

## AVF ANNUAL REPORT

February 1, 2002

I. Project Title: Effects of berry size and crop yield on wine composition and sensory quality

II. Principal Investigator: Mark Matthews  
Department of Viticulture and Enology  
University of California, Davis  
Davis, CA 95616  
Tel. (530) 752-2048  
Fax. (530) 752-0382  
mamathews@ucdavis.edu

Co-P.I. Jean-Xavier Guinard  
Department of Food Science and Technology  
University of California, Davis  
Davis, CA 95616  
Tel. (530) 754-8659  
Fax. (530) 752-4759  
jxguinard@ucdavis.edu

Co-P.I. Sue Ebeler  
Department of Viticulture and Enology  
University of California, Davis  
Davis, CA 95616  
Tel. (530) 752-0696  
Fax. (530) 752-0382  
seebeler@ucdavis.edu

Funding for 2001-2002: \$ 33,000

### III. Summary:

The effects of vine irrigation and crop yield on sensory quality of Cabernet Sauvignon wine from the 2000 harvest were investigated using descriptive analysis with a trained panel, quality ratings by members of the wine industry and tannin assays.

Wines produced from vines with low irrigation regimes were rated highest in dried fruit/raisin, jam, and red/black berry aromas, fruity by mouth, and acidity and lowest in brown color. The high irrigation wines were rated lowest in bitterness, ethanol, body, and darkness. The medium irrigation wines were ranked highest in veggie aroma, astringency, brown, dark, body, ethanol, and bitterness and were ranked lowest in cherry aroma. Low irrigation wines received slightly higher quality ratings from members of the wine

industry than high irrigation wines, but the difference was not significant, possibly because of differences among wine replicates.

Lower crop yields tended to produce wines with high bell pepper and black pepper aromas, high astringency and bitterness, and high ethanol and veggie by mouth flavors, whereas the higher yields tended to result in wines with higher red/black berry, jam, and cherry aromas, red color, fruity by mouth, and acidic characters. Tannin concentration was significantly higher in the wines produced from low crop yields, consistent with the higher bitterness and astringency ratings given to those wines by descriptive analysis.

We continued our investigation of the effects of crop yield on wine sensory quality using pruning and thinning trials on Cabernet Sauvignon grapes harvested in 2001.

In the pruning trial, six treatments that left 12 to 48 buds/vine at pruning were imposed for the second consecutive season on the same vines. Vines were pruned to variations of 1 to 4 bud spurs and shoot thinned accordingly. These treatments resulted in 24 to 60 clusters/vine and produced yields that varied almost 2.5 times from lowest (3 tons/acre) to highest (8 tons/acre). In addition to yield components, a number of vegetative growth parameters were measured including budbreak, shoot diameter, and shoot length. There was only a slight decrease in shoot diameter, but shoot length was a strong inverse function of bud number, varying about 100% from highest to lowest bud number per vine. The cluster weight did not differ significantly among treatments. Although berry size was not constant among treatments, the differences were not greater than about 10% and did not show any clear relationship to the crop loads.

In the thinning trial, vines were pruned to 2 or 4 bud spurs that were then cluster thinned at veraison to create 8 different crop load treatments. Crop load in this cluster thinning experiment was well distributed among the 8 thinning treatments, varying about 4-fold from 4 to over 16 lbs. per vine. These crop loads correspond to yields that vary from about 2 tons/acre to about 8 tons/acre. Thus, we were more successful in accomplishing low yield by cluster thinning than by severe pruning. There were 14 replicated yield treatments, six for the second year and eight for the first time in 2001. Wines were made from each treatment, and they are ready for bottling and subsequent sensory and chemical analysis this spring.

