Lodi Woodbridge Winegrape Commission
COMPREHENSIVE PROJECT REPORT 1997

PROJECT TITLE: Vegetative Effects of Long Term Water Deficits on Cabernet Sauvignon

PROJECT PERSONNEL:

Principle Investigator:
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Cooperators:
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Involvement of Investigators:

T. Prichard (10% of time). Coordinate project activities. Direct Staff Research Associate and Post Graduate Researcher activities in collection of data, analysis of data and preparation of reports.

P. Verdegaal (5% of time). Direct viticultural operations. Plan and supervise collection of vine physiological data.

All investigators will cooperate to determine treatments and provide a meaningful report.

OBJECTIVE:
Measure long-term physiological effects of water management regimes on vine vegetative growth.

BACKGROUND:
An experiment designed to evaluate the timing and severity of water deficits on the fruit and wine quality of Cabernet Sauvignon was conducted for five years. The mature Cabernet vineyard was on Dogridge rootstock and bilateral-cordon trained at 7½ x 11-ft spacing. All treatments are pruned alike at 20, 2-bud spurs per vine. The soil at the site has a moderate water-holding capacity with a root-limiting layer near six feet. A full-coverage microsprinkler irrigation system is used to supply water to each replicated treatment independently. The well water supply is of good quality and contains less than 150-ppm total dissolved solids. The experimental design is a randomized block of 5 treatments containing 4 replications of each treatment. The experimental site is located near Lodi, California.

Project Chronology
The study was initiated in 1992 with the imposition of 5 irrigation strategy treatments. Treatment 1 was supplied with adequate water so as to maintain favorable vine water status throughout the season. Vine water use was measured by soil water disappearance using a neutron probe. Water use of this treatment was considered full or 100 percent potential water use.

Treatments 2 and 3 were managed in a fashion to consume near 70 percent of the full potential water use (treatment 1) through harvest. Treatment 2 experienced a moderate pre-veraison water deficit followed by a more severe post-veraison through harvest period water deficit (Table 1). Treatment 3 experienced a more severe pre-veraison deficit followed by a moderate deficit in the post-veraison through harvest period.

Treatments 4 and 5 consumed 50 percent of full potential water use through harvest. Treatment 4 experienced a moderate pre-veraison water deficit followed by a more severe post-veraison through harvest period water deficit. Treatment 5 experienced a more severe pre-veraison deficit followed by a moderate deficit in the post-veraison through harvest period.

All treatments, with the exception of the full water use, did not receive irrigation from first berry color through full cluster color. All treatments were postharvest irrigated.

Table 1
Imposed Irrigation Levels and Water Deficit Timing

Treatment	Pre Veraison	Post Veraison	Postharvest
T1 - 100%	0	0	0
T2 - 70% +-	+	-	0
T3 - 70% -+	-	+	0
T4 - 50% +-	+	-	0
T5 - 50% -+	-	+	0

+ = moderate water deficits
- = increased water deficits
0 = no water deficits

RESULTS:
The first year (1992) of imposed irrigation strategies did not result in significant yield differences between treatments. Results presented herein are an average of the years 1993 through 1996.

Yield. Significant differences in yield were found between irrigation treatments (Tables 2). The full potential water treatment (T1) produced the highest yield at 37.3 lbs/vine (9.85 tons/acre). Both of the 70% of potential water use treatments (T2 and T3) averaged 29.6 lbs/vine or 79% of the full potential water use treatment. The 50% of full potential water treatments were the lowest group at 24.5 lbs/vine or 66% of the full potential water treatment.

The timing treatments (T3 and T5, pre-veraison water deficits) resulted in a few pounds/vine increase over the post-veraison treatment. In each case, however, the difference is not significant.

Table 2. 1993-1996 Lodi Cabernet Sauvignon Harvest Data

Treatment	Yield (lbs/vine)	T/A	Berries per vine	Berry Wt (gms)	Clusters per vine	Clusters per vine	Cluster Wt (lbs)	Berries per cluster
T1 100%	37.3 a	9.85	13,358 a	1.27 a	129 a	129 a	0.289 a	104 bc
T2 70% +-	28.8 b	7.60	12,560 a	1.06 bc	117 b	117 bc	0.250 b	109 ab
T3 70% -+	30.3 b	8.00	12,827 a	1.08 b	114 bc	114 bc	0.264 b	112 a
T4 50% +-	23.6 c	6.23	10,624 b	1.01 c	108 d	108 d	0.216 c	97 c
T5 50% -+	25.4 c	6.71	11,271 b	1.02 c	109 cd	109 cd	0.231 c	103 bc
p =	0.0000		0.0000	0.0000	0.0000		0.0000	0.0004

Common letters among means within columns denote
no significant different at $P \leq 5\%$ using DMR mean separation.

