AMERICAN VINEYARD FOUNDATION

Annual Project Report - March 2000

PROJECT TITLE: Development of Irrigation Management Strategies to Improve Fruit Quality

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SUMMARY OF PROJECT

This project seeks to develop an approach to vine water management appropriate to cooler growing regions that will provide growers the tools they need to know when to begin to irrigate, when to schedule subsequent irrigations and how much water to apply each time they irrigate. This research project utilized midday measurements of leaf water potential (LWP) as a threshold or trigger point to determine when to begin supplying irrigation water. After a threshold LWP has triggered the start of the irrigation season, water was supplied at a fraction of full vine water use. It was our goal to use water management, defined as the timing and quantity of applied water, to impose vine water deficits as a means of producing desirable must and wine characteristics. In order to fully evaluate such an approach, vine and must/wine measurements must be taken over numerous years.

Irrigation management strategies for red winegrape varieties, which rely on methods that can insure repeatable results, have not been developed for mature vines in cool regions. Climatic water demand and soil moisture loss variables are commonly used to schedule irrigations in the warmer growing regions in the state; however, these can grossly over estimate the amount of water necessary to insure high fruit quality. Growers are aware of this and realize they must “deficit irrigate” their vines in order to maximize fruit quality. This project will give them the tools they need to select an irrigation management strategy that integrates climate variables common to the cooler growing areas such as spring rains and summer fog.

OBJECTIVES

1. Determine the effects of irrigation management strategies that apply different amounts of water initiated at various timings on specific components of must and wine.
2. Determine the effects of these strategies on vine growth and crop yield.
3. Define an approach to vine water management appropriate for red winegrapes in cool climate North Coast conditions.

PROCEDURES

Trial Site

A Cabernet Sauvignon vineyard located at the University of California Hopland Research and Extension Center in Mendocino County is the project site. The vineyard was planted in 1991 using FPMS clone 8 on 5C rootstock. The irrigation system was designed and installed to facilitate independent water delivery to 24 plots. A plot consists of nine vines in each of three adjacent vine rows. Data was taken from vines located in the center row. Vines are trained to a lyre utilizing quadrilateral cordons and are shoot positioned. Vine spacing is 6 feet and row spacing 10 feet, yielding 726 vines per acre. Standard cultural practices were utilized throughout the season performed by Hopland Research and Extension Center personnel; however, row centers (in addition to vine rows) receive a single application of pre-emergent herbicide to achieve a completely weed-free vineyard floor.

The site has a moderate water-holding capacity, increasing in "stoniness" with depth. Nearly six feet of rocky schist material limits water-holding capacity. The well water supply is of good quality and delivered via a drip irrigation system

Treatments and Experimental Design

There are six irrigation strategy treatments. Irrigation strategy treatments were a combination of two LWP thresholds and three post threshold portions of full potential water use. The thresholds were –12 and -14 bars. Subsequent water applications were made at various fractions of full vine water use through harvest. Portions of full potential water use were 35 and 60%. A single treatment (T6) received 35% for one half the time from the initial threshold to harvest and 60% the second half. The treatments that received 30% of full vine water use in 1997 and 1998 were increased to 35% in 1999. This was in response to overly severe water deficit, which delayed harvest. Soil moisture disappearance was measured using a neutron probe in an adjacent area where vines were irrigated with the same strategy as Treatment 1. This measured water use was considered full potential water use or 100 percent. The complete array of treatments is shown in Table 1. The experimental design is a randomized complete block with four replications of each of six irrigation strategy treatments. All treatments were irrigated immediately after harvest.

Table 1. Irrigation Treatments
Timing of First Application and Volume of Water to be Applied

Treatment Number	Leaf Water Potential Trigger at Which Irrigation Will Occur	Criteria for Subsequent Irrigation
T1 100%	no trigger	supply full water
T2 14/60	-14 bars	supply 60% of daily full water use
T3 14/35	-14 bars	supply 35% of daily full water use
T4 12/60	-12 bars	supply 60% of daily full water use
T5 12/35	-12 bars	supply 35% of daily full water use
T6 12/35-60	-12 bars	supply 35-60% (variable) of daily full water use

1999 ACTIVITIES:

All treatments were pruned alike using two bud spurs averaging 46 primary buds per vine. Shoots were thinned to one per primary bud on May 10-11, 1999. On June 11, 1999, irrigation commenced on T1. Threshold leaf water potentials were reached, and irrigation was begun on July 16 for T4 and T6 and on August 13 for T2, T3 and T5 (Figure 1). Irrigation to replace a treatment-determined portion of full water use was conducted weekly.

