Project Title:

> Deficit Irrigation Management Strategies and the Influence of Extended Maturation on Vine Health, Fruit Yield and Quality: Syrah in Region III-IV. 2007

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OBJECTIVES:

The objective of this study is to determine the effects of irrigation management and extended maturation strategies on Syrah in Region III-IV. Vines, must, and wine were measured/tested to quantify treatment effects and any interactions.

TRIAL SITE:

A Syrah vineyard located near Galt in Sacramento County serves as the project site. The vineyard was planted in 1998 using FPMS clone 6 on SO4 rootstock. Vine and row spacing is 5 and 11 feet, respectively, resulting in 792 vines per acre. The irrigation system was designed and installed to facilitate independent water delivery to 32 plots. A plot consists of twenty vines in each of three adjacent vine rows. Data were taken from the 16 central vines located in the center row. Vines are trained to Livingston Divided Canopy (LDC) and are shoot-positioned. The site has a moderate water-holding capacity, increasing in "stoniness" with depth. The well water supply is of good quality delivered via a drip irrigation system. The experimental design is a randomized complete block, split-split-plot design with four replications of each of three irrigation strategy treatments. Standard cultural practices were utilized throughout the season provided by the cooperating grower. The total experimental area is about 2.4 acres Shoot thinning utilized to remove non-productive shoots in all plots. Fertilization consisted of fall applied potassium sulfate (150 lbs/A K) applied via a solutionizer through the drip system to all treatments.

TREATMENTS

Irrigation Strategy Treatments:

Irrigation strategies chosen include full potential water use (I-1) and 2 deficit irrigation approaches. Both deficit approaches relied on a level of water stress [-14 bars midday leaf water potential (MDLWP)] to occur prior to the initiation of irrigation. After the leaf water potential was reached irrigation volume was based on (1) land surface shaded at noon to determine a crop coefficient (Kc), (2) the ETo using the Lodi CIMIS station #166, and (3) a 50% regulated deficit irrigation level (RDI). The relationship between land surface shaded at midday and Kc was developed by Larry Williams at the Kearney Ag Center using grapevine in a weighing lysimeter. Essentially, shaded area × 1.7 × ETo × RDI % = irrigation volume applied. Treatment I-3 received 50% on a weekly irrigation schedule until harvest of all maturity treatments. Treatment I-2 was irrigated like I-3 until 19º Brix was reached on August 26. At that time, the irrigation volume was increased to 100% based on the canopy size and the current ETo. Irrigation

was the same for all plots in the experimental area during establishment of the trial in the 2003 season; with treatments imposed 2004 – 2007.

Crop Load Treatments:
Crop load treatments were varied by the number of 2-bud spurs on each vine. The 14-spur treatment (S-14) resulted in 5.6 primary buds per foot of row and 0.51 buds per square foot. The 18-spur treatment (S18) resulted in 7.2 buds per foot of row and 0.65 buds per square foot. The 18-spur treatment resulted in about a 30% increase over the 14-spur treatment.

Fruit Maturation Treatments:
Maturity treatment targets were 24º, 26º, and 28º Brix (B-24, B-26 and B-28). Harvest date was determined by sampling berry Brix of each treatment. When the berry samples indicated the Brix treatment level was near, harvest was scheduled for the next day. Harvest began with the treatments I-2 and I-3 at 24º Brix and S-14 and S-18 treatments on Sept 4. Harvests ended October 29 with irrigation treatment I-1 and I-1 at 28º Brix for both the S-14 and S-18 treatments. All of the spur treatments were harvested in pairs within specific irrigation and Brix strategies (Table 1).

