WATER USE OF CABERNET SAUVIGNON GRAFTED ONTO THREE ROOTSTOCKS IN A VINEYARD NEAR OAKVILLE IN THE NAPA VALLEY – VALIDATION OF CROP COEFFICIENTS AND REGULATED DEFICIT IRRIGATION FACTORS DEVELOPED IN THE CARNEROS DISTRICT ON CHARDONNAY

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SUMMARY:

The last year of a three-year study was completed in a Cabernet sauvignon near Oakville in 2000. The objective was to determine the applicability of crop coefficients developed using Chardonnay in different vineyard with different cultivars, rootstocks and row directions. The three rootstocks used in the trial were 5C, 110R and 3309C. Potential ET (ET_o) from budbreak (3 April) until harvest (21 September) was 875 mm (34.4 inches). Estimated full ET of the vines was determined by multiplying weekly ET_o by the crop coefficients developed in Carneros. Water use at 100% of estimated ET_c between the above two mentioned dates was equivalent to 209 gallons per vine (450 mm or 17.7 inches). Applied water in 2000 was equivalent to 187 gallons per vine.

Irrigation treatments at the vineyard were fractions (0, 0.25, 0.5, 0.75, 1.0 and 1.5) of estimated full ET_c. Prior to harvest midday values of leaf water potential for the irrigation treatments at 100% of ET_c or greater were less negative than –1.0 MPa. Vines that were deficit irrigated had midday leaf water potential values more negative than –1.0 MPa. There were significant irrigation and rootstock treatment effects on berry weight measured on 12 September. Berry weight was maximized at irrigation amounts from 75 to 100% of ET_c while the rootstock 5C had the largest berries. There were no differences in soluble solids among treatments on the sample date. Rootstock had no significant effect on pH and titratable acidity (TA). However, TA tended to increase as applied water amounts increased. Vines receiving no applied water or applied water at 0.25 ET_c had the lowest yields. Vines receiving 75% of estimated ET_c had the highest yield in 2000 (equal to 5.25 tons per acre). Wines were made as a function of irrigation treatment using fruit from all rootstocks. Wine color intensity and the total wine phenols index decreased as the amount of applied water increased. Two tasting panel sensory analyses indicated a preference for wine made from the 0.75 ET_c treatment.

Over the three-year course of the experiment, berry weight was maximized at the 0.75 ET_c irrigation treatment. This result is similar to studies I've conducted at other locations on wine grapes in the coastal valleys of California and on raisin and table grapes in the San Joaquin Valley. Pruning weights and yield were generally highest for the 0.75 ET_c treatment in this study. Both parameters leveled off at applied water amounts above this treatment level. Yields of vines receiving no applied water, 0.25 ET_c and 0.5 ET_c were 66, 77 and 96% of the maximum yield, respectively. The results indicate that one could deficit irrigate this particular vineyard and have minimal effects on productivity, while increasing water use efficiency and providing beneficial effects on fruit quality.

OBJECTIVES:

One of the major purposes of this study was to determine if a non water stressed crop coefficient developed on Chardonnay grapevines in the Napa Valley was useful in scheduling irrigations of grapevines grown in other areas of California using different cultivars or row direction. The term "useful" in the above sentence is meant to indicate that the amounts of applied water at estimated full ET are sufficient such that the vines are not water stressed at any time during the season. I will be determining non-stressed vineyard water use at the proposed vineyard site near Oakville.

The second major purpose of this study was to determine the effects of water deficits and potential over-irrigation on vine water status, yield, fruit characteristics and wine quality. Irrigation treatments were fractions, ranging from 0 to 150% of estimated full ET.

SPECIFIC OBJECTIVES:

1. Determine water use of mature, non-stressed Cabernet Sauvignon grapevines grafted onto three rootstocks and grown at Oakville in the Napa Valley.

2. Validate non-water stressed crop coefficients and regulated deficit irrigation factors developed in the Carneros District on Chardonnay for use with other wine grape cultivars.

3. Determine the effects of various irrigation amounts (as a fraction of estimated full ET) imposed from the initial irrigation to harvest on yield, fruit composition and wine quality.

