Lodi Woodbridge Winegrape Commission
2000 Comprehensive Project Report

Project Title: Management of Zinfandel to Modify Vine and Wine Characteristics

Project Personnel:
Principle Investigator: Terry L. Prichard, Water Management Specialist

Co-Investigators:
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Cooperators: Craig and Leonard Thompson, Lodi

Involvement of Investigators:

T. Prichard (20% 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 (10% of time). Direct viticultural operations. Plan and supervise collection of vine physiological data.

B. Guerra, J. Moso, K. Bogart (5% of time). Crush fruit, provide chemical and organoleptic wine analysis.

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

OBJECTIVES

(1) Measure effects of management regimes on must and wine parameters
(2) Measure physiological effects of management regimes on vines and fruit
(3) Utilize developed information to formulate management strategies to improve zinfandel quality and production in the Lodi District.

RESEARCH SITE/PLAN

The site is the Thompson vineyard located at the intersection of Highway 12 and Tecklenberg Road, Lodi, California. It satisfies the research criteria needed to create stress at various stages of vine growth and maturity. The zinfandel vineyard established on Freedom rootstock, is mature and bilateral cordon trained at 7 x 10 foot spacing. The cooperating grower was willing to arrange cultural practices including harvest to facilitate data acquisition. The experimental area contains 1200 vines.

The soil at the site is a Tokay fine sandy loam, which has a moderate water-holding capacity. A drip irrigation system is used to deliver 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 with 4 replications of each of the 10 treatments.

TREATMENTS

This trial evaluates irrigation strategy, canopy management, crop thinning dual harvesting, and cover crop treatments and some selected combinations. The goal is to improve fruit quality and sustain yields.

Table 1 presents treatments as a simple list while Table 2 presents head to head treatments comparisons.

Irrigation Treatments

The strategy used in this trial is called "Deficit Threshold Irrigation Management." It relies on pre-determined midday leaf water potential as a threshold of when to begin irrigation. After the threshold is reached, the imminent question becomes how much to irrigate. This experiment evaluates different post threshold irrigation levels. This method calculates the irrigation volume by a selected percentage of full vine water use for each irrigation period.. This portion of full vine water use, known as the regulated deficit irrigation coefficient (RDI %). It is simply a percentage of full vine water use. Calculation of the required irrigation water application is done weekly in this experiment but could be applied at any reasonable interval. Leaf water potential is measured as the indicator of plant water deficit to confirm the desired level of water stress.

This approach does not require the continued measurements of leaf water potential after the threshold is reached. However, leaf water potential measurements can be used to confirm that that the RDI factor (see below) is appropriate, rather than using the reading to determine irrigation volumes. The RDI coefficients used in this experiment are shown in Table 1.

$$\text{Treatment vine water use} = \text{ETo} \times \text{Kc} \times \text{Krdi}$$

Where:

- ETo = evapotranspiration reference value for the Lodi CIMIS station
- Kc = crop sunlight interception coefficient (vineyard shaded area)
- Krdi = regulated deficit irrigation factor which is a percent of full vine water

Treatments 1, 2 and 3 are irrigated to meet full potential water use beginning early in the growing season. The remaining treatments are not irrigated until a midday leaf water potential threshold of -13 bars is reached measured with a pressure chamber. Once the threshold, is reached, an estimate of full potential water use for this vineyard and a regulated deficit irrigation factor will be used to determine the weekly irrigation volumes depending on the treatment. Two levels expressed as a percentage of full potential water use are used: 60% and 35 %.

Canopy Management Treatments

Two pruning levels were used across the irrigation level treatments. The levels are 10 and 14 two-bud spurs. The 14-spur treatment was cluster thinned to reduce the crop when a high set occurs.

Additional canopy adjustments will be made using leaf removal in the fruit zone. A single treatment (T7) has 14 spurs and no leaf removal.

Dual Harvest Treatments

A late crop adjustment treatment, where about 50 percent of the full crop is removed near 17 °brix allows near 50 percent of the full crop to mature. The amount of crop removed varies according to the total crop set. In low set years, less crop as a percentage of the total will be removed. The first crop removed to be used as a white zinfandel harvest. This technique is combined with irrigation strategy treatments to constitute Treatments 2 and 6, which are across the two irrigation strategies.

Cover Crop Treatments

The last treatment (T5) combines the use of a cover crop with a 60% RDI irrigation strategy. The goal is to deplete soil moisture at a more rapid rate in the spring to impose vine water deficits to occur sooner. Treatment 5 was planted to a cover crop consisting of annual and perennial ryegrass in the fall

1997. It continues to reseed and produced a good stand. A comparison will be made with Treatment 4, which is equivalent with respect to irrigation crop load and canopy management.

Table 1. 2000 Zinfandel Treatments, Lodi

Treatment	Threshold Bars	RDI %	Pruning Spurs	Thinning	Leaf Removal	Dual Harvest	Cover
1	none	100	14	Yes	Yes	No	No
2	none	100	14	No	Yes	Yes	No
3	none	100	10	No	Yes	No	No
4	-13	60	14	Yes	Yes	No	No
5	-13	60	14	Yes	Yes	No	Yes
6	-13	60	14	No	Yes	Yes	No
7	-13	60	14	Yes	No	No	No
8	-13	60	10	No	Yes	No	No
9	-13	35	10	No	Yes	No	No
10	-13	35	14	Yes	Yes	No	No

Table 2. 2000 Zinfandel Treatment Comparisons, Lodi

Variable		Treatment	Constants				
Irrigation			RDI	Cover Crop	Leaf Removal	Harvest	Spurs
RDI	None	T1		None	LR	Single	14
	60 %	T4		None	LR	Single	14
	35 %	T10		None	LR	Single	14
	None	T3		None	LR	Single	10
	60 %	T8		None	LR	Single	10
	35 %	T9		None	LR	Single	10
Pruning							
Spur Number	14	T1	Full	None	LR	Single	
	10	T3	Full	None	LR	Single	
	14	T4	60 %	None	LR	Single	
	10	T8	60 %	None	LR	Single	
	14	T10	35%	None	LR	Single	
	10	T9	35%	None	LR	Single	
Dual Harvest							
	No	T1	Full	None	LR		14
	Yes	T2	Full	None	LR		14
	No	T4	60 %	None	LR		14
	Yes	T6	60 %	None	LR		14
Leaf Removal							
	No	T7	60 %	None		Single	14
	Yes	T4	60 %	None		Single	14
Cover Crop							
	Yes	T5	60 %		LR	Single	14
	No	T4	60 %		LR	Single	14

2000 Activities

Treatments were imposed beginning with differential pruning performed in February 2000 followed by differential irrigation, leaf removal, cluster thinning and harvest of white zinfandel in Treatments 2 and 6. Pruning weights were collected at time of pruning to assess differences in vegetative growth.