Table 1. Treatments and Harvest Dates 2007

| Irrigation Treatment Number	Brix Strategy	Spur Number	Leaf Water Potential Trigger at Which Irrigation Will Occur	Harvest Date
I-1	B-24	S-14	no trigger/ supply full water	Sept 26
	B-24	S-18		Sept 26
	B-26	S-14		Oct 18
	B-26	S-18		Oct 18
	B-28	S-14		Oct 29
	B-28	S-18		Oct 29
I-2	B-24	S-14	-14 bars/ 50%-100%	Sept 04
	B-24	S-18	Increase to 100% at 19º Brix	Sept 04
	B-26	S-14		Oct 15
	B-26	S-18		Oct 15
	B-28	S-14		Oct 28
	B-28	S-18		Oct 28
I-3	B-24	S-14	-14 bars/ 50%	Sept 04
	B-24	S-18		Sept 04
	B-26	S-14		Oct 08
	B-26	S-18		Oct 08
	B-28	S-14		Oct 29
	B-28	S-18		Oct 29

RESULTS

Water Use
An evaluation of available stored moisture was made at bud break, which indicated a full moisture profile. Subsequent rainfall continued to replenish the profile in excess of the calculated vine water use until May. Therefore, rainfall in excess of vine use which would have been considered as an input to the soil storage was considered runoff or deep percolation. The full profile status was verified by neutron probe soil water measurements. An irrigation controller and electric solenoids were used to control irrigations. A drip irrigation system with 2 emitters per vine was installed in the experimental area with the application rate of 0.47 gallons per hour per vine at 15-psi operational pressure. Emitter flow rate was measured in each plot area. Emission uniformity averaged 92% after chlorination and line flushing. The consumptive use of

each plot was measured as a sum of depleted soil moisture volume, applied water volume, and effective in-season rainfall. Soil moisture extraction was measured using a neutron probe to a soil depth of 105 inches. Single access well was installed in each plot totaling 32 wells. One vine in each irrigation treatment was instrumented with a grid pattern of access wells. Each well represents 3.4 square feet of surface area. The combined area represents one quarter of the vines allocated area.

Figure 1. Placement of intensive neutron probe wells
in a quadrant of vine rooting zone
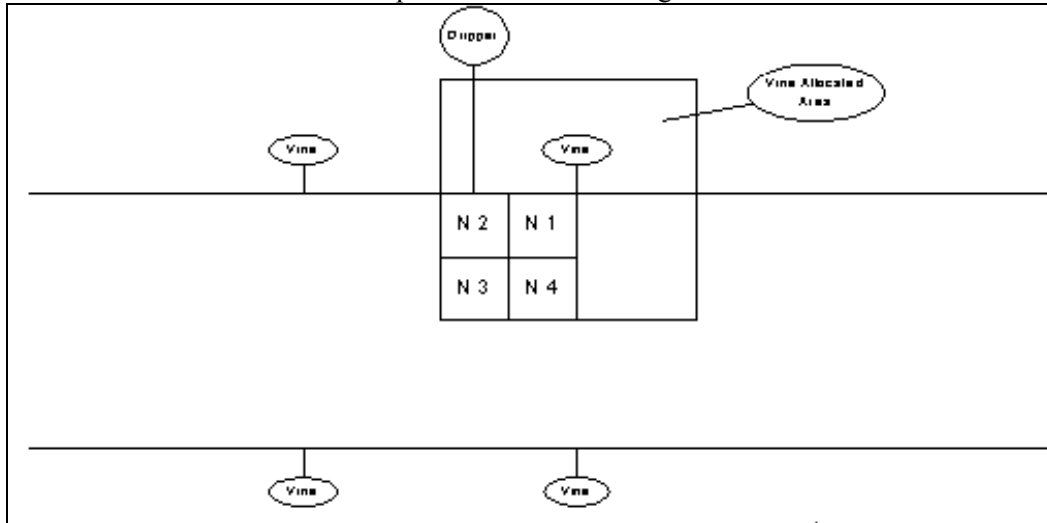
Soil samples were collected from the wells and volumetric water content measured along with the neutron probe count ratio prior to trial establishment. A calibration was developed between soil volumetric water content and count ratio at the site (Figure 2). In-season rainfall was measured on site. Irrigation volumes were measured using calibrated water meters. Soil water disappearance was based on the grid of neutron probe wells in the quadrant of the vines allocated area. Table 2 shows the water consumption components at both harvest and as a seasonal total. The water volumes consumed by the deficit treatments I-2 and I-3 compared to irrigation treatment I-1 was 68% and 51% respectively. Total applied water when compared to the full potential treatment (I-1) was 51% for irrigation treatment I-2 and 35% for the irrigation treatment I-3. Essentially, the increase in applied water between the deficit treatments was 5.2 inches applied to treatment I-2 from 19º Brix to harvest. This amount was about double the amount of difference when compared to the 2006 season due to less soil water content at bud break, and longer time period from the increased water application time and harvest.
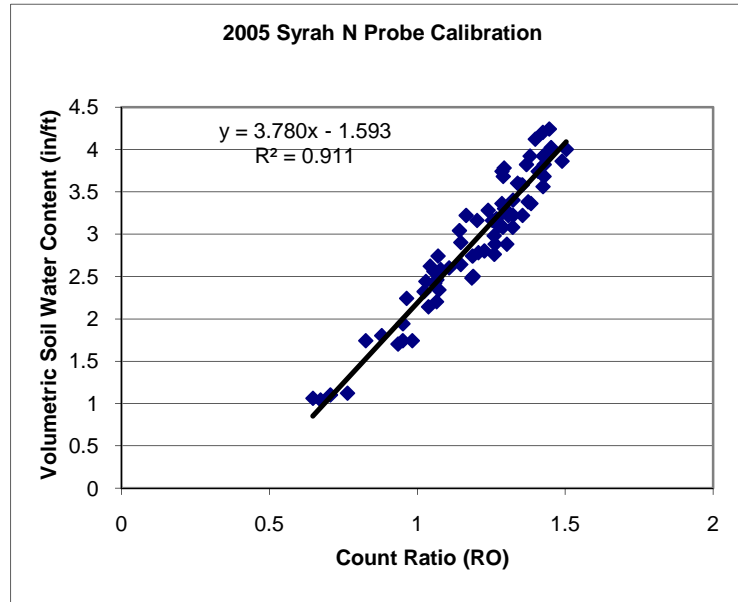
Figure 2. Neutron Probe Calibration