EXPERIMENTS CONDUCTED TO MEET STATED OBJECTIVES:

Vines in a mature Cabernet Sauvignon vineyard were used in this study. The vines were trained to bilateral cordons using a vertical trellis system. Vine and row spacing were 3.25 and 6.0 ft (19.5 ft^2 or 1.87 m^2 per vine), respectively. This gave a vineyard density of 2165 vines per acre (5348 vines ha^{-1}). The rows are oriented parallel to Highway 29 running through Napa Valley (thus the rows were not oriented true North to South). Irrigation of the vines was based upon evaporative demand. Potential ET (ET_o) was obtained from a CIMIS weather station at the Department of Viticulture and Enology's Oakville Field Station (located approximately 1.6 km from the experimental vineyard). The seasonal crop coefficients were developed on Chardonnay vines in the Carneros District for a VSP trellis using 7-foot rows (given in previous reports). The crop coefficients in this vineyard were increased due to the vineyard having a 6 foot row spacing. Full vine water use was calculated using the following equation:

$$ET_c = ET_o \ x \ k_c$$

Leaf water potential was measured periodically to determine if the irrigation amounts applied to the vines were appropriate (beginning after irrigations commenced). It had previously been determined that midday leaf water potential of vines irrigated at full ET will not be more negative than -1.0 MPa (-10 bars) at any time during the season.

Vineyard irrigation treatments consisted of water application amounts at various fractions of estimated ET beginning with the initial irrigation. There were six irrigation treatments: no applied water (0), 25, 50 75, 100 and 150% of estimated full ET. Altering emitter volume and number per vine was used to impose the irrigation treatments. Individual irrigation plots consisted of an entire row. Each treatment was replicated three times. Each one of the replicated blocks was comprised of a different rootstock. The rootstocks used were 5C, 110R and 3309C.

Vegetative growth of the vines was determined by taking pruning weights during vine dormancy. Yield and yield components were measured at harvest. The yield components measured were shoots per vine, berry size, cluster size, calculated berries per cluster, cluster number per shoot and cluster number per vine. Fruit composition was determined just prior to harvest. This included the measurements of soluble solids (^{o}Brix), titratable acidity and pH. Harvest took place at a pre-determined sugar level in the fruit based upon the grower-cooperator's standards. All irrigation treatments were harvested on the same day in 2000 as weather forecasts indicated the chance of rainfall the following week. The Robert Mondavi Winery made wine as a function of irrigation treatment, combining fruit from all three rootstocks.

SUMMARY OF MAJOR RESEARCH ACOMPLISHMENTS AND RESULTS:

Potential ET from budbreak until harvest was 875 mm (34.4 inches) (Tables 1 and 2). The calculated amount of water used from budbreak to harvest was 450 mm (17.7 inches). Irrigations commenced the week of 5 June. Total applied water for the 100% ET treatment between budbreak and harvest was 379 mm (14.9 inches) which was equivalent to 709 l vine^{-1} (187 gallons). The maximum water application per vine per week was slightly greater than 14 gallons the week of August 14, in 2000 (Table 1).

There were significant effects of irrigation treatment and rootstock on berry weight (Table 3). Berry size was maximized at irrigation amounts between 75 and 100% of ET and the 5C rootstock had the largest berries. Treatments had no significant effects on soluble solids when the berries were sampled on September 12th (Table 4). Neither irrigation treatment nor rootstock had a significant effect on berry pH or titratable acidity (Tables 5 and 6).

The lowest yields measured in 2000 (which was equivalent to 3.0 t/acre) were for the no-applied water and 0.25 ET_c treatments and the highest (which was equivalent to 5.3 t/acre) was for the 0.75 ET_c treatment (Table 7). The yield of the 0.75 ET_c irrigation treatment was significantly greater than any other treatment in 2000. There were no significant differences in yield among the 0.5, 1.0 and 1.5 ET_c, irrigation treatments. The rootstock 5C had the greatest yield when compared to the other two rootstocks.

Vines in the various irrigation treatments were harvested on the same date (at a target sugar level of approximately 24.5 ^{o}Brix) in order to make small wine lots (wine was made of all irrigation treatments, using fruit from all rootstocks, except the 1.5 treatment). Sugars in the fruit did vary to a greater extent than we had hoped for, although they were acceptable (Table 8). There were no clear trends in TA, pH and potassium in the must as a function of irrigation treatment. TA and color intensity tended to decrease, and pH and potassium increased in the wine as irrigation amount increased. Two tasting panels at the Robert Mondavi Winery preferred wine made from the 0.75 ET_c irrigation treatment to a greater extent than the other irrigation treatments.

There was a significant effect of irrigation treatment and rootstock on pruning weights in 2000 (Table 9). Pruning weights tended to increase as applied water amounts up until the 0.75 irrigation treatment. Vines on the 5C rootstock had the greatest pruning weights. These results were similar to those obtained in 1998 and 1999.