#### IV. Objectives and Experiments Conducted to Meet Stated Objectives:

Specific *objectives* for this funding cycle were:

1. From experiments in which wines were made from Cabernet Sauvignon berries of different sizes that were established by differential irrigation and by manual sorting of berry diameter (2000 harvest):
  - a. Determine the effects of berry size on the expression of the tannin-driven sensory qualities of bitterness and astringency, as measured (1) by sensory

- descriptive analysis, and (2) by Doug Adams' protein-based assay for tannins, in the wines produced from different berry sizes.
- b. Determine the effects of berry size on the expression of skin- and pulp-driven varietal flavor characteristics, as measured (1) by sensory descriptive analysis and (2) by GC-MS analysis and quantification of selected flavor compounds in the wines produced from different berry sizes (e.g., fruity and/or vegy varietal characters).
2. Test the hypothesis that wine quality is an inverse function of yield by evaluating the consequences of various crop loads on fruit size, fruit composition, wine composition, and wine sensory attributes in North Coast Cabernet Sauvignon (2001 harvest).
- a. Establish parallel yield trials in which crop load is established by winter pruning and by cluster thinning.
  - b. Evaluate the consequences of different crop loads for vigor, fruit size, sugar accumulation.
  - c. Determine the effects of yield on the sensory characteristics of the wines, as measured (1) by sensory descriptive analysis, (2) by Adams' protein-based assay for phenolics and (3) by Liquid/Liquid Extraction and GC-MS analysis of selected flavor compounds.

*Experiments conducted* were as follows:

1. Experimental wines from the 2000 harvest (made during the prior funding cycle):

Irrigation trial:

Wines were produced at the Robert Mondavi Winery in Oakville from Cabernet Sauvignon grapes grown under three irrigation regimes: (Low) no irrigation added; (Medium) 1.5 gallons/hour (standard), and (High) 3.0 gallons/hour (2X standard). Three wine replications were produced from each set of grapes, for a total of 9 wine samples.

Yield trial:

Cabernet Sauvignon vines at the UC Davis vineyard in Oakville were treated (12-1 bud spurs, 6-1 bud spurs + 6-2 bud spurs, 12-2 bud spurs, 6-2 bud spurs + 6-3 bud spurs, 12-3 bud spurs, and 12-4 bud spurs) to produce six different yields: 2.7, 5.2, 6.2, 7.5, 9.2 and 9.9 tons/acre, respectively. Again, three wine replications were produced from each set of grapes, for a total of 18 samples.

All wines were made using standard practices at the Robert Mondavi Winery (Irrigation samples) and at the UC Davis Winery (Yield samples). All wines underwent malolactic fermentation and were bottled, without any oak contact during the winemaking process.

Descriptive Analysis:

Wines were evaluated by a panel of 13 trained judges in the Sensory Evaluation Laboratory of the Dept. of Food Science and Technology at UC Davis, from March to June 2001. Panelists were selected based on interest and availability, and they were compensated for their participation. The panel went through term generation sessions during which panelists developed a scorecard of descriptors of the sensory attributes in the wines. References were prepared jointly with the experimenters to illustrate each aroma attribute.

Aroma Standards:

Veggie	2.5g chopped asparagus + 2.5g chopped green bean
Bell Pepper	5g bell pepper
Soy/Molasses	2 drops Aloha Shoyu and 1.5g Grandma's "Robust Flavor" Molasses
Black Pepper	Pinch (0.05g) of Safeway Crown Colony Coarse Ground Black Pepper
Earthy/Musty/Mushroom	1 chopped small mushroom from Safeway
Red/Black Berry	5ml fresh Strawberry/raspberry/blackberry juice (runoff through cheesecloth)
Jam/Cooked Berry	1ml of each preserve from Safeway (red raspberry, blackberry, boysenberry, strawberry)
Dried Fruit/Raisin	10 crushed Safeway California seedless raisins

All standards were made in 40 ml base wine (unoaked cabernet sauvignon made by V&E department).

The final scorecard listed the following attributes:

Appearance:

Red color	Brown color	Darkness
-----------	-------------	----------

Aroma:

Volatile acidity	Veggie	Bell pepper
Soy/molasses	Black pepper	Earthy/musty/mushroom
Fresh cherry	Red/black berry	Jam/cooked berry
Dried fruit/raisin		

Flavor by mouth & mouthfeel:

Astringent	Acidic/sour	Hot/ethanol
Body	Black pepper	Fruity
Bell pepper/veggie		

Training sessions followed during which panelists worked as group and then individually to scale attribute intensities. Judge performance during training was monitored by computing standard deviations for the judges and by applying analysis of variance procedures to training data. With this approach, the ability to discriminate among the wines, the reproducibility and the consistency with the rest of the panel can be measured for each judge. Based on these indicators, the panel was deemed ready after a month of training.