Water was supplied to each treatment using a controller and electric valves. Irrigation volumes are measured to each treatment using individual water meters. Frost control was provided five times with a solid set sprinkler system.

Treatments 2, 3 and 4 were harvested October 19, and T1, T5, and T6 were harvested on October 25, 1999. Fruit was weighed and crushed and samples taken for juice analysis and winemaking.

1999 RESULTS

Imposing Irrigation Treatments

Leaf Water Potential Threshold. Irrigation in T2 through T6 commenced when LWP values matched or exceeded the threshold indicated by treatment. Temperatures remained fairly cool during the 1999 season, leading to gradual changes in leaf water potential. Due to dry spring conditions, irrigation on T1 began on June 11, and the other treatments reached their target leaf water potentials over a period of two months (Figure 1). The T6 irrigation amounts were switched from 35 to 60% of full ET on September 3, giving 49 days at 35% and 52 days at 60% of full potential water use.

Irrigation Volumes. Water use of fully irrigated vines was calculated for weekly treatment irrigations using the following equation:

$$ETc = ETo \times Kc$$

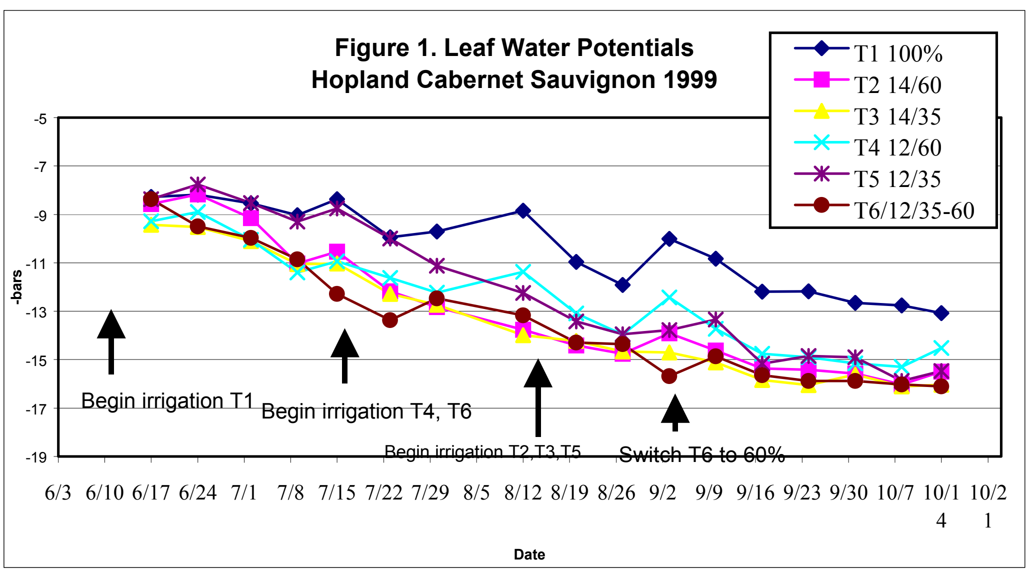
Where ETo is weekly summation of the daily on-site CIMIS station's Reference Evapotranspiration and Kc is the vine development coefficient for that period of time. Actual water use is also measured using a neutron probe in vines irrigated the same as T1 and compared to the estimate.

The full water treatment (T1) receives at least the calculated water volume, which maintains adequate available water in the soil root zone. The other treatments receive a treatment-determined portion of the full water volume.

With full irrigation, T1 showed lower water stress than the other treatments throughout the season (Figure 1). Treatments 2 and 4 received 60% of full ET following leaf water potential triggers of –14 and –12 bars, respectively. Because of these different triggers, irrigation in T2 was started four weeks after that in T4. This 4 week time period compares with previous years of 2 weeks due to the mild climatic conditions during that period of time in 1999. Water deficits remained more negative (indicating more stress) in T2 than T4 throughout the season.