Yield Component Analysis
An attempt was made to develop a relationship between the independent variables and the dependent variables, in this case, yield in pounds per vine. The procedure quantifies the linear relationship between variables and measures the strength of the relationship. Using simple regression, the number of berries per vine explains the largest amount of the variability in yield at 64.3 percent (adjusted r^2). Berry weight by itself explains 45.9 percent (adjusted r^2) of the variation in yield.

Using multiple regression with both yield components in the model, an excellent fit is achieved (adjusted $r^2 = 98.6$). Yield can be described as:

$$\text{yield (lbs/vine)} = -28.3581 + 0.0022995 \times \text{berries per vine} + 27.1235 \times \text{berry weight}$$

Vine Canopy Response

Each year resulted in slightly different total shoot growth and canopy light measurements. For brevity, the 1994 results are presented. Vine response to water deficits are measured as maximum shoot length, the percent of land surface shaded by the canopy, the mass of prunings, and leaf cover of the fruit. Additionally, a relationship of yield per unit prunings was developed to assess the balance of vegetation to reproductive structures.

Total shoot length. The length of sixteen primary bud shoots per plot was measured on August 4, 1994. Shoots were significantly longer in the full water use treatment as compared to all other treatments (Table 3).

Land surface shading by the canopy was measured midday throughout the season. By midseason (July 8), the canopy size of all treatments, with the exception of full water use treatment, was maximized at near 55 percent (Table 3). It is important to note that while the rate of shoot growth for the full water treatment exceeded all others after July 8, the land surface shaded area only increased 3 percent to a maximum of 63 percent by harvest.

Prunings. The mass of prunings was significantly different between treatments. The full water treatment (T1) was greatest at 8.7 lbs/vine, followed by the 70 percent treatments (T2 and T3), and lastly by the 50 percent treatments (T4 and T5) (Table 3).

Table 3. 1993-1996 Lodi Cabernet Sauvignon Canopy Measurements

Treatment	Shoot Length 8/4/94 (cm)	Land Surface Shading 7/8/94 (%)	Mass Pruning (lbs/unit)	Yield/Pruning (ratio)
T1 - 100%	313 a*	60 a	8.7 a	5.3 a
T2 - 70% +-	170 b	55 b	7.7 b	4.3 b
T3 - 70% -+	168 b	55 b	7.6 b	4.8 ab
T4 - 50% +-	162 b	54 b	6.3 c	4.3 b
T5 - 50% -+	202 b	55 b	6.9 bc	4.3 b

*Common letters among means within columns denote no significant difference at $P \leq 0.05$.

PAR canopy-penetrating light. Leaf cover of the fruit is probably best measured by the amount of light penetrating the canopy at the cordon level. Measurements of photosynthetically active radiation (PAR) were made using Sunfleck Ceptometer®. Measurements were made on top of the cordon for a length of one meter in each direction. Measurements were made just prior to harvest.

Juice Quality

An attempt was made to harvest all treatments at similar °Brix. Treatment sugar levels measured at harvest were not significantly different, averaging 23.6 °Brix (Table 4). Differences between treatments were found in pH, titratable acidity (TA), malate concentration, and potassium (K+) concentration. Levels of each quality component were higher (least desirable for pH and potassium) in the full potential water treatment.

Table 4. 1993-1996 Lodi Cabernet Sauvignon Juice Analysis

	pH	TA (gms/l)	Malate (ppm)	K+ (ppm)	°Brix
T1 - 100%	3.53 a	6.36 a	2935 a	1581 a	23.3
T2 - 70% +-	3.53 a	5.70 b	1939 b	1569 a	23.6
T3 - 70% -+	3.46 b	5.78 b	1663	1530 a	23.8
T4 - 50% +-	3.46 b	5.72 b	1595 b	1472 ab	23.6
T5 - 50% -+	3.41 b	5.86 b	1618 b	1386 b	23.7
p =	0.0000	0.0000	0.0000	0.0119	n.s.