2005 Syrah N Probe Calibration

$y = 3.780x - 1.593$
$R^2 = 0.911$

(Y-axis: Volumetric Soil Water Content (in/ft); X-axis: Count Ratio (RO))

Table 2. Water Consumption Components 2007

Irrigation Treatment	Water Applied (in) Pre Harvest	Post Harvest	Soil Use (in)	Effective In-Season Rainfall (in)	Total Water Consumed (in) Pre Harvest	Inc. Post Harvest	% of Irrigation Treatment I-1 Pre Harvest	Seasonal
I-1	33.8	1.0	2.5	0.2	36.5	37.8	100	100
I-2	17.1	1.0	7.4	0.2	24.7	25.7	68	68
I-3	11.9	1.0	6.3	0.2	18.4	19.4	50	51

Vine Response to Water Deficits:
The vine response to water deficits was monitored by measuring midday leaf water potential (MDLWP). Irrigation treatment I-1 received irrigation volume to meet full potential water use in combination with stored soil moisture. Weekly irrigations continued until the final harvest. Irrigation began on May25 in 2007, at which time leaf water potential was a level of -9.9 bars, indicating a non-stressed condition (Figure 3). The seasonal average (May 24 – Oct 9) was -9.6 bars ranging from -8.6 to -11.6 bars.