Judges rated the 27 wines in triplicate over a period of 18 sessions, with 4 or 5 wines presented per session. Each judge completed 3 sessions per week, over 6 weeks. Sessions lasted approximately 20-25 minutes.

Data from the descriptive analyses were analyzed with the SAS software by analysis of variance (ANOVA) and by Principal Component Analysis (PCA).

Quality ratings by members of the wine industry:

The Grape Expectations Conference, held at UC Davis on April 11 and 12, 2001, was chosen as the setting for the collection of quality ratings by members of the wine industry. Over 200 industry professionals participated.

Quality ratings were collected from the attendees (n=191) for the 9 wines from the irrigation trial. Each person was served 3 wines (a low-irrigation wine, a medium-irrigation wine, and a high-irrigation wine), and was asked to rate their quality on a scale from 0 (lowest quality) to 15 (highest quality).

The wines from the yield trial were available for quality rating in an optional tasting. Only 40 of the participants tasted those wines. Those individuals were served 6 wines (one from each yield treatment) and rated the wines on the 15-point scale.

### Tannin Assays:

Tannin concentration in the wines from both trials were measured using Adams' Tannin Assay, and are expressed as Catechin Equivalents (mg/L).

#### 2. Experimental wines from the 2001 harvest (made during the current funding cycle):

Cabernet Sauvignon vines were grown at the Oakville Experimental Vineyard to produce a range of crop loads by varying buds/vine and by cluster thinning in adjacent experiments. In the pruning trial, six treatments that left 12 to 48 buds/vine at pruning were imposed for the second consecutive season. These treatments resulted in 24 to 60 clusters/vine and produced yields that varied almost 2.5 times from lowest to highest. In addition to yield components, a number of vegetative growth parameters were measured including budbreak, shoot diameter, and shoot length. There was only a slight decrease in shoot diameter, but shoot length was a strong inverse function of bud number, varying about 100% from highest to lowest bud number per vine. In the thinning trial, eight treatments were imposed that left between 12 and 96 clusters/vine after thinning at the onset of veraison. These treatments produced yields that varied almost 4 times, from about 2 to 8 tons/acre. Thus, there were 14 replicated yield treatments, six for the second year and eight for the first time in 2001. Wines were made from each treatment, and they are ready for bottling and subsequent sensory and chemical analysis this spring.

## V. Summary of Major Research Accomplishments and Results (by Objective):

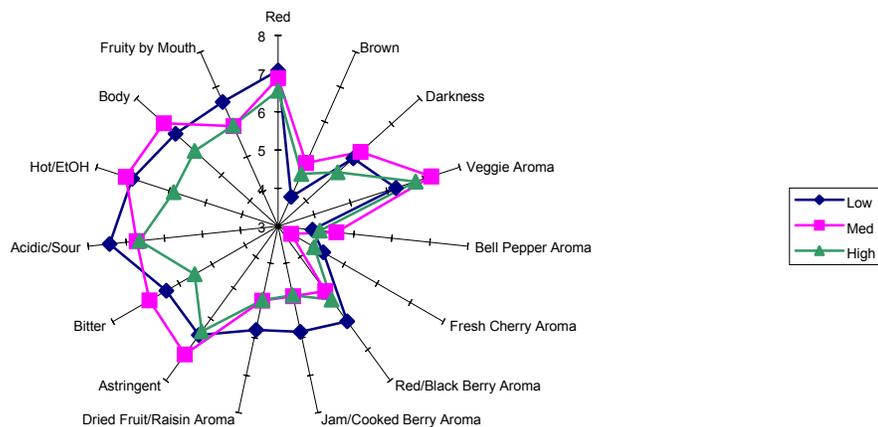
### Objectives 1 (2000 harvest)