Potassium concentration was higher and not significantly different in all but the lowest water level treatments. Malate concentration was dramatically decreased by nearly half in the deficit treatments when compared to the full potential water treatment.

Juice pH was found to be significantly higher in the full and 70% post-veraison deficit treatments. Treatments 2 and 3 consumed similar volumes of water. However, the timing of the deficit apparently reduced pH more if imposed pre-veraison as in T3.

Wine Analysis

As seen in the juice, water deficits reduce wine pH. Table 5 indicates a wine pH difference between T1 and T3 of 0.22 units. The wine pH was further reduced by increasing severity of water deficits. Additionally, pre-veraison water stress causes further reductions when compared to more severe post-veraison deficits. The titratable acidity and potassium content results are similar to that of pH.

Wine Color

Significant wine color differences were found as a result of imposed treatment. Increase color density measured at the 420 nm to 520 nm wavelength indicates a strong relationship between color and water consumed (Table 5). When comparing Treatments 2 and 3 to Treatment 1, the color density at 70% water level improved by 30% (420 nm), then to 70% for the 50% water level. At the 520 nm wave length, only the full potential water treatment was significantly different.

When comparing color density as the sum of the two wavelengths (420 nm + 520 nm), the 70% treatments (T2 and T3) were nearly doubled when compared to the full water treatment (T1). It was only slightly improved by the 50% water deficit treatments (T4 and T5) compared to the 70% treatments. In the pre-veraison water deficit treatment (T3), the color density improved slightly over post-veraison (T2) based on the average of 1993-96. However, in three of the four years, differences were more striking.

Table 5. 1993-1995 Lodi Cabernet Sauvignon Wine Analysis

	TA	pH	K (ppm)	420 nm	520 nm	420 nm + 520 nm
T1 - 100%	5.23 ab	4.00 a	1667 a	1.66 a	2.09 a	3.75
T2 - 70% +-	5.17 a	3.88 b	1450 ab	2.14 b	4.73 b	6.87
T3 - 70% -+	5.57 bc	3.71 c	1333 bc	2.27 b	4.77 b	7.04
T4 - 50% +-	5.70 cd	3.67 c	1183 c	2.95 c	4.51 b	7.46
T5 - 50% -+	6.03 d	3.59 d	1092 c	2.74 c	4.44 b	7.18
p =	0.0038	0.0000	0.0038	0.0013	0.0183	

SUMMARY OF PREVIOUS WORK

Five irrigation strategies were imposed on Cabernet Sauvignon winegrapes near Lodi, California. Treatments varied in controlling the timing and severity of water deficits experienced by the vine (with the exception of the full water treatment). Significant differences were found in yield, measured juice and wine parameters. The results significant to the Lodi area are reduced pH and increased depth of color while producing an average 8.0 tons/acre on the Treatments 2 and 3.

Treatment 3 reduced water use by 30% through harvest and imposed early (pre-veraison) water deficits when compared to the full water treatment (T1). This treatment resulted in a significant reduction in wine pH, potassium, and a significant increase in wine color density when comparing the sum of the 420 nm and 520 nm wavelength. This increase in quality was achieved at a 19% yield reduction.

1997 PROJECT RATIONALE

After completion of the 5-year study and review of the results briefly stated above, it is our opinion the relationship between fruit yield and measured quality parameters has been adequately characterized. Our concern is now focused on the long-term effect of continual deficit irrigation on the vines vegetative and reproductive structures, which over time can change the yield/quality relationship.