Figure 3.
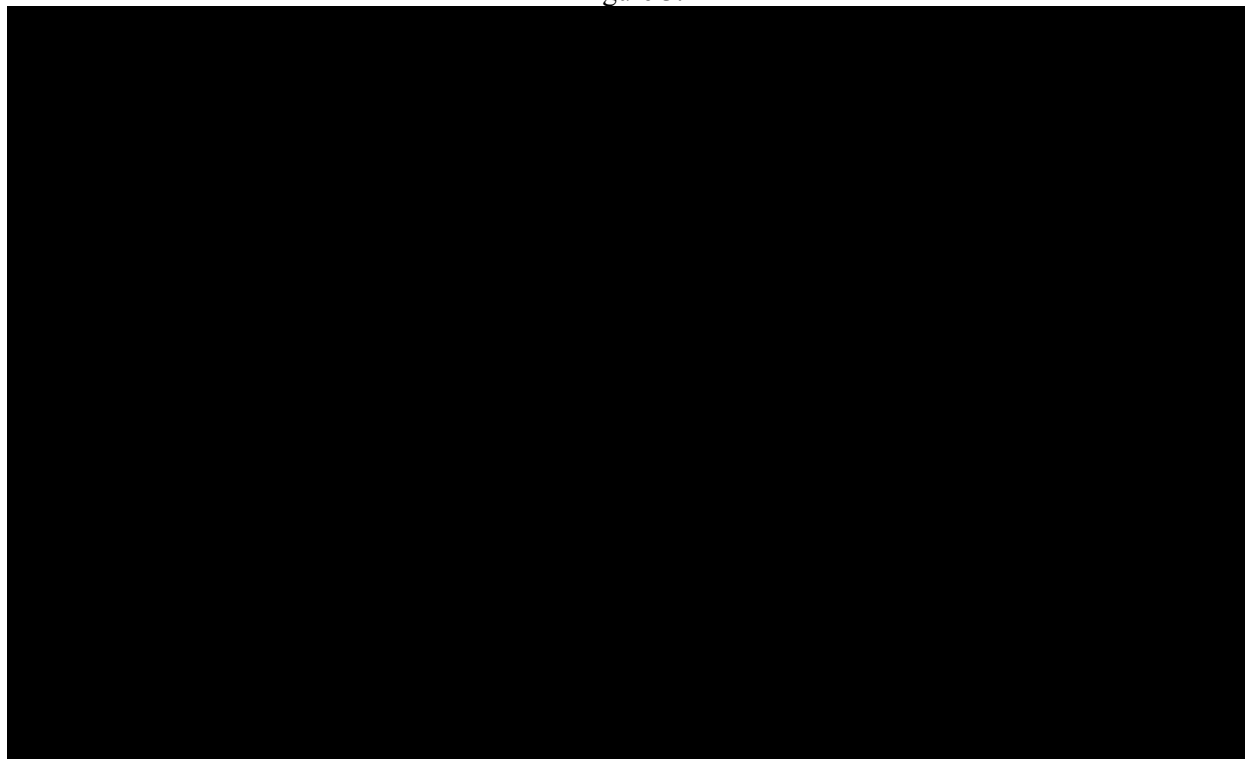
Irrigation treatment I-2 and I-3 received no irrigation until a MDLWP of -14.5 was reached on June 22. Irrigation water volumes were then applied weekly at the rate of 50% of calculated full potential continuing to harvest for treatment I-3. MDLWP was measured periodically until harvest with the differences related to climatic conditions and the length of time the measurement was made from the weekly irrigation. The seasonal average MDLWP for irrigation treatment I-3 (5/22 – 10/09) was -14.4 bars. Berry sampling and Brix analysis on August 17 indicated the 19º Brix level was reached in treatment I-2 at which time the volume of irrigation water was increased from 50% to full potential as indicated on Figure 1 by an ♦ symbol. The MDLWP averaged a 2.6 bar reduction in water stress when compared to the sister Treatment 3 after the irrigation volumes were increased. The average MDLWP for Treatment 2 after August 17th was -11.0 bars. In the case of Treatment 3, the volumes of water applied generally stabilized the MDLWP at an average of -13.6 bars after the initiation of irrigation, for the remainder of the season. The solid bar on Figure 3 indicates the harvest date range. Also see Table 1 for harvest date of each treatment.