Treatments 3 and 5 had leaf water potential thresholds of –14 and –12 bars, respectively, after which they received 35% of full ET. Water stress was slow to develop in T5, and therefore T3 and T5 reached their leaf water potential triggers on the same day, August 13. Water stress remained slightly lower in T5 than in T3 throughout the season.

Following a –12 bars leaf water potential threshold, T6 received 35% of full water use which switched to 60% half-way through the irrigation season. Despite this switch to higher irrigation amounts, T6 leaf water potentials remained similar to other low water (35%) treatments until the end of the season.



Water Use

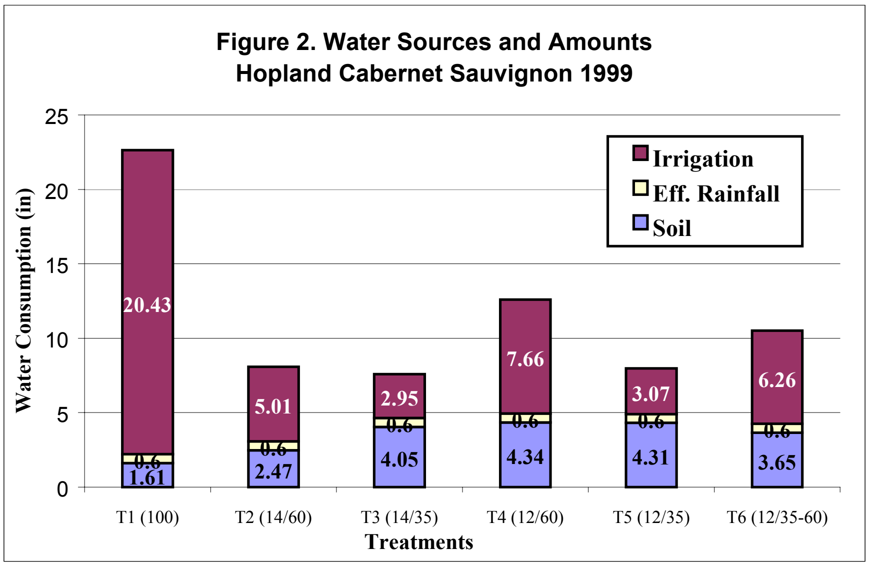
The amount of water consumed by each treatment was a summation of water volumes extracted from the stored root zone moisture and irrigation. There was 0.62 inches of effective in-season rainfall in 1999. Table 2 and Figure 2 show the amounts each component contributed to the total water consumed by each treatment.

Consumed water volumes were less than previous years due to the reduced climatic demand during the 1999 growing season and a consequence of a later time the threshold was met. Additionally some emitter clogging resulted in less applied water then planned. This also can explain the increased water deficits in all treatments as harvest approached.

Table 2.
Water Volumes Consumed Through Harvest and
Relative Volumes of Each Treatment in Comparison to Treatment One
1999 Hopland Cabernet Sauvignon

	Soil	In season Effective Rain	Irrigation	Total	% of T1
T1(100%)	1.6	0.6	20.4	22.6	100
T2(14/60)	4.2	0.6	5.0	9.8	44
T3(14/30)	4.1	0.6	2.9	7.6	34
T4(12/60)	4.3	0.6	7.7	12.6	56
T5(12/30)	4.3	0.6	3.1	8.0	35
T6(12/30-60)	3.7	0.6	6.3	10.6	47

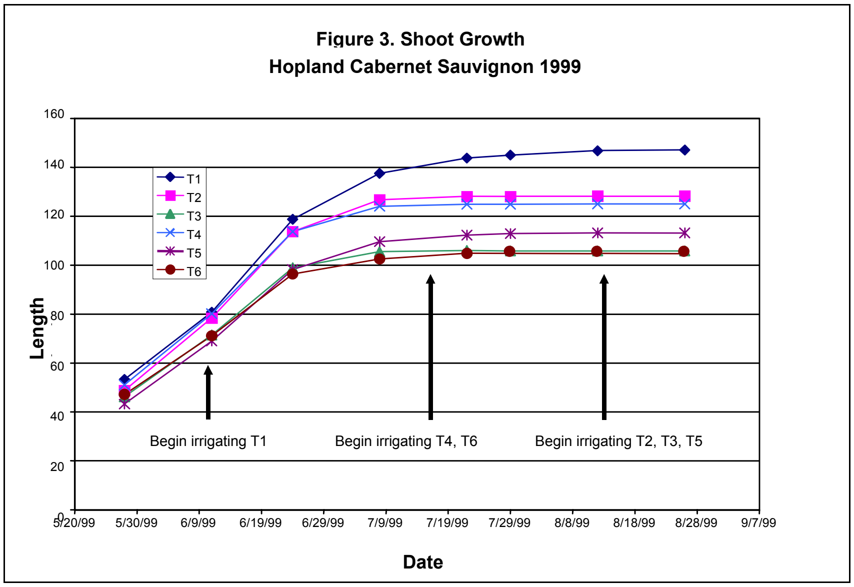
Figure 2.