This concern is validated by a reduction of spur diameter in the deficit treatments. Average treatment spur diameter was measured by in January 1997. Measurements were taken at the mid point between the primary buds (two bud spurs) on the third spur from the trunk of each cordon of each vine. Significant differences between treatments were found (Table 6). Results indicate shoot diameters were reduced in the 50% treatments (T4 and T5) by 15% and in the 70% treatments

(T2 and T3) by 11%. These results were presented in the proposal. After submittal of the proposal, additional spur diameter measurements were made of all spurs rather than just two per vine. The goal was to better quantify the differences in spur diameter between treatments and to look for a possible interaction between spur position and irrigation treatment. In this subsequent analysis, significant differences were also found however the were not the same as in the first measurements. The more extensive study obviously is a better assessment of average treatment spur diameter. The results indicate a lesser difference between treatments 4 and 5 (50%) than originally found (Table 7) with only an average of 11 % reduction when compared to the full water treatment (T1) instead of the original 15 %. Significant differences were found between spur position on the cordon. Generally the positions 1-6 were larger diameter than 7-10 (Table 8). No significant interaction was found between spur position and irrigation treatment (Figure 1). In plain English, this means no clear pattern exists in spur diameter by spur position and irrigation treatment. One such effect could have been smaller spur diameter at the outer most spurs in the treatments experiencing more severe deficits. The lack of significant interaction indicates there is no evidence to support this theory.

Table 6. Third Spur Diameter
1996 Cabernet Sauvignon, Lodi, CA

Treatment	Diameter (mm)
T1 - 100%	11.9 a
T2 - 70% +-	10.38 b
T3 - 70% -+	10.73 ab
T4 - 50% +-	10.1 b
T5 - 50% -+	10.1 b
p =	0.0472

Table 7. 1996 Cabernet Sauvignon, Lodi
Average Spur Diameter at Pruning

Treatment	Diameter (mm)
1	10.9 a
2	
3	
4	9.6 b
5	9.8 b
P =	0.0000

Table 8. 1996 Cabernet Sauvignon, Lodi
Spur Diameter from Trunk to Cordon End

Trunk	Diameter (mm)	
1	10.6	a
2	10.6	a
3	10.4	ab
4	9.9	bc
5	9.8	bc
6	10.1	ab
7	9.6	c
8	9.7	bc
9	9.6	c
10 (cordon end)	9.7	bc
P =	0.0000	
Treatment spur position interaction		
P =	0.6299	n.s.

1997 RESEARCH PLAN

The experimental trial would be continued by imposing deficits as in past years. This includes measuring soil water disappearance using neutron probe and applying proportions of full water use to appropriate treatment plots. Leaf water potential measurements will be made to verify the effect of the irrigations, however at a lesser frequency than in previous years. Vegetative growth will be measured by spur diameter between the first and second primary buds after pruning.

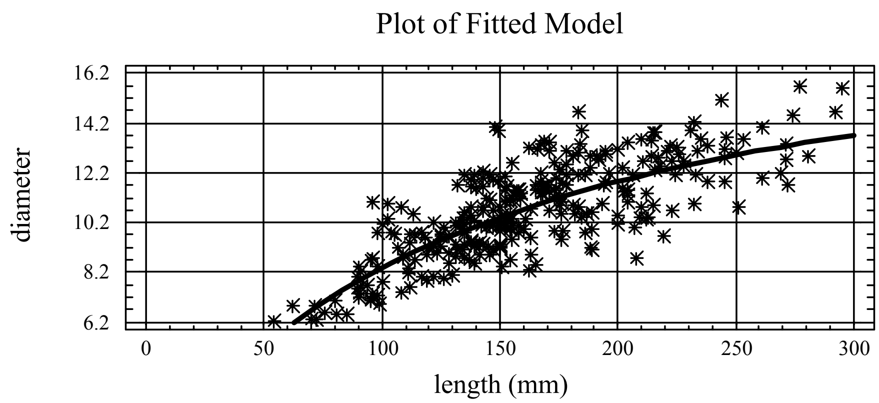
1997 Results:
Vegetative growth is usually measured as the weight of prunings. In commercial vineyards, vine hedging is a common practice during the growing season to provide for equipment access while severe hedging prior to harvest is common with mechanical harvest. The practice of hedging makes pruning weights less reliable as a measure of vegetative growth.

In an attempt to develop a more reliable method of evaluating vegetative growth, spur diameter was measured between the first and second primary bud on spurs, which were measured for shoot growth prior to hedging on June 11, 1996. When comparing shoot length on June 11, 1996, to the spur diameter at pruning, the relationship is quite good with a significant slope and intercept using a double reciprocal model. The relationship was highly significant (P = 00000) with a moderately strong correlation coefficient of 0.82. The diameter formula is as follows:

Spur diameter = 1/(0.0495694 + 6.97819/shoot length)

The relationship explains that shoot length on June 11, 1996 was 67.4% of the variability in spur diameter. With this information, it is thought that spur diameter may be a much better indication of vegetative growth I commercial vineyards than pruning weights.