OUTSIDE PRESENTATIONS OF RESEARCH:

Portions of this study were presented at the Napa Valley Technical Working Group in May of 2000, the Paso Robles Vintners and Growers Association meeting in May of 2000 and at a University of California Extension course on wine grape production in February of 2001. The 1999 and 2000 data from this study were presented at the monthly meeting of the North Coast Viticultural Research Group in February 2001

RESEARCH SUCCESS STATEMENTS:

One of the major accomplishments of this study was the adaptation of seasonal crop coefficients, developed for a VSP trellis in another vineyard for use in this study. The crop coefficients were initially developed in a Chardonnay vineyard with 7-ft. row spacings, versus 6-ft. row spacings used in this study. In the past, crop coefficients did not take into account differences in row spacing. The crop coefficients used in the Cabernet vineyard were adjusted upward from those developed in the Chardonnay vineyard by 17% (7 ft. divided by 6 ft. equals 1.17, or an increase of 17%). This adjustment is the basic premise of crop coefficients I've developed which is: water use per unit length of row is the same, even though row spacings differ as long as the trellis system is similar and no mutual shading occurs between rows. Therefore, two vineyards planted next to one another with the same vine spacing, but different row spacing, will use the same amount of water per vine but different amounts of water per unit land area. Changing the crop coefficients as I did in this study validated the above assumption. Lastly, I also used crop coefficients as a function of degree-days from budbreak. This allowed for the proper irrigation amounts despite differences in date of budbreak and other phenological events among cultivars and years.

The effects of different irrigation amounts on berry juice characteristics, vegetative and reproductive growth and vine water status in this vineyard were similar in many respects to that found in similar trials on raisin and table grapes in the San Joaquin Valley (L.E. Williams, unpublished data). It is also comparable to wine grape studies conducted at other locations in the coastal valleys of California (L.E. Williams, see previous reports to the American Vineyard Foundation). Over the three year duration of this study berry size was generally maximized at water application amounts equal to 75% of estimated vineyard ET as was harvest yield (see

Table 10). It should also be noted that yield of vines receiving applied water at 50% of estimated ET_c was 96% of the maximum yield. There are several reasons that may explain the results. This grape production area normally receives considerable rainfall during the winter such that the soil water content of the vineyard's soil is at field capacity when the vine initiates shoot growth in the spring. In addition, during the 1998 and 2000 growing seasons significant amounts of rain fell subsequent to budbreak. Therefore, vine growth may not become water limited until early to mid-summer at this location. In fact, when midday leaf water potential was measured at veraison in this vineyard (during the 2000-growing season), only the no applied water and the 0.25 ET_c treatments had water potential values that would have indicated they were under water stress. It should be pointed out here that the irrigation frequency used in the study was once per week.

Sensory analyses of the wines made from the irrigation treatments in this study, by the Robert Mondavi Winery taste panel, were not conclusive. In duo-trio test comparisons, there were rarely significant results. Preference analysis also indicated that the preferred wines varied from year to year. It should be pointed out that wine color does increase as the amount of applied water decreases and that the above sensory analyses were conducted in black glasses. The lack of an effect of irrigation amount on sensory evaluations may be due to several reasons. Firstly, the use of a VSP trellis system may mitigate the effects of irrigation on vegetative growth of the vine. Shoot positioning and hedging the vines, as done for this trellis system, may result in a fruiting zone microclimate that differs only slightly from irrigation treatment to irrigation treatment. Climatic variables have been shown to affect the composition of the fruit. Secondly, the irrigation amounts that I calculate to be full ET are less than others have used in the past. This may indicate that irrigation amounts close to that replacing the amount of water a vine actually uses, is not as detrimental as once thought. Unfortunately, in most cases irrigation studies conducted in the past had no idea the actual amount of water a vine requires nor were there measures of vine water status or applied water amounts. Lastly, clusters were routinely removed from the vines in this study at some point during the growing season and, therefore, the effect of irrigation amount on crop load may not have been realized.

FUNDS STATUS:

Monies obtained for this study have been expended or have been encumbered. Expenses included the cost of traveling to and from the vineyard site and salary for my technician and temporary summer help.

Table 1. Weekly potential ET (ET_o), crop coefficient (k_c) and estimated vine ET (ET_c) at Oakville, CA, beginning 3 April and ending on 9 October, 2000. ET_c (in mm) equals ET_o multiplied by k_c. ET_c in liters equals ET_c (in mm) multiplied by 1.87 (area in m^2 per vine allotted to calculate water use in liters, this is 19.5 ft^2). ET_c in gallons per week equals ET_c (in liters) divided by 3.78. There are 25.4 mm per inch.