#### **Effect of vine irrigation on wine sensory quality**

##### Descriptive Analysis:

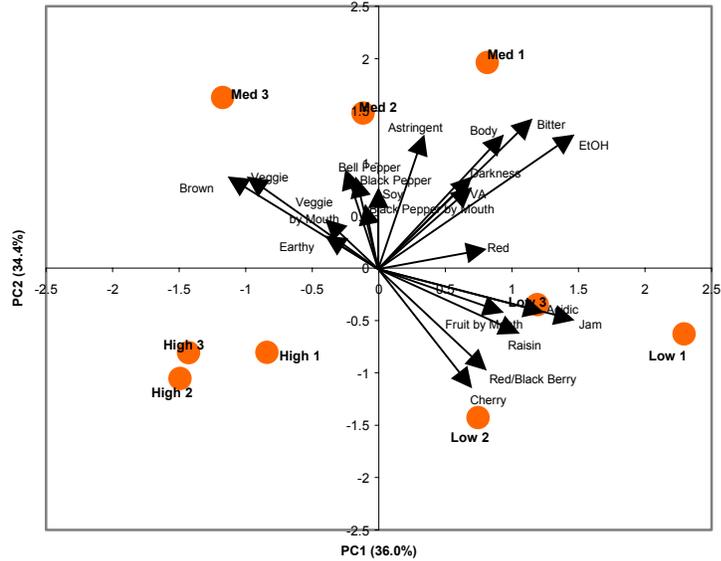
There were significant differences among the flavor profiles of the wines produced from grapes with different irrigation regimes. The spider web plot below shows that the *low irrigation wines were rated highest in dried fruit/raisin, jam, and red/black berry aromas, fruity by mouth, and acidity and lowest in brown color.* The *high irrigation wines were rated lowest in bitterness, ethanol, body, and darkness.* The medium irrigation wines were ranked highest in veggie aroma, astringency, brown, dark, body, ethanol, and bitterness and were ranked lowest in cherry aroma.

**Spider Web Plot of Mondavi wines (attribues which showed significant differences among irrigation treatments)**



The irrigation treatments were well separated as well by principal component analysis (PCA). The first three principal components (PCs) accounted for 36.0%, 34.4%, and 8.5% of the variance. The low irrigation treatments were high in cherry, red/black berry, raisin, and jam aromas, acidic, and fruity by mouth and low in brown color and veggie aroma. The medium irrigation treatments were correlated with bell pepper, black pepper, soy/molasses, and veggie aromas, and astringency. The high irrigation treatments were negatively correlated with bitterness, body, astringency, darkness, and ethanol.

Mondavi 2000 Low, Medium, and High Irrigation Treatments



By ANOVA, 15 of the 21 attributes differed significantly among the irrigation regimes. The three color attributes (red, brown, and darkness) also showed significant differences among wines nested within the irrigation treatments. This shows that the winemaking replications within each treatment may have produced significant color variation. Judges were a significant source of variation for all the attributes. This is expected for this type of panel work. Judge replications were significantly different for only two attributes, volatile acidity and dried fruit/raisin aroma. The volatile acidity judge by replication significance could have been avoided by spot checking each bottle for defects.

Quality ratings:

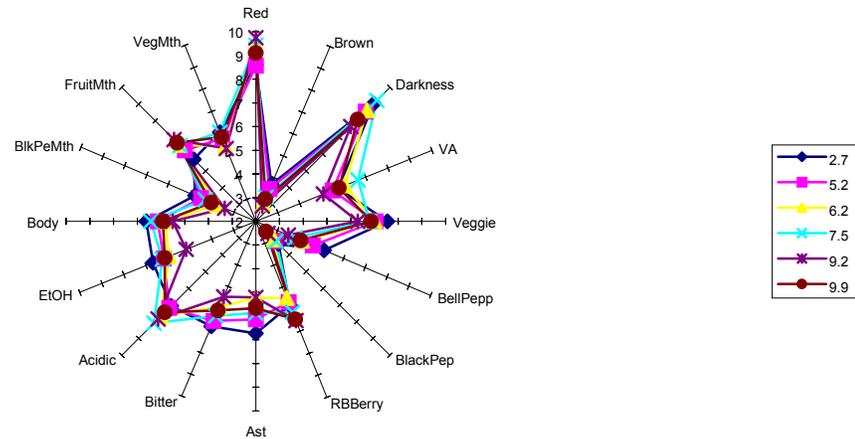
By mixed model ANOVA on the entire irrigation data set, no significant differences were found between irrigation treatments ( $p=0.5903$ ). Significant differences were found among wines nested within irrigation treatment and set of judges ( $p=0.0004$ ). On average, the quality scores for the low irrigation treatments were higher than the quality scores for the high irrigation treatments.