Data collected include vegetative growth measured as the weight of prunings, percent land surface shaded at midday, canopy-penetrating light at the fruit level measured pre-harvest, and water use from the soil measured by neutron probe. Leaf water potential was measured weekly pre-veraison through harvest.

Leaf removal occurred May 31. Crop thinning by cluster removal was performed on July 18 on all 14-spur treatments (with the exception of the dual harvest Treatments 2 and 6). The goal was to reduce the final harvest yield to near 7.5 tons/acre. Treatments 2 and 6 (double harvest treatments) were harvested for white zinfandel on August 16 by removing approximately 50 to 60 percent of the total crop. Care was taken to harvest green fruit, rotten fruit or closely positioned clusters leaving the best quality fruit for the red zinfandel harvest. The white zinfandel treatments were not cluster thinned.

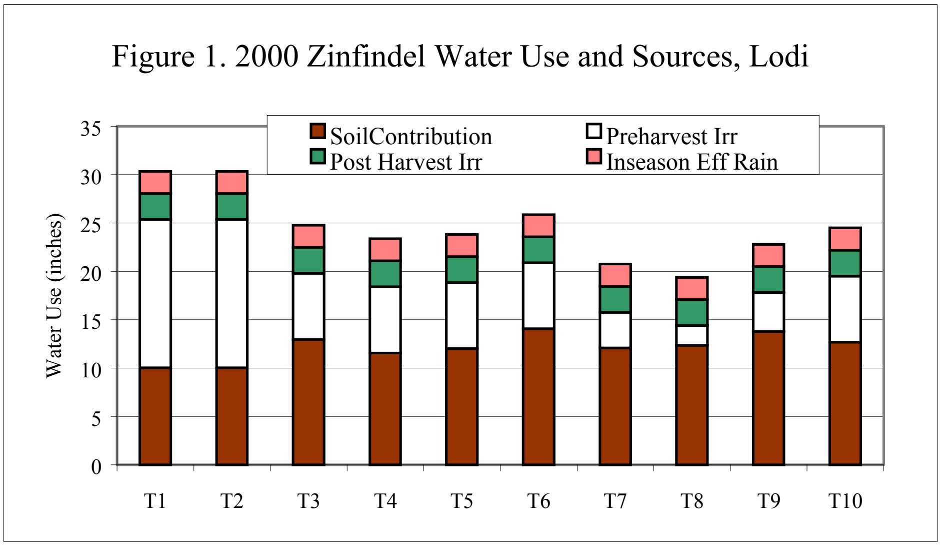
Weekly berry samples were collected to assess the fruit ripening process and to estimate treatment harvest date. Each treatment was harvested at similar °brix as monitored by sugar sampling. After the treatments were harvested, postharvest irrigation was applied to meet full water use.

Water Use

The amount of water consumed by each treatment was the summation of water volumes extracted from the stored root zone moisture, effective in-season rainfall and irrigation. Figure 1 and Table 3 show the amounts of each component to reach the total water consumed by the average of each treatment.

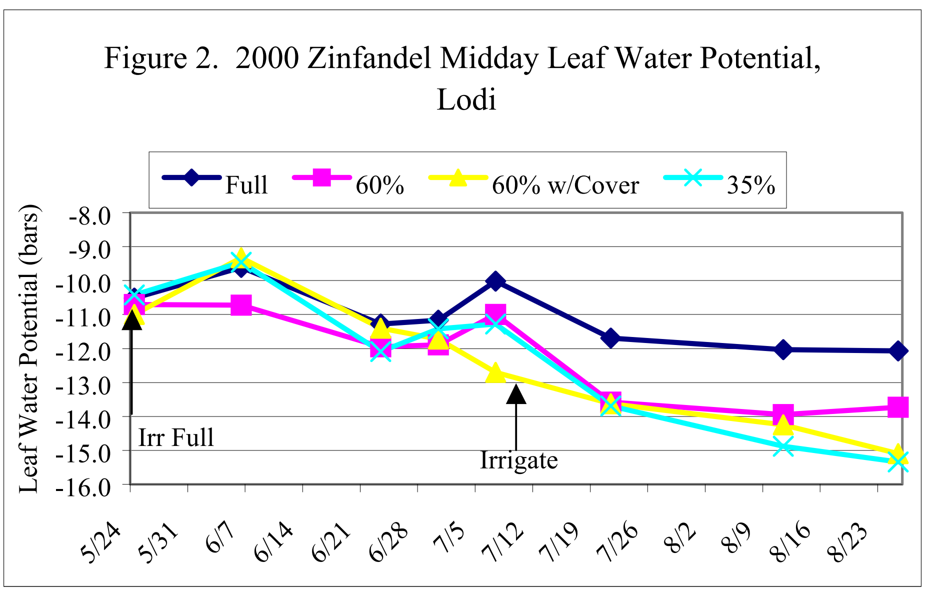
Table 3. 2000 Zinfandel Water Volumes Consumed and
Relative Volumes of Each Treatment in Comparison to Treatment 1, Lodi

Treatment	Soil Contribution	In-Season Effective Rain	Pre-Harvest Irrigation	Percent of Potential
T1	7.29	1.08	16.21	100
T2	6.45	1.08	16.21	97
T3	7.87	1.08	16.21	102
T4	8.27	1.08	6.65	65
T5	6.30	1.08	6.65	57
T6	7.87	1.08	6.73	64
T7	7.61	1.08	6.73	63
T8	7.35	1.08	6.73	62
T9	6.51	1.08	3.56	45
T10	7.47	1.08	3.49	49



Leaf Water Potential. Midday leaf water potential data were collected from each treatment. Measurements were made for the most part from 11:00 am to 2:00 pm on clear sky days with normal (85-95 °F) temperatures. The full potential irrigation (T1 thru T3) was irrigated May 24, 2000 and weekly thereafter at an amount to equal full potential water use each week. The leaf water potential remained as less than –11 bars until August when it increased in stress to –12 bars (Figure 2).