Month		Week	ET_o (mm)	K_c	ET_c (mm)	ET_c (l/vine)	ET_c (gal/vine)	Rainfall (mm)
Apr	BB*	3	27.7	0.17	4.7	8.8	2.4	0
		10	20.3	0.17	3.4	6.4	1.7	40.6
		17	29.2	0.19	5.5	13.7	3.7	11.2
		24	35.5	0.20	7.1	13.3	3.5	0
May		1	27.4	0.21	5.8	10.8	2.8	13.7
		8	28.7	0.22	6.3	11.8	3.1	10.2
		15	34.5	0.27	9.3	17.4	4.6	9.6
		22	42.1	0.33	13.9	26.0	6.9	0
	BL*	29	42.4	0.35	14.8	32.2	8.5	0
June	Irr*	5	36.0	0.41	14.7	32.1	8.5	4.1
		12	45.9	0.47	21.6	40.4	10.7	0
		19	42.9	0.50	21.4	40.1	10.6	0
		26	41.9	0.58	24.3	45.4	12.0	0
July		3	40.1	0.61	24.5	45.7	12.1	0
		10	37.5	0.63	23.7	44.2	11.7	0
		17	40.9	0.65	26.2	49.0	13.0	0
		24	41.6	0.65	27.1	50.6	13.4	0
	VE*	31	40.1	0.70	28.1	52.5	13.9	0
Aug		7	37.8	0.71	26.8	50.2	13.2	0
		14	39.8	0.73	29.1	54.4	14.4	0
		21	35.3	0.75	26.5	49.5	13.1	0
		28	18.0	0.76	13.7	25.6	6.8	3.3
Sept		4	33.7	0.78	26.3	49.2	13.0	0
		11	28.9	0.79	22.9	42.7	11.3	0
	HAR*	18	27.1	0.80	21.7	40.5	10.7	1.8
		25	25.4	0.81	20.6	38.4	10.2	0
Oct		2	20.3	0.81	16.4	30.7	8.1	0
		9	14.5	0.81	11.7	22.0	5.8	5.3

* BB, BL, VE and HAR equals budbreak, bloom, veraison, and harvest dates, respectively. Irr indicates the week of first irrigation

Table 2. The seasonal water budget, for a Cabernet Sauvignon vineyard near Oakville. ET_c and irrigation amounts (Irr) are expressed on an area of 1.87 m^2 (19.5 ft^2) per vine. The date of budbreak (BB) was approximately April 3, bloom (BL) May 29 and veraison (Ver) July 31. The first irrigation took place the week of June 5. The number in parentheses in the right column is the amount of water applied in gallons per vine. There is 25.4 mm per inch.

Time Period	ET_o	Rainfall	ET_c	Irr
	(mm)			
BB→BL	288	85	71	0
BB→Ver	655	89	283	212 (105)
BB→Harvest	875	92	450	379 (187)

Table 3. The effect of irrigation treatments and rootstock on berry weight (g 100 $berries^{-1}$) of Cabernet Sauvignon at a vineyard in Oakville. Samples were taken on 12 September 2000. Each value is one replicate. Data were analyzed via analysis of variance and means separated using Duncan's multiple range test.

	Irrigation Treatment						Avg. Effect
Rootstock	0.0	0.25	0.5	0.75	1.0	1.5	Rootstock
5C	103	119	125	136	129	123	122
110R	92	96	113	128	131	120	113
3309C	110	107	124	125	121	111	116
Avg. Effect Irrigation	102	108	121	130	127	118	
$LSD_{0.05}$	Irr = 14		Rootstock = ns				

* ns = not significant

Table 4. The effect of irrigation treatments and rootstock on soluble solids (^{0}Brix) of Cabernet Sauvignon at a vineyard in Oakville. Other information as given in Table 3.

Rootstock	Irrigation Treatment 0.0	0.25	0.5	0.75	1.0	1.5	Avg. Effect Rootstock
5C	24.2	23.9	23.4	22.7	22.7	22.5	23.2
110R	24.9	24.9	23.9	23.2	23.5	23.5	24.0
3309	24.3	25.0	23.5	23.9	23.6	24.2	24.0
Avg. Effect Irrigation	24.5	24.3	23.7	23.3	23.3	23.4	
$LSD_{0.05}$	Irr = ns		Rootstock = ns				

Table 5. The effect of irrigation treatments and rootstock on pH of Cabernet Sauvignon at a vineyard in Oakville. Other information as given in Table 3.