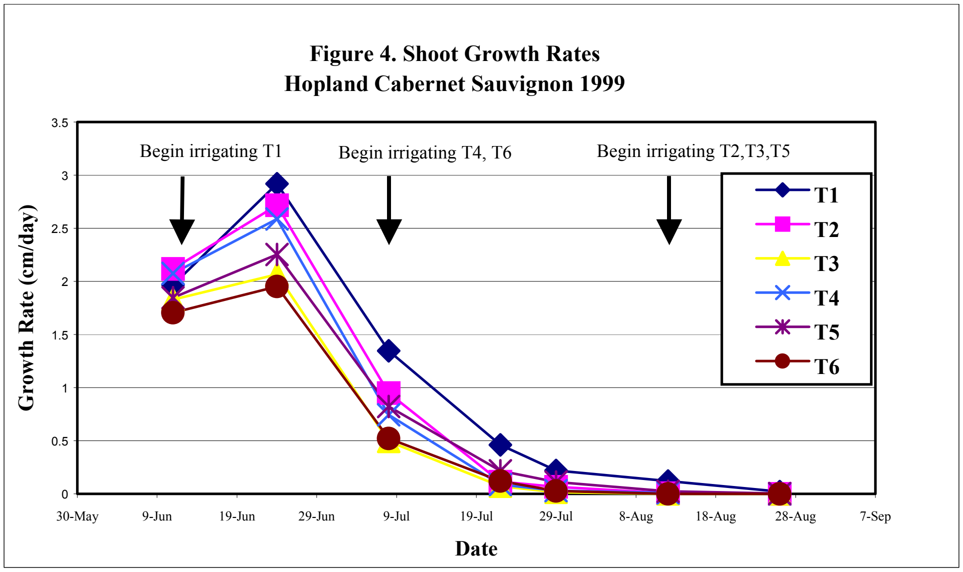
The full potential water use treatment (T1) used nearly the same water volume (22.6 inches) as the estimated value (22.3 inches). Treatment volumes as a percent of the measured use in T1 varied from 35-56 percent (Table 2). Treatment 4, with a threshold requiring earlier irrigation than T2, used substantially more water than T2. Treatments 3 and 5, which reached their thresholds on the same day, had almost identical water use.

Canopy Measurements

Vegetative growth was reduced in 1999 compared to 1998, probably because the last effective rainfall was on April 11 in 1999 as compared to May 29 in 1998 (Figure 3). For example, the average shoot length achieved in T1 in 1998 was 169 cm, and the average in 1999 was 147 cm. Shoot lengths and shoot tip ratings were measured every two weeks. Shoot lengths were significantly different only on the first date of measurement when lengths of T1 and T4 were significantly higher than those of T5.