Treatments receiving 60% RDI generally maintained leaf water potential at the –14 level throughout the season after the initiation of irrigation on July 11, 2000. The cover crop treatment also has the 60% RDI resulting in more stress at the threshold (July 11). It then responded to the irrigation showing less water stress followed by more stress near harvest. The 35% RDI responded similarly to the 60% RDI treatments until a few weeks after irrigation initiation when it exhibited more stress towards harvest.



Harvest

Weekly berry samples were collected to assess the progress of fruit ripening and to estimate harvest date. The harvest date of each treatment was determined by °brix of berry samples with a target of 24.0

°brix. Fruit was harvested from Treatments 2 and 6 (dual harvest) at 17 °brix. Harvest of these vines for red wine occurred over a 13-day period, Sept 15 through September 20, 2000 (Table 4).

Table 4. 2000 Zinfandel Harvest, Lodi

	Harvest Date		
Treatment	White Zinfandel	Red Zinfandel	ºBrix
1		Sept. 15	25.5
2	Aug. 16	Sept. 18	23.1
3		Sept. 20	23.5
4		Sept. 12	25.1
5		Sept. 12	25.5
6	Aug. 16	Sept. 18	24.1
7		Sept. 12	25.1
8		Sept. 20	24.1
9		Sept. 7	24.7
10		Sept. 7	24.7

YIELD

Due to the number of treatments and potential comparisons of irrigation, canopy thinning/dual harvest, and the use of cover crops combined with the available types of harvest parameters yields will be compared in many ways.

Total Yield

For Treatments 2 and 6, total yield is the sum of the pickings for white zinfandel, red zinfandel and the rotten fruit. This comparison shows the amount of fruit harvested to be the largest in the dual harvest treatments (Table 5 and Figure 3). The increase is due to the lack of thinning and subsequent picking of the fruit as white zinfandel instead of discarding it as thinned fruit. The full water treatment (T2) had over 60 pounds of total fruit per vine and due to the selective picking, only 8 pounds of rotten fruit when the red zinfandel crop was harvested. Treatment 6 (RDI 60%) had half the rotten fruit as the comparable full water Treatment 2. However, it also had less total yield at 48 lbs/vine. Treatment 3 (a full water treatment receiving no thinning) was also significantly higher in yield than the other single pick treatments. However the increase in total fruit was countered by the near 15-lbs/vine rotten fruit. Treatments 4 and 8 were similar in yield since all treatment factors between the two were the same with the exception of the number of spurs. Treatment 4 was pruned to 14 spurs while Treatment 8 was pruned to 10 spurs. Total yields were similar but the fewer spur treatment (T8) had six times more rot due to a more compact fruit clusters.

Dual Harvest Yield

A comparison of white zinfandel yield of the dual harvest treatments (T2 and T6) shows a significant yield difference in weight with Treatment 2 at 26.2 lbs per vine and Treatment 6 at 19.1 lbs/vine (Table 6). However, the numbers of clusters removed were not significantly different and resulted in larger clusters in the full water Treatment 2. Treatment 2 also contained significantly more rot at the time of the white zinfandel harvest.

Red Zinfandel Yield

No significant differences were found between treatments in the yield of red zinfandel. Treatments 4 and 7 (RDI 60% both with and without leaf removal) along with two of the full water treatments (T1 and T3) were the highest yielding group averaging 27.9 lbs/vine (Table 5 and Figure 3). Treatment 4 achieved the highest red zinfandel yield by having a low level of rot (1.2 lbs/vine) while the comparable full water treatment (T1) averaged 6.8 lbs/vine of rotten fruit. Treatment 9 resulted in the lowest yield at 22.1 lbs/vine with virtually no rotten fruit. Treatments 2 and 6 (both dual harvest treatments) were numerically lowest in yield of red zinfandel.

Rotten Fruit Yield

Treatment 3 resulted in significantly more rotten fruit than all other treatments (Tables 5 and 8). It was a full irrigation treatment with 10 spurs. This treatment resulted in the largest number of clusters confined into a tighter 10-spur fruiting area (Table 7).

Table 5. 200 Zinfandel Yield, Lodi

Treatment	Total Yield (lbs/vine)	Total Number of Clusters/Vine	White Yield (lbs/vine)	Red Yield (lbs/vine)	Rot Yield (lbs/vine)
1	33.9 d	48.0 d		27.0	6.84 c
2	60.4 a	79.3 a	26.2 a	23.2	8.06 b
3	42.6 c	69.8 b		27.4	15.17 a
4	32.0 e	45.8 d		30.8	1.24 de
5	26.3 f	42.9 d		26.1	0.24 e
6	48.0 b	70.3 b	19.1 b	23.8	4.55 cd
7	27.5 f	41.8 d		26.3	1.20 e
8	33.5 d	56.6 c		25.9	7.56 bc
9	27.7 ef	41.3 d		26.1	1.53 de
10	26.5 f	42.1 d		25.9	0.57 e
P =	0.0000	0.0000	0.0061	0.0860	0.0000

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

Figure 3. 2000 Zinfandel Yield, Lodi

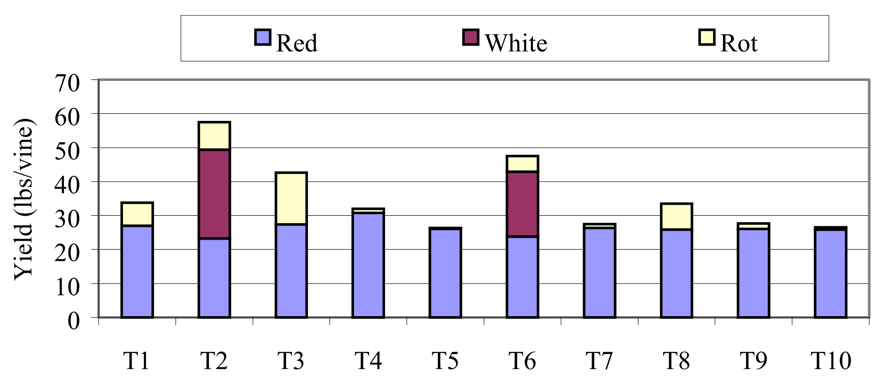


Table 6. 2000 White Zinfandel Yield, Lodi

Treatment	Rot Free			Rot		
	Yield (lbs/vine)	Cluster/ Vine	Cluster Wt (lbs)	Yield (lbs/vine)	Cluster/ Vine	Yield (lbs/vine)
2	26.2 a	28.8	0.91	2.97 a	3.69 a	0.84
6	19.1 b	24.7	0.78	0.47 b	0.56 b	0.88
P =	0.0061	0.1265	0.1312	0.0018	0.0066	0.7884