## Effect of crop yield on wine sensory quality

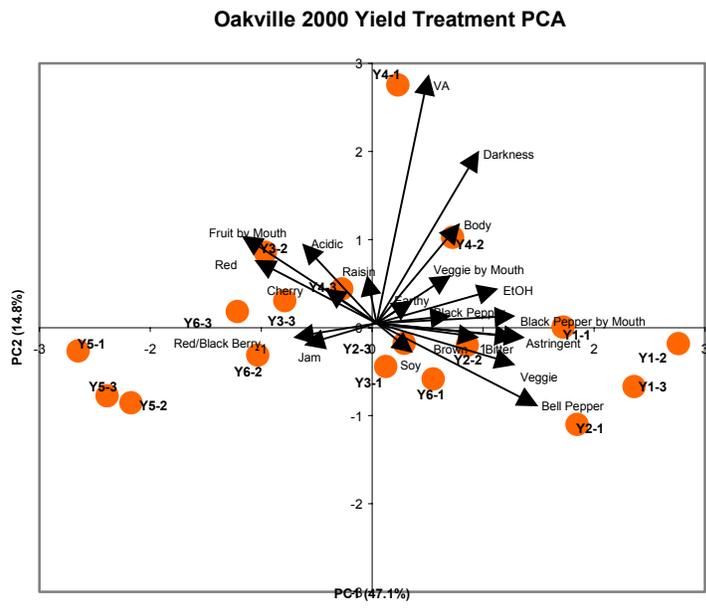
### Descriptive Analysis:

Sixteen of the 21 attributes separated the yield treatments by ANOVA. The differences in the mean intensity ratings for the three treatments are shown in the spider web plot below. In general, the lower crop yields tended to produce wines with high bell pepper and black pepper aromas, high astringency and bitterness, and high ethanol and veggie by mouth flavors, whereas the higher yields tended to result in wines with higher red/black berry, jam, and cherry aromas, red color, fruity by mouth, and acidic characters. There were significant differences among wines nested within yield treatments for red color, darkness, VA, veggie aroma, and fruity by mouth. There were other significant differences in judge replications, judges, and interaction terms, just as in the irrigation experiment.

**Spider web plot of yield treatments (only attributes which showed significant differences between yield treatments)**



The yield treatments were somewhat grouped by PCA (not nearly as nicely as in the irrigation PCA). The first three PCs accounted for 47.1%, 14.8% and 8.7% of the variance. The first PC separated wines that were high in bell pepper and black pepper aromas, astringency, bitterness, ethanol and veggie by mouth from wines that were high in red/black berry, jam, and cherry aromas, red color, fruity by mouth, and acidic. The second PC separated wines that were high in volatile acidity and darkness from those that were not. In general, the lower yield treatments tended to fall on the positive end of PC1 (high bell pepper and black pepper aromas, astringency, bitterness, ethanol and veggie by mouth) while the higher yield wines tended to fall on the negative end of PC1 (high in red/black berry, jam, and cherry aromas, red color, fruity by mouth, and acidic). Wine 10 (7.5 tons/acre, rep1) was high on PC2; its mean VA rating was much higher than the other wines, suggesting problems with winemaking for this sample.



Tannin Assays:

The yield treatments had a significant effect on the tannin concentration in the wines. As shown below (means and std deviations in mg/L of Catechin Equivalents), tannin concentration decreased significantly as yield increased.

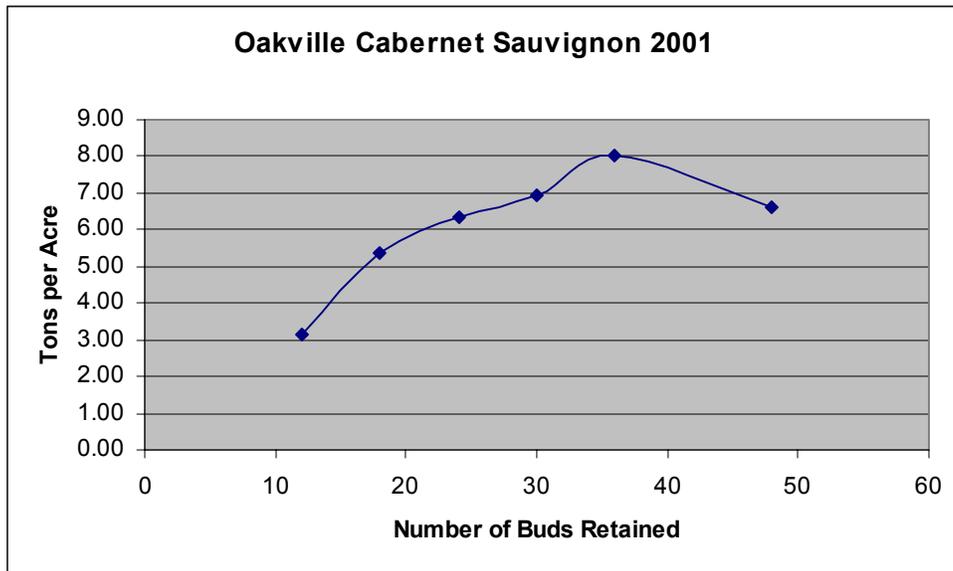
Yield	LOW	→		HIGH
Catechin	301 +/- 56	198 +/- 32	152 +/- 13	99 +/- 25
			99 +/- 25	113 +/- 5