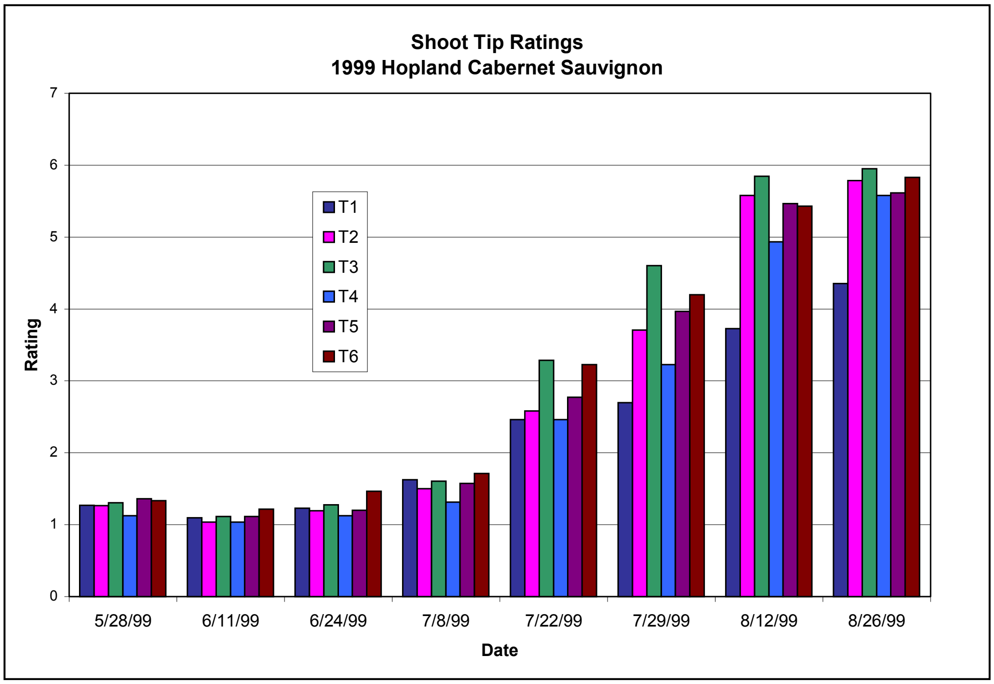


Shoot growth rates peaked early in the season, before irrigation started in the deficit treatments (Figure 4). Shoot growth rates did not provide a useful method to distinguish levels of water stress. Only in the time periods ending on July 29 and August 12 were there significant differences in shoot growth rates, and these differences primarily distinguished T1, the full water treatment, from the other deficit irrigation treatments.



Like shoot growth rates, tip ratings (1-6) could only distinguish between full and deficit irrigation treatments, and this distinction occurred too late for initiation of irrigation in the deficit treatments. Shoot tip ratings differed significantly only on the last three measurement dates (Figure 5). It seems that both shoot growth and tip ratings are not sensitive enough to determine when to begin irrigation at least at the –14 bar level.

Figure 5



Canopy Light Measurements

Measurements of relative light level in the area of the canopy containing the fruit were taken periodically after veraison using a ceptometer. The lowest light level was always measured in the full water treatment (T1), however; only on the last measurement date (October 15, 1999) were there significant treatment differences in light in the fruit area (Table 3). Light levels measured in the canopy were higher in 1999 than in 1998. They ranged from 1.8 to 12.5 percent of full sun in 1999 and 1.0 to 3.2 in 1998.

Table 3
Canopy Light Measured at Fruit Level
By Treatment (% of Full Sun)
1999 Hopland Cabernet Sauvignon

Treatment	9-1-99	9-15-99	9-29-99	10-15-99
T1 100%	1.8	3.0	2.8	4.0 a
T2 60/14	3.1	4.8	5.6	7.9 ab
T3 35/14	5.8	8.5	9.0	12.5 b
T4 60/12	3.0	4.8	5.1	8.3 ab
T5 35/12	6.4	8.2	8.4	10.6 ab
T6 35-60/12	5.2	6.9	7.1	8.5 ab
P=	0.4944	0.4704	0.1948	0.0202
	NS	NS	NS	*

* Indicates significance at P< 0.05. NS=not significant. In a column, means followed by the same letter are not significantly different at the 0.05 level by Tukey's HSD.

Harvest

The fruit weight of each of the seven data vines within each plot was measured. Yields were significantly different among treatments, with the full water treatment (T1) having the highest yield, (29.3 lbs/vine or 10.6 tons/acre), the two 60% and the 35-60% water treatments (T2, T4, T6) having intermediate yields (averaging 22.4 lbs/vine or 8.1 tons/acre), and the two 35% treatments having the lowest yields (averaging 19.1 lbs/vine or 6.9 tons/acre) (Table 4, Figure 7). Yields in treatments 1, 2, 4 and 6 were higher than in 1998, while yields in T3 and T5 were lower or the same. In 1999, no significant yield differences were found between the full potential treatment (T1) and any of the treatments receiving 60% for all or some of the period before harvest. These results agree with previous data indicating a 60% of full potential water use to be a relatively "safe" management option.

