression equation	R	R2	p value
Cluster weight	Linear	y = 8.5478x + 35.011	0.670	0.449	***
Berry weight	Linear	y = 0.0366x + 1.1304	0.287	0.082	*
Berries/Cluster	Linear	y = 5.581x + 32.231	0.575	0.330	***
Clusters/Shoot	Linear	y = 0.3174x + 0.6154	0.763	0.582	***

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at $p < 0.05$, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 11: Relationship between fruit yield and yield components based on regression analysis

yield T/Ac	Cluster weight (g)	Change in Cluster weight (g)	% Change	Berry weight (g)	Change in Berry weight (g)	% Change
0.5	39.3			1.15		
1	43.6	4.3	10.9	1.17	0.02	1.6
1.5	47.8	4.3	9.8	1.19	0.02	1.6
2	52.1	4.3	8.9	1.20	0.02	1.5
2.5	56.4	4.3	8.2	1.22	0.02	1.5
3	60.7	4.3	7.6	1.24	0.02	1.5
3.5	64.9	4.3	7.0	1.26	0.02	1.5
4	69.2	4.3	6.6	1.28	0.02	1.5

Table 12: Relationship between fruit yield and yield components based on regression analysis

yield T/Ac	Berries per Cluster	Change in Berries/Clstr	% Change	Cluster per Shoot	Change in Clstrs/Shoot	% Change
0.5	3.1			0.8		
1	5.9	2.8	89.4	0.9	0.2	20.5
1.5	8.7	2.8	47.2	1.1	0.2	17.0
2	11.5	2.8	32.1	1.3	0.2	14.5
2.5	14.3	2.8	24.3	1.4	0.2	12.7
3	17.1	2.8	19.5	1.6	0.2	11.3
3.5	19.9	2.8	16.3	1.7	0.2	10.1
4	22.7	2.8	14.0	1.9	0.2	9.2

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 acids (Table 13). As in site #1, the number of clusters per vine was the largest factor contributing to yield per vine (Table 14) and the number of berries per cluster was more strongly correlated to cluster weight than was berry weight (Table 15).

Table 13: Correlation coefficient of fruit composition to yield components

	Brix		pH		TA	
	Correlation	P-Value	Correlation	P-Value	Correlation	P-Value
Cluster weight (g	-0.761	***	-0.643	***	0.278	*
Berries/Cluster	-0.723	***	-0.517	***	0.226	ns
Yield/Vine (kg)	-0.622	***	-0.544	***	0.458	***
Clusters/Vine	-0.316	*	-0.264	ns	0.42	**
Clusters/Shoot	-0.314	*	-0.208	ns	0.295	*
Berry weight (g)	-0.216	ns	-0.348	*	0.176	ns
Shoots/Vine	0.066	ns	-0.085	ns	0.279	*

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

Table 14: Correlation coefficient of yield components to yield

	yield/vine (kg)	
	Correlation	P-Value
Clusters/Vine	0.841	***
Clusters/Shoot	0.763	***
Cluster weight (g)	0.670	***
Berries/Cluster	0.575	***
Berry weight (g)	0.285	*
Shoots/Vine		ns

Table 15: Correlation coefficients of berry number and berry weight, to final cluster weight.

	cluster weight (g)	
	Correlation	P-Value
Berries/Cluster	0.894	***
Berry weight (g)	0.389	**

Significance of t-test: ns denotes non-significance, *, **, and *** denote significant treatment difference at p< 0.05, 0.01, and 0.001 levels, respectively. A negative correlation coefficient indicates that factors change in opposite directions.

DISCUSSION

It may be noted that both sites, change in °Brix was only significant at uneconomical crop levels (0.5 - 1 ton/acre). At site #2, changes in pH and titratable acids, similarly, were significant only at crop levels considered uneconomical. Although changes in pH and titratable acids at site #1 were linear, they were relatively minimal as well when compared to lost revenues due to crop thinning. 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 (16). 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. 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.

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