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

Table 7. 2000 Red Zinfandel Rot Free Yield and Yield Components, Lodi

Treatment	Yield (lbs/vine)	Berry Size (gm/berry)	Fruit Load (berries/vine)	Clusters/ Vine	Cluster Size (lbs)
1	27.0	2.20 a	5282	38.5	0.70 ab
2	23.2	2.15 ab	4909	34.9	0.67 abc
3	27.4	2.05 abc	6269	45.6	0.60 c
4	30.8	1.90 bcd	6718	43.8	0.71 a
5	26.1	1.78 d	6670	42.5	0.62 c
6	23.8	2.16 a	5500	38.1	0.63 bc
7	26.3	1.96 abcd	5609	39.6	0.67 abc
8	25.9	1.95 abcd	7287	43.4	0.60 c
9	26.1	1.82 cd	6442	39.1	0.67 abc
10	25.9	2.05 abc	6743	41.2	0.63 bc
P =	0.0860	0.0060	0.0745	0.2060	0.0139

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

Table 8. 2000 Red Zinfandel Rot Yield, Lodi

Treatment	Yield (lbs/vine)	Clusters/ Vine	Lbs/ Cluster
1	6.84 b	9.5 b	0.69 ab
2	8.06 b	11.9 b	0.69 ab
3	15.17 a	24.2 a	0.63 ab
4	1.24 cd	2.1 cd	0.57 b
5	0.24 d	0.3 d	0.79 a
6	4.55 bc	7.0 bc	0.64 ab
7	1.20 cd	2.2 cd	0.54 b
8	7.56 b	13.1 b	0.57 b
9	0.80 cd	1.2 cd	0.62 ab
10	1.53 cd	2.1 cd	0.60 b
P =	0.0000	0.0000	0.0496

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

Yield Comparison by Variable

Irrigation

Treatments 1, 4, and 10 compared the full water 100%, 60% RDI, and 35% RDI all at the 14-spur per vine level of pruning with cluster thinning. Total yield was not significantly reduced by the moderate water stress Treatment 4 (RDI 60%) when compared to the full water Treatment 1 (Table 9). Treatment 10 (RDI 35%) was significantly reduced when compared to both Treatments 1 and 4. Rotten fruit was significantly higher in the full water treatment. Red zinfandel yield was highest in Treatment 4 but not significantly different than other treatments.

Treatments 3, 8, and 9 compare the full watered vines, 60% RDI, and 35% RDI at the 10-spur per vine level of pruning. Total yield was significantly higher in the full water treatment followed by Treatment 8 (60% RDI), then Treatment 9 (35% RDI) (Table 9). The yield of rotten fruit increased with increasing water volume consumed with the full water having the highest amount at over 15 lbs/vine. The RDI 35% treatment resulted in less than 2 lbs/vine of rotten fruit. Clearly, a relationship exists between water applied and the amount of rotten red zinfandel (Figure 4). Similar results were found in the 14-spur comparison with red zinfandel yield highest in Treatment 3 but not significantly different from other treatments.

Pruning (Spur Number)

Treatments 1 and 3 compare the 14- and 10-spur pruning levels, both at the full water irrigation level. Total yield was significantly higher in the 10-spur treatment (T8). Yield of red zinfandel was similar at approximately 27 lbs/vine while the 10-spur treatment (T3) produced the higher total yield. Treatment 3 also resulted in significantly more rotten fruit at near 15 lbs/vine in contrast to near 7 lbs/vine for Treatment 1. These results indicated the 14-spur treatment and thinning produced less rotten fruit than the 10-spur treatment with no thinning.

Treatments 4 and 8 compared the 14- and 10-spur level of pruning at the same RDI 60% irrigation level. As with the full water treatment comparison, total yield was significantly increased in the 10−spur with no thinning treatment. However, the amount of rotten fruit in the 10-spur treatment was significantly higher than the 14-spur level of pruning with cluster thinning.

Treatments 10 and 9 compare the 14- and 10-spur level of pruning at the same RDI 35% irrigation level. Total yield, red zinfandel yields and rot yield were not significantly different from each other. However, the same yield trends exist as in the other irrigation levels.

The 10-spur levels of pruning with no cluster thinning produced more clusters than the 14-spur treatments (with the exception of the RDI 35% irrigation level) in a more compact area resulting in a higher level of rotten fruit. Total yield was significantly higher in the 10-spur treatments with the exception of the RDI 35% irrigation level. Red zinfandel yields were similar because of the higher amount of rotten fruit. The total number of clusters was significantly higher 10 spur treatments than the 14 spur treatments; 21 clusters in the full water treatment and 11 more in the RDI 60% treatment.. In the 35% RDI treatments, the number of clusters was nearly the same. The relationship between RDI% and rotten fruit, shown in Figure 4, for both spur levels indicated a similar slope between fruit levels until the rotten fruit level drops below 1.0 lb/vine.