These results are consistent with the descriptive analysis findings of higher bitterness and astringency in the low yield wines.

Objectives 2 (2001 harvest)

**Yield treatments via pruning:**

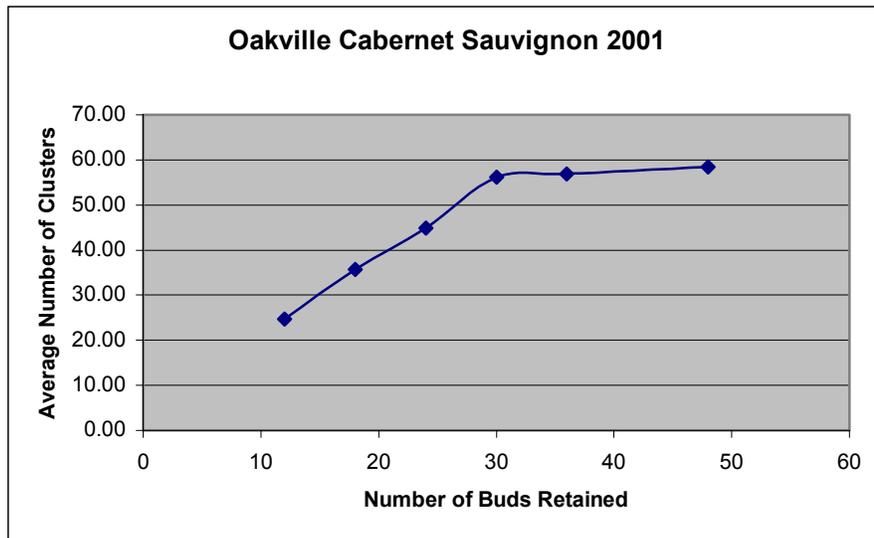
This experiment was conducted for the second consecutive season on the same vines. Vines were pruned to variations of 1 to 4 bud spurs and shoot thinned accordingly. The crop load treatments imposed by pruning caused final yields to vary from about 3 to 8 tons/acre, a range of over 2.5-fold. This range of yields is less than in the previous (first year) of imposing these treatments. Yield did not differ between the two highest crop load treatments.



Yield (tons/acre) for vines pruned to different buds/vine for the second consecutive year.

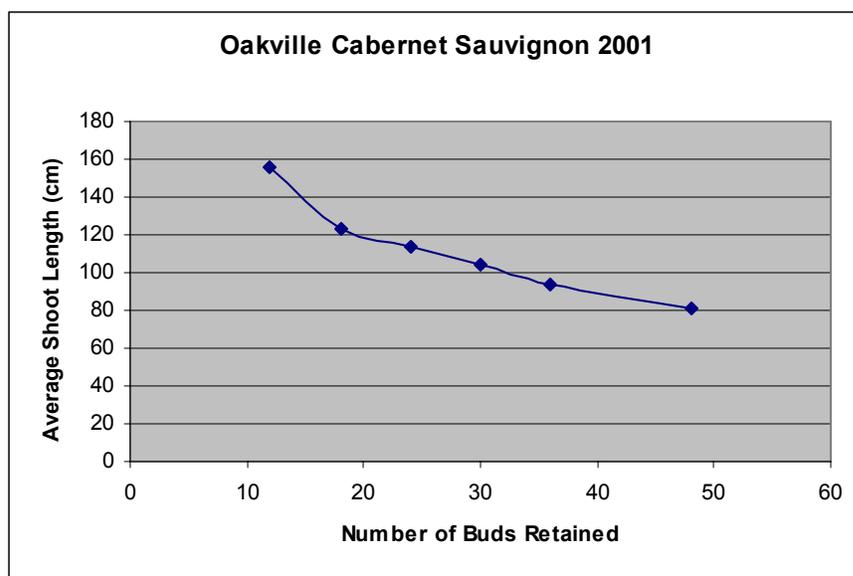
The number of clusters/vine increased with buds/vine up to about 55 clusters at 30 buds/vine and remained at about 55 clusters as buds/vine increased on to 50 buds/vine. Thus, in the second year a decrease in fruitfulness of shoots on vines pruned to high crop loads was observed compared to the first year.