Table 4
Harvest Components by Treatment
1999 Hopland Cabernet Sauvignon

Treatment	Yield (lbs/vine)	Berry weight (gm/berry)	Fruit Load (berries/vine)	Number Clusters/vine	Cluster weight (lbs/cluster)
T1 100%	29.3 a	1.14	12925	90.2	0.33 a
T2 14/60	22.9 ab	0.94	12575	88.0	0.26 b
T3 14/35	18.5 b	0.89	11957	80.0	0.23 b
T4 12/60	21.7 ab	0.92	13075	83.1	0.26 b
T5 12/35	19.6 b	0.92	12191	83.8	0.23 b
T6 12/35-60	22.7 ab	0.92	12784	90.6	0.25 b
P=	0.0082	0.0543	0.8715	0.0594	0.0167
	**	NS	NS	NS	*

*,** Indicates significance at P< 0.05. NS=not significant. In a column, means followed by the same letter are not significantly different at the 0.05 level by Tukey's HSD.

Yield Component Analysis.

No significant differences were found between treatments at the 5% probability level in the basic yield components of berry weight or fruit load (berries per vine). However, the full potential water treatment had the highest berry weight (6% level), the highest number of clusters (6% level), and the largest cluster weight (2% level). The R-Squared statistic indicates that the model for yield vs. berry weight explains 84% of the yield variability. The correlation coefficient of 0.89, indicates a moderately strong relationship between the variables. The R-Squared statistic for berries per vine (fruit load) explains 12% of the yield variability. The correlation coefficient of 0.35 indicates a relatively weak relationship between the variables. The number of clusters per vine (6% level) was generally controlled by shoot removal, but as can be seen it was not completely effective.

Figure 6

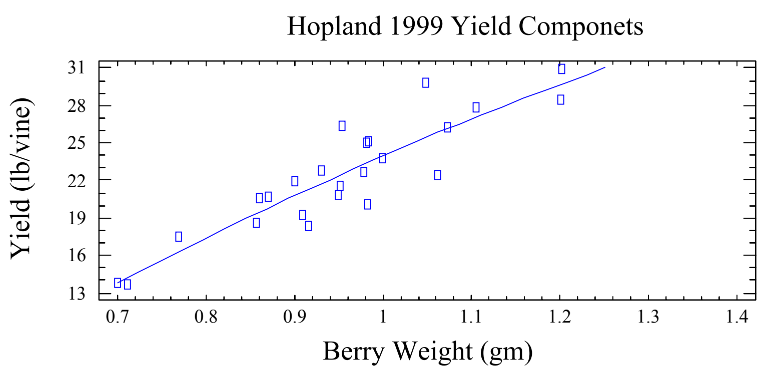
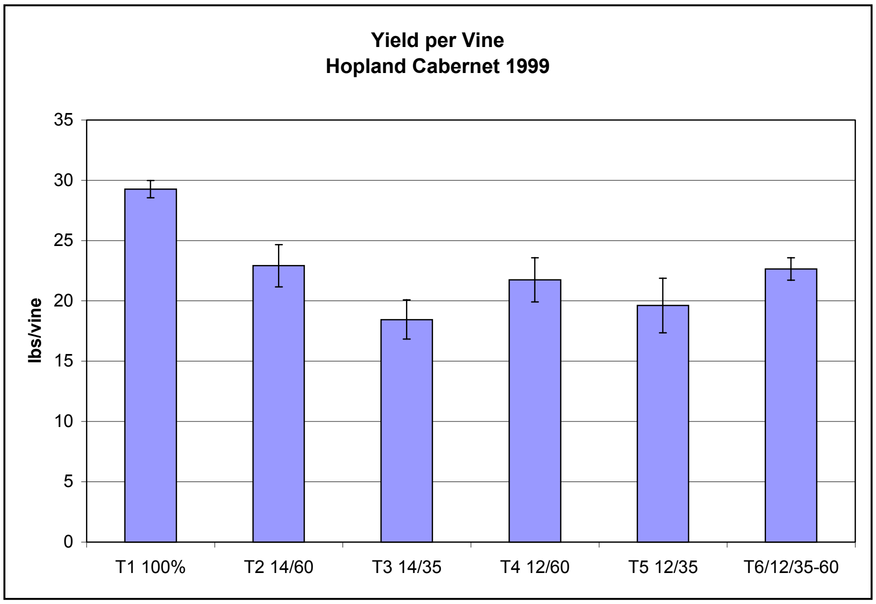


Figure 7



Bars indicate ± one standard error.