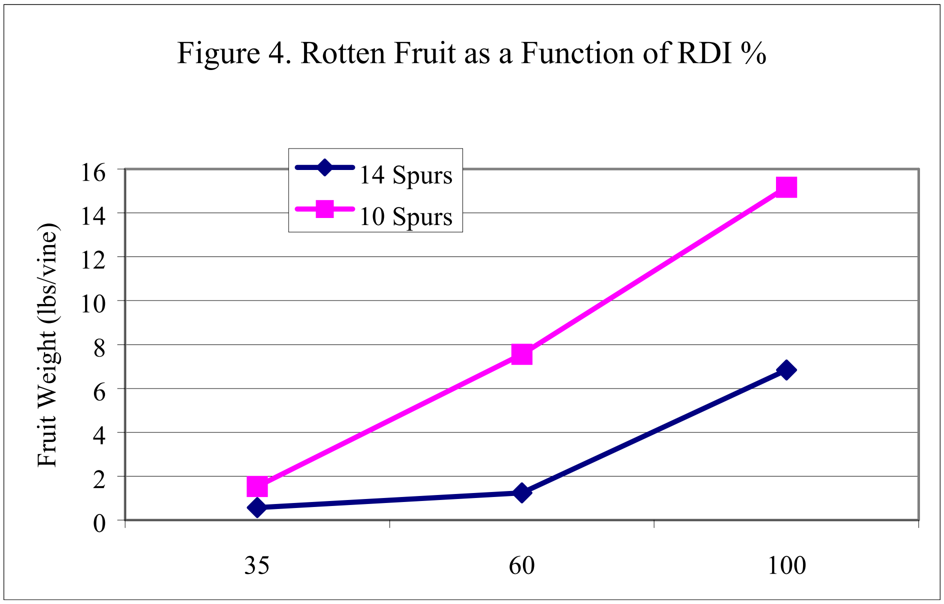


Table 9. 2000 Zinfandel Yield Comparison by Factor, Lodi

Treatment	Variable	Total Yield (lbs/vine)	Red Yield (lbs/vine)	Rot Yield (lbs/vine)
		Irrigation Level		
14 Spurs				
1	Full	33.9 d	27.0	6.84 c
4	-13/60%	32.0 e	30.8	1.24 de
10	-13/35%	26.5 f	25.9	0.57 e
10 Spurs				
3	Full	42.6 c	27.4	15.17 a
8	-13/60%	33.5 d	25.9	7.56 bc
9	-13/35%	27.7 ef	26.1	1.53 de
		Pruning Level		
Full Irrigation				
1	14 Spurs	33.9 d	27.0	6.84 c
3	10 Spurs	42.6 c	27.4	15.17 a
60% RDI				
4	14 Spurs	32.0 e	30.8	1.24 de
8	10 Spurs	33.5 d	25.9	7.56 bc
35% RDI				
10	14 Spurs	26.5 f	25.9	0.57 e
9	10 Spurs	27.7 ef	26.1	1.53 de
P =		0.0000	0.0868	0.0000

Common letters among means within columns denote no significant difference at $P \leq 5\%$ using Duncan's mean separation.

Dual Harvest Strategy

Treatments 1 and 2 compare the dual harvest strategy versus single harvest under a full water irrigation regime. Treatment 1 was cluster thinned as previously described. The total yield of the non-thinned treatment (T2) was obliviously greater than the thinned treatment at 60.4 lbs/vine versus 33.9 for the thinned treatment (T1) (Table 10). The yield of rotten fruit was similar averaging about 7 lbs/vine. Red zinfandel yield was also not significantly different averaging 25.1 lbs/vine. The 26.2 pounds of white zinfandel brought the total saleable fruit of Treatment 2 up to 49.4 lbs/vine.

Treatments 4 and 6 compare the dual harvest strategy under the RDI 60% irrigation regime. Treatment 4 was cluster thinned as previously described. Just as in the comparison at full water, the total yield of the dual harvest treatment was greater than the thinned treatment (T4) at 48.0 lbs/vine versus 32.0 for the thinned treatment (Table 10). The yield of rotten fruit was numerically greater in the thinned Treatment 4 at 4.6 lbs/vine while Treatment 4 was 1.2 lbs/vine. The yield of red zinfandel was not significantly different between the two treatments. The 19.1 lbs/vine yield of white zinfandel brought the total saleable fruit of Treatment 6 to 42.9 lbs/vine.

The dual harvest strategy seems to work best in years such as this when thinning is necessary to adjust crop load. It could be an excellent strategy by cutting thinning costs, potentially increasing the fruit quality and decreasing rotten fruit in the subsequent red zinfandel harvest. One economic caveat: this strategy can only work in a short crop environment when additional white zinfandel is sought after the season begins.

Leaf Removal

Treatments 7 and 4 compare leaf removal across a single irrigation strategy, 60% RDI and the standard spur pruning of 14 combined with cluster thinning. Total yield, red zinfandel and rotten fruit were not significantly different between these two treatments. At a RDI % below 60% leaf removal becomes less important except in high vegetative growth years (as in 1998). This year at a 60% RDI level, rot was not a serious problem resulting in no significant difference in red zinfandel yield; however, improvements in wine color were found to exist. (See wine evaluation section.)

Table 10. Comparisons by Factor

Treatment	Variable	Total Yield (lbs/vine)	White Yield (lbs/vine)	Red Yield (lbs/vine)	Rot Yield (lbs/vine)
		Dual Harvest			
Full Irrigation					
1	Single Harvest	33.9 d		27.0	6.84 b
2	Dual Harvest	60.4 a	26.2 a	23.2	8.06 b
RDI 60%					
4	Single Harvest	32.0 e		30.8	1.24 cd
6	Dual Harvest	48.0 b	19.1 b	23.8	4.55 bc
		Leaf Removal			
RDI 60%					
7	No	27.5 ef		26.3	1.20 cd
4	Yes	32.0 e		30.8	1.24 cd
		Cover Crop			
RDI 60%					
4	No	32.0 e		30.8	1.24 cd
5	Yes	26.3 f		26.1	0.24 d
P =		0.0000	0.0061	0.0868	0.0000

Common letters among means within columns denote no significant difference at $P \leq 5\%$ using Duncan's mean separation.

Cover Crop

Treatments 4 and 5 compare the use of a cover crop at the 60% RDI level. Total yield was significantly reduced in the cover crop treatment (T5) at 26.3 lbs/vine compared to the otherwise identical Treatment 4 at 32.0 lbs/vine. Yield of rotten fruit was not significantly different averaging less than one percent. Yield of red zinfandel was not significantly different.

Yield Component Analysis

Yield component analysis is a valuable tool to access the factors responsible for the change in yield across all treatments. Unfortunately the components of the number of berries per vine and the berry size in the rotten fruit were of little value since it is a weight of split-dehydrated berries. This fact only makes it possible to evaluate the red zinfandel, which in this trial was not significantly different, and the fact that both rot and pruning, which tends to remove the largest berries affected the yield. A significant relationship between the fruit load measured a berries per vine and yield of red zinfandel exists, however the level of confidence is low (r^2 28%). A relationship between berry size and yield was not significant.

Vine Canopy Response

Vine canopy responses to water deficits were measured as the maximum percentage of land surface shaded by the canopy, light reaching the fruiting level inside the canopy. and pruning weights .

Land Surface Shading. Land surface shading by the canopy was measured at maximum canopy expansion on July 15. The canopy size was maximized at 49-60 percent (Table 6).

Table 11. 2000 Zinfandel Canopy Measurements, Lodi

Treatment	Land Surface Shaded	Prunings (lbs/vine)	Total Yield/Prunings	Red Zinfandel Yield/Prunings
1	60	5.7 a	6.1 de	4.8 e
2	60	5.9 a	10.2 a	8.4 a
3	61	5.1 bc	8.3 b	5.3 de
4	52	4.9 c	6.6 de	6.3 cd
5	49	3.8 e	7.1 cd	7.0 bc
6	50	5.6 ab	8.7 b	7.8 ab
7	52	4.6 cd	6.0 e	5.7 de
8	51	4.2 de	8.0 bc	6.2 cd
9	49	4.6 cd	6.1 de	5.7 de
10	50	4.7 cd	5.6 e	5.5 de
P =	0.06652	0.0000	0.0000	0.0000

Common letters among means within columns denote no significant difference at $P \leq 5\%$ using Duncan's mean separation.