The cluster weight did not differ significantly among treatments. Although berry size was not constant among treatments, the differences were not greater than about 10% and did not show any clear relationship to the crop loads.



Clusters/vine for vines pruned for the second consecutive year to various numbers of buds per vine.

There were several interesting vegetative responses to the pruning treatments. The shoot length decreased with increasing buds/vine. Budbreak was inhibited in the treatments with high buds/vine. On one sampling date, budbreak was 95% on vines with 10-20 buds/vine and only 10-20% on vines with 36-48 buds/vine. The low bud count vines also had about 20% more "water sprouts"/ vine than the high bud count vines. The maximum shoot length was about 160 cm and the minimum was about 80 cm, indicating a high sensitivity of shoot length to pruning level and perhaps to crop load. There were no clear differences in internode length. However, the radial growth of canes was also affected. Canes on low yield treatments were 30-35% greater in diameter at basal internodes than canes on the high yield treatments.

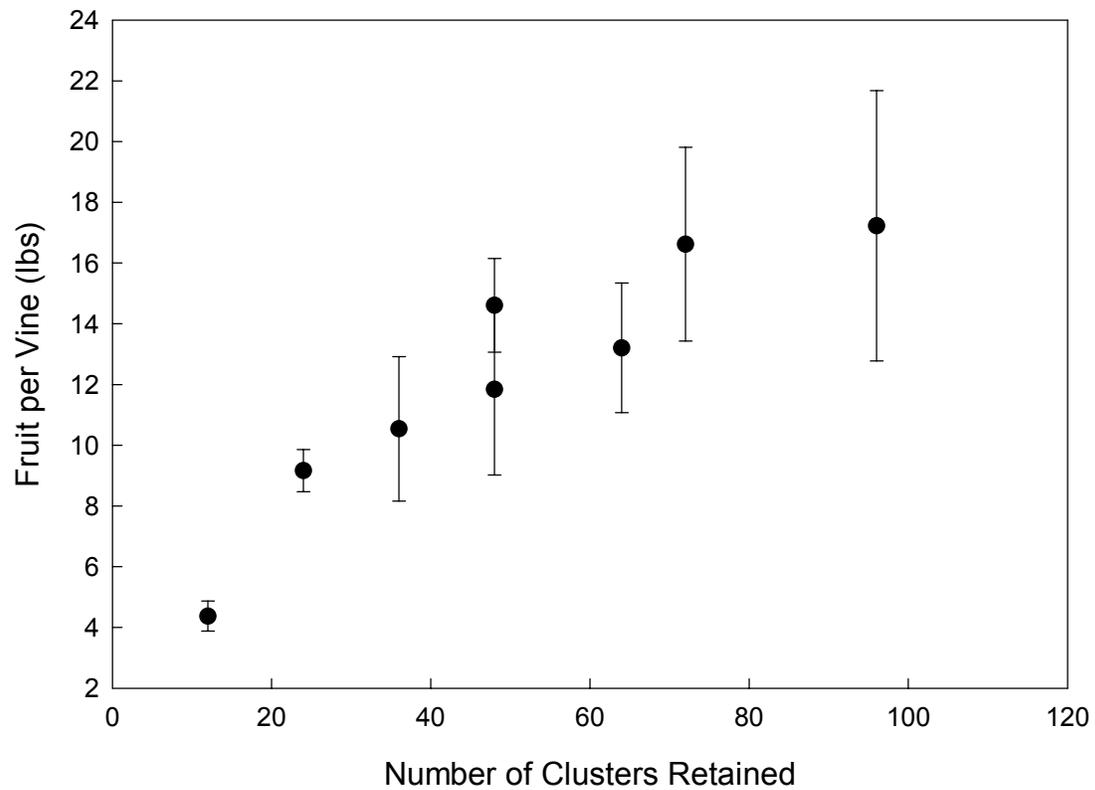


Shoot length of vines pruned to various numbers of buds per vine.