Figure 1. 1996 Lodi Cabernet



Spur Diameter
Treatments were imposed as in previous years as previously discussed. Average treatment spur diameter was measured by in January 1998 after pruning. Measurements were taken at the mid point between the primary buds (two bud spurs) on each spur of the westerly cordon of all vines in each plot. Significant differences were found between treatments with the full water treatment having the largest diameter at 10.5 mm (Table 9). When comparing the treatments as a percentage of the full water treatment, it is easy to compare the difference between the 1996 and 1997 growth. Treatments 2 and 3 (70%) were the same at a 10% reduction while treatments 4 and 5 (50%) averaged 84%. Significant differences were found between spur positions on the cordons similar to 1996. Positions 1-4 were larger diameter than that of spur 5-10 (Table 10). As in the previous year, no significant interaction was found between spur position and irrigation treatment, however the relationship did improve (Figure 2).

Figure 2.

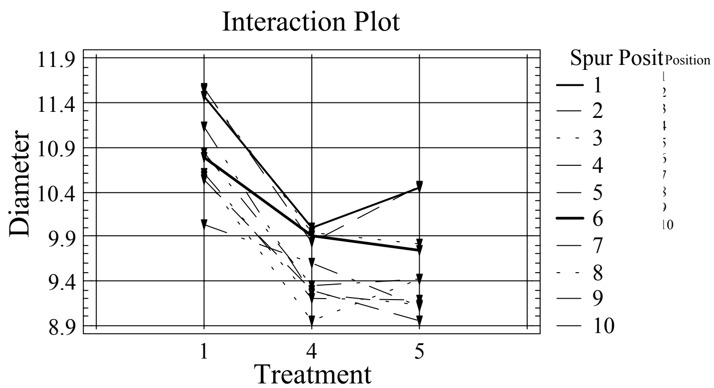


Figure 3.

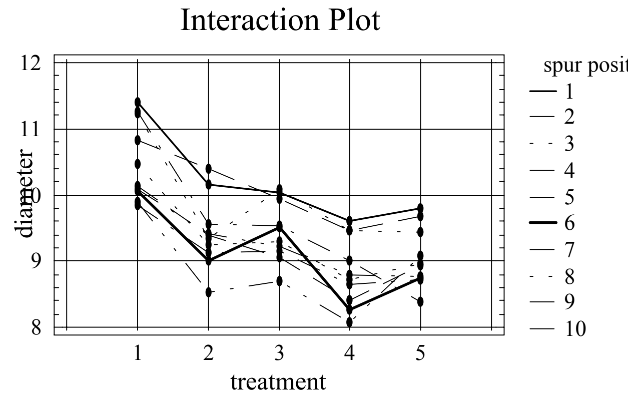


Table 9. 1997 Cabernet Sauvignon, Lodi
Average Spur Diameter at Pruning

Treatment	Diameter (mm)	
1	10.5	a
2	9.4	b
3	9.5	b
4	8.4	c
5	9.0	c
P =	0.0000	

Table 10. 1997 Cabernet Sauvignon, Lodi
Spur Diameter from Trunk to Cordon End

Trunk	Diameter (mm)	
1	10.2	a
2	10.1	a
3	9.9	ab
4	9.6	bc
5	9.3	cde
6	9.2	de
7	9.2	cde
8	9.3	cd
9	9.1	de
10 (cordon end)	8.9	e
P =	0.0000	
Treatment spur position interaction		
P =	0.3827	n.s.

DISCUSSION

Significant differences in spur diameter were found between treatments in 1996 and 1997. The differences were similar in magnitude each year. In 1997, the spur diameters were averaged near 8 percent smaller than in 1996. It appears that differences in spur diameter when viewed as a percentage of the full water treatment is the most valuable to compare the treatments. Treatments 2 and 3 (70 %) were similar each year at about a 90 percent when compared to the full water treatment while treatments 4 and 5 (50%) averaged 89% in 1996 and 84% in 1997. Spur diameter is directly correlated with water consumption however the slope of the relation ships different each year. No significant interaction was found between spur position and irrigation treatment in either year.