Fruit Level Light Conditions. Measurements of the light conditions at the fruit level inside the canopy were made at midday on 9/6/00. Values are expressed as the percentage of photo synthetically available radiation (PAR) light measured above the canopy. The cover crop treatment resulted in the highest light level at 10.3 % but was not significantly different than the two RDI 35% treatments T9 and T10 (Table 12). As a group they were higher than all other treatments. The full water Treatment 1 resulted in the lowest light level at only 5.4%. Generally, the full water treatments received the least light at the fruit level while the RDI 60% were intermediate with the cover crop and RDI 35 % treatment receiving the most. Leaf removal Treatment 4 resulted in significantly more light than the non-leaf removal Treatment 8.

Table 12. 2000 Zinfandel Fruit level light conditions, Lodi

Treatment	Fruit level light (% of available)
1	5.4 e
2	6.4 cde
3	6.0 cde
4	7.9 bc
5	10.3 a
6	6.4 cde
7	5.7 de
8	7.6 bcd
9	8.6 ab
10	9.2 ab
P =	0.0001

Prunings. The weights of prunings were found to be significantly different as a result of the imposed treatments (Table 11). They varied from a high of 5.9 lbs/vine to a low of 3.8 lbs/vine. Necessary hedging of the vines midseason to improve access for cultural operations and prior to mechanical harvest no doubt influenced this parameter, especially in the full water treatments. In general, the full water treatments (T1 and T2) were in the larger prunings group with the cover crop treatment being lowest.

Crop Yield to Pruning Ratio. The relationship of yield per unit of prunings was calculated to assess the balance of vegetative to reproductive structures. Significant differences were found to exist between treatments (Table 11). The ratio can be determined in two fashions, with total yield and the yield of red zinfandel only. By comparing the red zinfandel yield only ignores the rotten fruit and the white zinfandel harvested fruit. On a red zinfandel yield basis, the lowest ratio was 5.2, which was only significantly different from the dual harvest treatments (T2 and T6) and the cover crop treatment T5. On a total crop basis, Treatment 2 resulted in the highest ratio of 10.2. Treatments 6, 3 and 8 followed averaging 8.3. Treatments 2 and 6 were dual harvest treatments.

Juice Analysis

Juice pH varied between treatments from 3.28 to 3.52 (Table 13). The highest pH juice was from full water Treatment 1 while the lowest was the cover crop Treatment 5. Significant differences were found between Treatment 1 and all others. The effects of RDI are not apparent on pH. Titratable acidity was remarkably similar with only the cover crop Treatment 5 being significantly lower (5.55 g/L) than most of the other treatments. Juice malate concentration was significantly higher in the full water Treatment 1 at 3769 ppm when compared to all other treatments (Table 13). The -13/60% RDI treatments (T4, 5, 6, 7, and 8) were nearly equal with no effect by the variables of pruning, thinning, dual harvest, or the use of a cover. The cover crop was lowest in malate concentration at 1881 ppm.

Table 13. 2000 Zinfandel Juice Analysis, Lodi

Treatment	°Brix	pH	Titratable Acidity (g/L)
1	25.5 a	3.52 b	7.55 a
2	24.1 d	3.38 a	7.05 a
3	23.1 e	3.38 a	7.68 a
4	25.0 abc	3.39 a	6.85 a
5	25.4 a	3.28 a	5.55 b
6	24.1 d	3.38 a	7.35 a
7	25.2 ab	3.40 a	7.48 a
8	24.3 cd	3.33 a	7.13 a
9	24.8 abcd	3.38 a	6.65 ab
10	24.5 bcd	3.38 a	7.38 a
P =	0.0004	0.0139	0.0304

Common letters among means within columns denote no significance difference at P ≤ 5% using Duncan's mean separation.

Table 14. 2000 Zinfandel Juice Analysis, Lodi

Treatment	Malate (ppm)	Potassium (ppm)	Ammonia (ppm)
1	3769 e	1838 f	133 d
2	2756 cd	1288 bcd	223 ab
3	2619 bcd	1650 ef	155 cd
4	2288 abc	1138 ab	178 abcd
5	1881 a	950 a	145 d
6	2213 ab	1188 abc	228 a
7	2381 abcd	1138 ab	210 ab
8	2081 a	1488 cde	173 bcd
9	2860 d	1513 cde	203 abc
10	2830 d	1438 bcde	218 ab
P =	0.0000	0.000	0.0005

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

Table 15. 2000 Zinfandel Wine Analysis, Lodi

Treatment	ALC	TA	pH	280nm	Phenolics 420nm	520nm	Colors 620nm	Hue 420/520	Intensity 420+520
1	14.2	5.4	3.92	33.9	2.25	2.52	1.14	0.893	4.77
2	13.6	5.7	3.61	35.2	2.05	2.36	0.91	0.869	4.41
3	14.1	5.4	3.69	35.3	1.39	2.25	1.16	0.618	3.64
4	14.5	5.9	3.74	39.1	2.31	2.95	0.86	0.783	5.26
5	15.7	6.4	3.61	47.0	2.56	3.72	1.01	0.688	6.28
6	14.1	5.8	3.55	35.7	1.74	2.31	0.64	0.753	4.05
7	14.5	5.9	3.74	39.1	2.31	2.95	0.86	0.783	5.26
8	14.5	6.2	3.53	34.0	1.63	2.90	0.96	0.562	4.53
9	14.5	5.9	3.56	43.2	2.08	2.86	0.74	0.727	4.94
10	14.5	5.9	3.56	43.2	2.08	2.86	0.74	0.727	4.94

Wine Analysis

Like the juice, the wine from the full irrigation T1 resulted in the highest pH at 3.92 (Table 15). The effect of irrigation level across the 14-spur level of pruning can be seen in the pH values. The highest pH occurred in the full irrigation (T1) at 3.92 while the -13/60% (T4) was 3.74 and the -13/35% (T10) level was at 3.56. A similar pattern occurred across the 10-spur treatments. The highest pH occurred in the full irrigation (T3) at 3.69 while the -13/60% (T8) was 3.53 and the -13/35% (T9) level was at 3.56. The pruning level resulted in a lower pH for the 10-spur treatments at full irrigation and at the 60% RDI while no differences were found at the 35% RDI level. In the full water treatment comparison of the single harvest (T1) versus the dual harvest (T2), the pH was lower by 0.31 units in the dual harvest treatment. Similarly in the 60% RDI, the dual harvest (T6) was lower Ph by 0.19 units than the single harvest treatment (T4). No difference was found between fruit from vines with or without leaf removal.