Fruit: The extent of veraison was rated visually when 100% of the clusters on the full water treatment (I-1) had some color. All plots were rated on July 18 as to the percent of the clusters which had some color. The differences were found between the full potential irrigation strategy and the deficit regimes with I-1 at 92% and the deficit treatments at 79%. Treatment I-1 had been irrigated since May 25 where as treatments I-2 and I-3 were irrigated on June 22.

Canopy: Canopy size was evaluated by maximum shoot length and land surface shaded at midday. Significant differences in canopy size were found between irrigation treatments and spur treatments (Table 3). Shoot lengths of irrigation treatment I-1 were longest at 74 cm followed by I-2 at 70 cm and I-3 at 64 cm. Irrigation treatment I-1 and I-3 were significantly different from each other following level of water consumption level. Land surface shading was measured using digital photography and pixel color

5

density evaluating software to determine the percent land surface shading as an indicator of canopy size. Significant differences were found between irrigation treatments with I-1 the highest ground shading at 62 % followed by I-3 at 52% and I-3 at 48%. The land surface shaded measurements in Table 3 are from 8/16/07. Significant differences in shoot length were found between Brix treatments – a first for this trial and possibly an anomaly. No Significant differences in shoot length were found between the S14- and S18-spur treatments.

Table 3. Canopy Measurements

	Shoot Length (cm)	Land Surface Shaded
Irrigation		
I-1	74.2 a[a]	62a
I-2	69.7 ab	48 b
I-3	64.1 b	52 b
P =	0.0148	0.0480
Brix		
24	72.8 a	
26	64.2 b	
28	71.1 a	
P =	0.0301	
Spurs		
14	70.3	
18	68.4	
P=	0.4847	
Interactions	NS	

[a] *Different letters in the same column indicate significant differences as indicated by the stated p value using Duncan's means separation test.*

Yield:
The fruit weight of each of 15 data vines within each plot was measured. Harvest date was determined by sampling berry Brix of each treatment. When the berry samples indicated the Brix treatment level was near, harvest was scheduled for the next day.

Vine yield compared across all Brix and spur treatments, indicated differences among irrigation treatments (Table 4). Treatment I-1 averaged 22.8 pounds per vine (9.0 tons/acre) compared to the deficit treatments at 14.9 pounds per vine for I-2, and 11.7 for I-3. The yield reductions from full irrigation were 35% and 49 % for treatments I-2 and I-3 respectively.

Significant yield differences were also found between the Brix treatments (Table 4). The yield of brix treatment B-24 as the lowest level of maturity was significantly higher than the B-26 and B-28 treatments. The yield reduction from B-24 to B-26/B-28 treatments was 11%.

A significant difference was found between the spur treatments S-14 and S-18. The S-18 was 9% higher in yield than S-14 treatment. No significant interaction between irrigation, Brix level or spur number treatments were found to exist.

By increasing the number of two-bud spurs from 14 to 18, the yield reduction from the 26 to 28 Brix treatments is reduced by 81 percent.

6

Yield Components:

Berry size was measured as weight (g) per berry from 5 clusters per plot (40 per treatment). Berry size was significantly larger in highest-level irrigation treatment (I-1) compared to the other irrigation treatments and largest[r] in the lowest Brix treatment B-24 (Table 4). No significant differences were found between spur treatments.

Fruit load, as measured by number of berries per vine, was significantly higher in the irrigation treatment I-1 compared to treatments I-2 and I-3. Irrigation treatment I-2 was significantly higher in fruit load than I-3. No significant differences in fruit load were found between Brix treatments. The fruit load was significantly larger in the S-18 spur treatment due to the increased spur and bud numbers.

There is a statistically significant relationship between yield and berry weight; however, the R-Squared statistic indicates that the model as fitted explains 41.3% of the variability in yield. The correlation coefficient equals 0.64, indicating a moderately strong relationship between these variables.

There is a statistically significant relationship between yield and fruit load. The R-Squared statistic indicates that the model as fitted explains 79.1% of the variability in yield with respect to fruit load. The correlation coefficient equals 0.89, indicating a moderately strong relationship between the variables.