#### **Yield treatments via cluster thinning:**

This was the first season for this trial. Vines were pruned to 2 or 4 bud spurs that were then cluster thinned at veraison to create 8 different crop load treatments. Crop load in cluster thinning experiment was well distributed among the 8 thinning treatments, varying about 4-fold from 4 to over 16 lbs. per vine. These crop loads correspond to yields that vary from about 2 tons/acre to about 8 tons/acre. Thus, we were more successful in accomplishing low yield by cluster thinning than by severe pruning. However, yield did not differ between the highest 2 crop load treatments. Variability in the yield increased with the number of retained clusters. The intermediate crop load (clusters/vine) was created in both 2 and 4 bud, spur-pruned vines. The vines with 4-bud spurs had less yield than the vines with 2-bud spurs, although all of those vines were thinned to the same number of clusters/vine.

## Oakville Cabernet Sauvignon Thinning 2001



Crop yield (lbs. per vine) for 8 different cluster thinning treatments imposed at veraison in Cabernet Sauvignon at the Oakville Experimental Vineyard in 2001.

The wines made from these grapes have just undergone malolactic fermentation and they will be bottled in February of 2002.

## VI. Outside Presentations of Research:

Results of the descriptive analysis, quality ratings and tannin assays for the 2000 experimental wines will be presented at the Annual Meeting of the American Society for Enology and Viticulture, in Seattle, June 2002, and at the Annual Meeting of the Institute of Food Technologists, in Anaheim, June 2002 (acceptance of abstracts pending).

David Lum, who conducted the sensory work on the 1999 experimental wines, completed his Master's Thesis entitled "Effects of Berry Size and Crop Yield on Wine Sensory Quality" at UC Davis.

We are in the process of writing publications for submission to the American Journal of Enology and Viticulture.

## VII. Research Success Statements:

This research is providing grape growers and winemakers with valuable data regarding the link between viticultural practices and wine quality. Specifically, it is showing that low irrigation, even though it is associated with lower yields, can result in wines with desirable sensory properties of increased fruity characters. Furthermore, this research is shedding valuable light on the notion that wine quality is inversely related to crop yield. There seems to be some truth to this statement, yet we believe that there may be a yield cut-off point where quality starts to drop as crop yield continues to increase, and we are poised to find it with the last set of experimental wines produced in 2001.

## VIII. Funds Status:

The funding awarded to this project was \$33,000. The funds were used to cover the Graduate Research Assistantship of Dawn Ahlgren, Ph.D. Candidate, for this academic year. Dawn Ahlgren conducted the descriptive analysis of the 2000 wines, started setting up instrumentation for the GC-MS work, and assisted with field work and winemaking. Undergraduate Research Assistants (Jay and Brennen) carried out most of the vineyard and winemaking operations, under the supervision of P.I. Mark Matthews. Supplies were purchased as planned for the field work, winemaking, descriptive analysis and instrumental set up. Judges in the descriptive analysis of the 2000 wines were compensated as planned.

Because this research project was funded at 72% of the proposed budget, P.I. Mark Matthews was not able to hire a technician for the field work and winemaking. Even though our undergraduate assistants did an outstanding job at both, they could not commit all their time to this project because of coursework and off-campus jobs. That probably jeopardized the quality of the research (e.g., some problems occurred in the vineyards and in the winery, resulting in loss of grape samples from contaminated vines,

and of wine samples from contaminated fermentations, or delayed bottling because of sluggish malolactic fermentations).

As of February 1, 2002, three quarters of the funds have been spent, with the remaining quarter allocated to Dawn Ahlgren's research assistanship for the remainder of the year, and to expenses associated with descriptive analysis and instrumental flavor analysis to be carried out this Spring. All funds will be spent by the end of the funding cycle.