Titratable acidity was highest in the wine of the cover crop treatment (T5) but was lowest in the juice analysis. This result is explained by a low malate content (lowest of all treatments) in the cover crop plots, which, under malolactic fermentation, left behind more titratable acidity. The lowest titratable acidity was found in the full water treatments T1 and T3.

Across the wavelength spectrum, the cover crop wine (T5) registered the highest values. The intensity of color (420+ 620 nm) was also the highest at 6.28. Comparisons across the irrigation levels in the 14-spur level of pruning showed increase in intensity from the full irrigation (T1) value of 4.77 to that of T4 (-13/60%) at 5.26. The more stressed Treatment 10 (-13/35%) decreased to 4.94. At the 10-spur level of pruning, a similar pattern was seen. The full water T3 resulted in a wine intensity of 3.64 while the -13/60% Treatment 8 was increased to 4.53 and further increased in T9 (-13/35) to 4.94. It seems the 14-spur treatments combined with cluster thinning resulted in more intense color at the full and moderate levels of water stress (-13/60%). The single harvest strategy in the full irrigation as well as the moderate stress level of -13/60% resulted in higher wine color intensities compared to the dual harvest strategy.

Wine Evaluation

A panel of experienced tasters ranked the wines. Due to the large number of treatments, the wines were arranged in groups for comparison of specific variables within a group. Group One evaluated the 14-spur treatments across the irrigation levels. Table 16 shows the treatments, total points and ranking of each group. The full irrigation treatment (T1) was least preferred with a slight but insignificant preference for Treatment 10 over Treatment 4.

Table 16. 2000 Zinfandel Wine Preference, Group 1

Treatment	Variable	Total Points	Rank
Irrigation Level			
14 Spurs			
1	Full	48	3
4	-13/60%	22	2
10	-13/35%	20	1

Group Two evaluated the 10-spur treatments across the irrigation levels. Table 17 shows the treatments, total points and ranking of each group. The full irrigation treatment (T3) was again the least preferred followed by Treatment 8 and the most preferred wine Treatment 9. The order of preference in both the 14- and 10-spur treatments was directly related the amount of deficit. The full water treatment is always least preferred and the most severe deficit (-13/35%) the most preferred.

Table 17. 2000 Zinfandel Wine Preference, Group 2

Treatment	Variable	Total Points	Rank
Irrigation Level			
10 Spurs			
3	Full	35	3
8	-13/60%	22	2
9	-13/35%	19	1

Group Three compared the cover crop, dual harvest strategy and leaf removal under the same irrigation strategy (-13/60%). Table 18 shows the treatments, points, and ranking of the wines in this group. Treatment 4 as a standard was compared to the cover crop, dual harvest and no leaf removal treatments. The cover crop was strongly preferred in this group at 26 points with 34 for the standard Treatment 4. The dual harvest strategy was very close with a slight preference for the single harvest strategy. Wine of the leaf removal treatment was preferred over the non-leaf removal Treatment 7. The non-leaf removal treatment was the least preferred.

Table 18. 2000 Zinfandel Wine Preference, Group 3

Treatment	Variable	Total Points	Rank
Cover Crop			
4	No	34	3
5	Yes	26	1
Dual Harvest			
4	Single harvest	34	3
6	Dual harvest	36	2
Leaf Removal			
7	No	40	4
4	Yes	34	3

SUMMARY

This study was conducted to evaluate an approach to vine water management that will provide growers a method to know when to begin to irrigate, when to schedule subsequent irrigations, and how much water to apply each time they irrigate. Additionally, canopy management, the use of a cover crop and a dual harvest strategy was evaluated. 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 at a fraction (RDI %) of full vine water use. It is our goal to use water management, defined as the timing and quantity of applied water, to impose vine water deficits as a means of optimizing desirable must and wine characteristics.

The experimental site is located in a mature zinfandel vineyard near Lodi, California. The trellis system is a bilateral cordon with vine spaced 7 by 10 feet and established on Freedom rootstock. The soil is a Tokay fine sandy loam.

The full potential water use treatments (T1 thru T3) were irrigated May 24, 2000 and weekly thereafter at an amount to equal full potential water use each week. The leaf water potential remained at less than –11 bars until August when it increased slightly in stress to –12 bars.

Treatments receiving 60% RDI on a weekly basis generally maintained leaf water potential at the –14 level throughout the season after the initiation of irrigation on July 11, 2000. The cover crop treatment also had the 60% RDI resulting in more stress at the threshold (July 11). It then responded to the irrigation followed by more stress near harvest. The 35% RDI was similar to the 60% RDI treatments until a few weeks after the initiation of irrigation when it exhibited more stress approaching harvest

Yield

No significant differences in red zinfandel yields were found to exist between treatments with a grand mean of 25.9 lbs/vine. Significant differences were found between treatments in total yield (red + white + rotten fruit) as well as the amount of rotten fruit.

Irrigation Strategy. Treatments 1, 4, and 10 compared the full water 100%, 60% RDI, and 35% RDI all at the 14-spur per vine level of pruning with cluster thinning. Total yield was not significantly reduced by the moderate water stress Treatment 4 (RDI 60%) when compared to the full water Treatment 1. Treatment 10 (RDI 35%) was significantly reduced when compared to both Treatments 1 and 4. Rotten fruit was significantly higher in the full water treatment. Red zinfandel yield was highest in Treatment 4 but not significantly different than other treatments.

Treatments 3, 8, and 9 compare the full watered vines, 60% RDI, and 35% RDI at the 10-spur per vine level of pruning. Total yield was significantly higher in the full water treatment followed by Treatment 8 (60% RDI), then Treatment 9 (35% RDI). The yield of rotten fruit increased with increasing water volume consumed with the full water having the highest amount at over 15 lbs/vine. The RDI 35% treatment resulted in less than 2 lbs/vine of rotten fruit. Clearly, a relationship exists between water applied and the amount of rotten red zinfandel. Similar results were found in the 14-spur comparison with red zinfandel yield highest in Treatment 3 but not significantly different from other treatments.