Rootstock	Irrigation Treatment 0.0	0.25	0.5	0.75	1.0	1.5	Avg. Effect Rootstock
5C	3.39	3.65	3.55	3.54	3.38	3.35	3.48
110R	3.63	3.66	3.64	3.56	3.58	3.40	3.58
3309	3.46	3.46	3.42	3.64	3.46	3.42	3.48
Avg. Effect Irrigation	3.49	3.59	3.54	3.58	3.47	3.39	
$LSD_{0.05}$	Irr = ns		Rootstock = ns				

Table 6. The effect of irrigation treatments and rootstock on titratable acidity (g 1000 ml^{-1}) of Cabernet Sauvignon at a vineyard in Oakville. Other information as given in Table 3.

	Irrigation Treatment						Avg. Effect
Rootstock	0.0	0.25	0.5	0.75	1.0	1.5	Rootstock
5C	7.5	4.8	6.3	6.5	8.7	8.9	7.1
110R	4.5	5.2	5.1	6.0	5.5	7.9	5.7
3309	7.5	7.6	7.8	5.5	7.3	7.9	7.2
Avg. Effect Irrigation	6.3	6.2	6.7	6.9	6.6	6.7	
$LSD_{0.05}$	Irr = ns		Rootstock = ns				

Table 7. The effects of irrigation and rootstock treatments on final yield (kg 9 $vines^{-1}$). The harvest date for all vines was 21 September. Vine density in this vineyard was 5348 vines ha^{-1} (2165 vines $acre^{-1}$). There are 2.2 lbs. per kilogram. Other information as found in Table 3.

	Irrigation Treatment						Avg. Effect
Rootstock	0.0	0.25	0.5	0.75	1.0	1.5	Rootstock
5C	16.1	19.0	22.8	30.9	23.2	25.7	23.0
110R	12.1	12.4	18.0	22.2	18.8	25.4	18.2
3309	19.2	15.3	18.6	21.3	18.1	14.5	17.9
Avg. Effect Irrigation	15.8	15.6	19.8	24.9	20.0	21.9	
$LSD_{0.05}$	Irr = 1.3		Rootstock = 0.9				

Table 8. The effect of irrigation treatments on must and wine composition of Cabernet Sauvignon grown at Oakville. Wine lots were made as a function of irrigation treatment only (fruit from each rootstock at a particular irrigation treatment were added in equal proportions to make the sample). Harvest date was September 21, 2000.

	Irrigation Treatment	^{0}Brix	TA* (g l^{-1})	pH	K^{+} (ppm)	Color** Intensity
Must	0.00	24.7	5.50	3.42		
	0.25	25.2	5.54	3.40		
	0.50	24.1	6.05	3.35		
	0.75	24.4	5.82	3.44		
	1.00	24.1	5.90	3.40		
Wine	0.00		6.25	4.01	1600	5.25
	0.25		6.07	4.03	1700	5.13
	0.50		6.20	3.99	1750	4.61
	0.75		5.94	4.03	1730	4.45
	1.00		5.90	4.02	1720	4.45

*TA equals titratable acidity
**Color intensity is relative absorbance units (sum of readings at 420 and 520 nm). The greater the number the greater the color of the wine.

Table 9. The effect of irrigation treatments and rootstock on pruning weight (kg 3 vines^{-1}) of Cabernet Sauvignon at a vineyard in Oakville. Other information as found in Table 7.

Rootstock	Irrigation Treatment 0.0	0.25	0.50	0.75	1.0	1.5	Avg. Effect Rootstock
5C	1.61	1.65	1.73	1.83	1.47	1.75	1.67
110R	0.99	1.12	1.33	1.52	1.64	1.73	1.39
3309	1.15	1.36	1.31	1.77	1.55	1.47	1.43
Avg. Effect Irrigation	1.25	1.38	1.45	1.70	1.56	1.65	
$LSD_{0.05}$	Irr = 0.28		Rootstock = 0.2				

Table 10. Relative berry weight, yield and pruning weights as a function of applied irrigation amounts (fraction of estimated ET_c) at the Oakville Cabernet Sauvignon vineyard used in the experiment. Values are the means of the three rootstocks averaged across three growing seasons. The means of each treatment were divided by the treatment with the greatest weight. The treatment with the greatest weight was set to 100%.

Factor	------------------ Irrigation Treatment (fraction of estimated ET_c) -------------------					
Measured	0.0	0.25	0.5	0.75	1.0	1.5
	-------------------------------- (percent of maximum weight) -------------------------					
Berry Wt.	71	83	93	98	100	98
Yield	66	77	96	100	99	99
Pruning Wt	71	85	89	100	96	99