Juice Analysis

Harvest of each treatment was determined by berry sampling each plot until the target of 23.5 °Brix was reached. Treatments 2, 3 and 4 were harvested on October 19, 1999, and treatments 1, 5, and 6 on October 25, 1999. Unlike 1997 and 1998, the order of harvest in 1999 did not follow irrigation amounts. In 1997 the two low water treatments (T3 and T5), and in 1998 the three lowest water treatments (T3, T5, and T6), had delayed harvests. Analysis of juice samples indicated that the treatments were at Brix ranging from 23.0 to 23.9, and some of these differences were significant (Table 5).

Juice samples were taken at harvest from a minimum of 35 pounds of grapes proportionally selected from each vine in a plot. Malate and titratable acidity were highest in the full water treatment (T1), intermediate in T2 and T4, receiving 60% of full ET, and lowest in the 35 and 35/60% treatments (T3, T5, T6). There were significant differences in pH and potassium levels among the treatments as well, however these differences did not seem to follow irrigation amounts.

Wine Analysis
Not available by reporting date.

Table 5. Juice Analysis by Treatment
1999 Hopland Cabernet Sauvignon

Treatment	Brix	PH	TA (gm/l)	Malate (ppm)	Potassium (ppm)
T1 100%	23.8 ab	3.47 ab	5.53 b	2420 b	1408 b
T2 14/60	23.0 a	3.42 a	5.08 ab	1875 ab	1225 ab
T3 14/35	23.3 ab	3.47 ab	4.55 ab	1650 a	1170 a
T4 12/60	23.4 ab	3.48 ab	4.83 ab	1833 ab	1245 ab
T5 12/35	23.9 b	3.60 c	4.55 ab	1555 a	1388 b
T6 12/35-60	23.3 ab	3.53 bc	4.38 a	1605 a	1310 ab
P=	0.0419	0.001	0.0473	0.0122	0.0096
	*	***	*	*	**

*,**,*** Indicates significance at P< 0.05. NS=not significant. In a column, means followed by the same letter are not significantly different at the 0.05 level by Tukey's HSD.

SUMMARY

A study is being conducted to evaluate an approach to vine water management appropriate to cooler growing regions that will provide growers the tools they need to know when to begin to irrigate, when to schedule subsequent irrigations, and how much water to apply each time they irrigate. This research project utilizes measurements of midday leaf water potential (LWP) as a trigger to determine when to begin supplying irrigation water. After a threshold LWP has triggered the start of the irrigation season, water is supplied, depending on treatment, at a fraction of full vine water use. It is our goal to use water management, as defined as the timing and quantity of applied water, to impose vine water deficits as a means of producing desirable must and wine characteristics.

The experimental site is located in a Cabernet Sauvignon vineyard at the UC Hopland Field Station.

A dry spring and cool summer characterized the 1999 season. Due to lack of spring rain, irrigation was started approximately one month earlier in the full water treatment than in 1998. With the cool weather in 1999, leaf water deficits took two months to develop as compared to five weeks in 1998.

Canopy growth was somewhat reduced in 1999 as compared to 1998. Final shoot lengths were shorter in all treatments, and fruit level light conditions were higher in 1999 than in 1998.

Yields varied significantly among the treatments with the full water treatment resulting in the highest yield, the intermediate water treatments, 60% or 35/60% full ET, resulting in intermediate yields, and the 35% full ET treatments resulting in the lowest yields. Yields averaged from 18.5 (6.7 tons/acre) to 29.3 (10.6 tons/acre) pounds per vine. Yields were higher in the full, 60% and 35/60% full ET treatments relative to 1998, and were the same or lower for the 35% ET treatments.

Malate and titratable acidity were highest in the full water treatment (T1), intermediate in T2 and T4, receiving 60% of full ET, and lowest in the 35 and 35/60 % treatments (T3, T5, T6). Significant differences among the treatments in pH, Brix, and potassium also occurred, however these differences did not appear to follow irrigation levels.

The results thus far indicate the approach of using leaf water potential as a trigger to begin irrigation and to use portions of full water ET to schedule subsequent application volumes is an effective method of irrigation scheduling that takes into account quality and yield parameters.