Pruning (Spur Number). Treatments 1 and 3 compare the 14- and 10-spur pruning levels, both at the full water irrigation level. Total yield was significantly higher in the 10-spur treatment (T8). Yield of red zinfandel was similar at approximately 27 lbs/vine while the 10-spur treatment (T3) produced the higher total yield. Treatment 3 also resulted in significantly more rotten fruit at near 15 lbs/vine in contrast to near 7 lbs/vine for Treatment 1. These results indicated the 14-spur treatment and thinning produced less rotten fruit than the 10-spur treatment with no thinning.

Treatments 4 and 8 compared the 14- and 10-spur level of pruning at the same RDI 60% irrigation level. As with the full water treatment comparison, total yield was significantly increased in the 10 spur with no thinning treatment. However, the amount of rotten fruit in the 10-spur treatment was significantly higher than the 14-spur level of pruning with cluster thinning.

Treatments 10 and 9 compare the 14- and 10-spur level of pruning at the same RDI 35% irrigation level. Total yield, red zinfandel yields and rot yield were not significantly different from each other. However, the same yield trends exist as in the other irrigation levels.

The 10-spur levels of pruning with no cluster thinning produced more clusters than the 14-spur treatments (with the exception of the RDI 35% irrigation level) in a more compact area resulting in a higher level of rotten fruit. Total yield was significantly higher in the 10-spur treatments with the exception of the RDI 35% irrigation level. Red zinfandel yields were similar because of the higher amount of rotten fruit. The total number of clusters was significantly higher 10 spur treatments than the 14 spur treatments; 21 clusters in the full water treatment and 11 more in the RDI 60% treatment. In the 35% RDI treatments, the number of clusters was nearly the same. The relationship between RDI% and rotten fruit, shown in Figure 4, for both spur levels indicated a similar slope between fruit levels until the rotten fruit level drops below 1.0 lb/vine.

Dual Harvest Strategy

Treatments 1 and 2 compare the dual harvest strategy versus single harvest under a full water irrigation regime. Treatment 1 was cluster thinned as previously described. The total yield of the non-thinned treatment (T2) was obliviously greater than the thinned treatment at 60.4 lbs/vine versus 33.9 for the thinned treatment (T1). The yield of rotten fruit was similar averaging about 7 lbs/vine. Red zinfandel yield was also not significantly different averaging 25.1 lbs/vine. The 26.2 pounds of white zinfandel brought the total saleable fruit of Treatment 2 up to 49.4 lbs/vine.

Treatments 4 and 6 compare the dual harvest strategy under the RDI 60% irrigation regime. Treatment 4 was cluster thinned as previously described. Just as in the comparison at full water, the total yield of the dual harvest treatment was greater than the thinned treatment (T4) at 48.0 lbs/vine versus 32.0 for the thinned treatment. The yield of rotten fruit was numerically greater in the thinned Treatment 4 at 4.6 lbs/vine while Treatment 4 was 1.2 lbs/vine. The yield of red zinfandel was not significantly different between the two treatments. The 19.1 lbs/vine yield of white zinfandel brought the total saleable fruit of Treatment 6 to 42.9 lbs/vine.

The dual harvest strategy seems to work best in years such as this when thinning is necessary to adjust crop load. It could be an excellent strategy by cutting thinning costs, potentially increasing the fruit quality and decreasing rotten fruit in the subsequent red zinfandel harvest. One economic caveat: this strategy can only work in a short crop environment when additional white zinfandel is sought after the season begins.

Leaf Removal. Treatments 7 and 4 compare leaf removal across a single irrigation strategy, 60% RDI and the standard spur pruning of 14 combined with cluster thinning. Total yield, red zinfandel and rotten fruit were not significantly different between these two treatments.

This year at a 60% RDI level, rot was not a serious problem resulting in no significant difference in red zinfandel yield; however, improvements in wine color were found to exist.

Cover Crop. Treatments 4 and 5 compare the use of a cover crop at the 60% RDI level. Total yield was significantly reduced in the cover crop treatment (T5) at 26.3 lbs/vine compared to the otherwise identical Treatment 4 at 32.0 lbs/vine. Yield of rotten fruit was not significantly different averaging less than one percent. Yield of red zinfandel was not significantly different

Juice Analysis

Juice pH varied between treatments from 3.28 to 3.52. The highest pH juice was from full water Treatment 1 while the lowest was the cover crop Treatment 5. Significant differences were found between Treatment 1 and all others. The effects of RDI are not apparent on pH. Titratable acidity was remarkably similar with only the cover crop Treatment 5 being significantly lower (5.55 g/L) than most of the other treatments. Juice malate concentration was significantly higher in the full water Treatment 1 at 3769 ppm when compared to all other treatments. The -13/60% RDI treatments (T4, 5, 6, 7, and 8) were nearly equal with no effect by the variables of pruning, thinning, dual harvest, or the use of a cover. The cover crop was lowest in malate concentration at 1881 ppm.

Wine Analysis

Like the juice, the wine from the full irrigation T1 resulted in the highest pH at 3.92. The effect of irrigation level across the 14-spur level of pruning can be seen in the pH values. The highest pH occurred in the full irrigation (T1) at 3.92 while the -13/60% (T4) was 3.74 and the -13/35% (T10) level was at 3.56. A similar pattern occurred across the 10-spur treatments. The highest pH occurred in the full irrigation (T3) at 3.69 while the -13/60% (T8) was 3.53 and the -13/35%(T9) level was at 3.56. The pruning level resulted in a lower pH for the 10-spur treatments at full irrigation and at the 60% RDI while no differences were found at the 35% RDI level. In the full water treatment comparison of single harvest (T1) versus the dual harvest (T2), the pH was lower by 0.31 units in the dual harvest treatment. Similarly in the 60% RDI the dual harvest (T6) was lower Ph by 0.19 units than the single harvest treatment (T4). No difference was found between fruit from vines with or without leaf removal.

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The results of this and past years in this trial indicate the approach of using leaf water potential levels as a threshold of when to begin irrigation and to use portions of full water ET to schedule subsequent application volumes is an effective and reliable method of irrigation scheduling that improves the quality and maintains yield parameters. Combining irrigation strategies with cultural practices such as pruning/thinning, leaf removal and the use of cover crop increased wine quality with no significant difference in yields. This fact alone is a principal driving force breaking down the barriers to adoption of these practices by growers.

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