Upon further analysis, the number of clusters (or the fruit load packets) necessary were significantly higher in the irrigation treatment I-1 compared to I-2 or I-3 (Table 5). Cluster number of Irrigation treatment I-2 was significantly higher than I-3. The reduction in cluster number is a typical multi-year effect of the irrigation treatments—deficits result in fewer clusters the following year. The number of clusters is correlated with the amount of consumed and applied water. No crop reduction by cluster or shoot thinning was performed, as only non-bearing shoots were removed on May 25. Significant differences were found between Brix treatment B-28 and the other Brix treatments (earlier maturity levels). Cluster size (lbs/cluster) was significantly larger in I-1 when compared to the other treatments— about 30% larger. Cluster weight was significantly reduced at the B-28 Brix level compared to both of the other treatments. Cluster size was not significantly different between the I-1 and I-2 treatments.

Table 4. Yield and Yield Components, 2007 Syrah, Galt

	Yield (lb/vine)	Relative Yield %	Berry Size (g)	Relative Berry Size %	Fruit Load (berry/vine)	Relative Fruit Load %
Irrigation						
I-1	22.8 a	100	1.36 a	100	7622 a	100
I-2	14.9 b	65	1.11 b	82	6163 b	81
I-3	11.7 c	51	0.99 c	73	5488 c	72
P =	0.0000		0.0000		0.0000	
Brix						
24	17.8 a	100	1.23 a	100	6476	100
26	15.9 b	89	1.15 b	93	6210	96
28	15.8 b	89	1.07 c	87	6562	101
P =	0.0140		0.0000		0.4043	
Spurs						
14	15.7 b	91	1.15	100	6068 b	90
18	17.3 a	100	1.15	100	6764 a	100
P=	0.0111		0.5237		0.0000	
Interactions	NS		NS		NS	

[a] *Different letters in the same column indicate significant differences as indicated by the stated p value using Duncan's means separation test.*

Table 5. Yield and Yield Components, 2007 Syrah, Galt

	Cluster Number (Clusters/vine)	Relative Cluster No. %	Cluster Size (lbs/Cluster)	Relative Cluster Size %
Irrigation				
I-1	65.2 a	100	0.35 a	100
I-2	55.8 b	86	0.27 b	77
I-3	47.1 c	72	0.26 b	74
P =	0.0000		0.0000	
Brix				
24	53.7 b	85	0.33 a	100
26	51.5 b	82	0.31 a	94
28	63.0 a	100	0.25 b	76
P =	0.0000		0.0001	
Spurs				
14	52.1 b	87	0.30	100
18	60.0 a	100	0.29	97
P=	0.0000		0.2867	
Interactions	Irr X Brix		Irr X Brix	
P=	0.0000		0.101	

[a] *Different letters in the same column indicate significant differences as indicated by the stated p value using Duncan's means separation test.*

Water Use Efficiency:
Water use efficiency can be viewed from the perspective of the amount of grapes per unit of applied water consumed or the total water consumed. Total water consumed (ETc) includes soil water contribution, effective in season rainfall, and irrigation water. The applied and total consumed (ETc) water is shown in Table 2 while yield is shown in Table 4. Using applied water volumes for comparison, irrigation treatment I-1 was the least efficient while the I-3 treatment was highest in water use efficiency (Table 6 and Figure 4). The increase in applied water use efficiency correlates positively with lower applied water treatments. Using total consumed water as a measure of water use efficiency, no significant difference in water use efficiency is found among all irrigation treatments. This is a result of increased water application in I-1and to a lesser extent 1-2, resulting in water remaining in the soil at the end of the season.

Table 6. Water Use Efficiency
2007 Syrah, Galt

| Irrigation Treatment | Lbs Product / Acre Inch Water | |
	Applied Water	Consumed Water
I-1	514	478
I-2	651	459
I-3	718	477

Figure 4. Water Use Efficiency 2007 Syrah, Galt
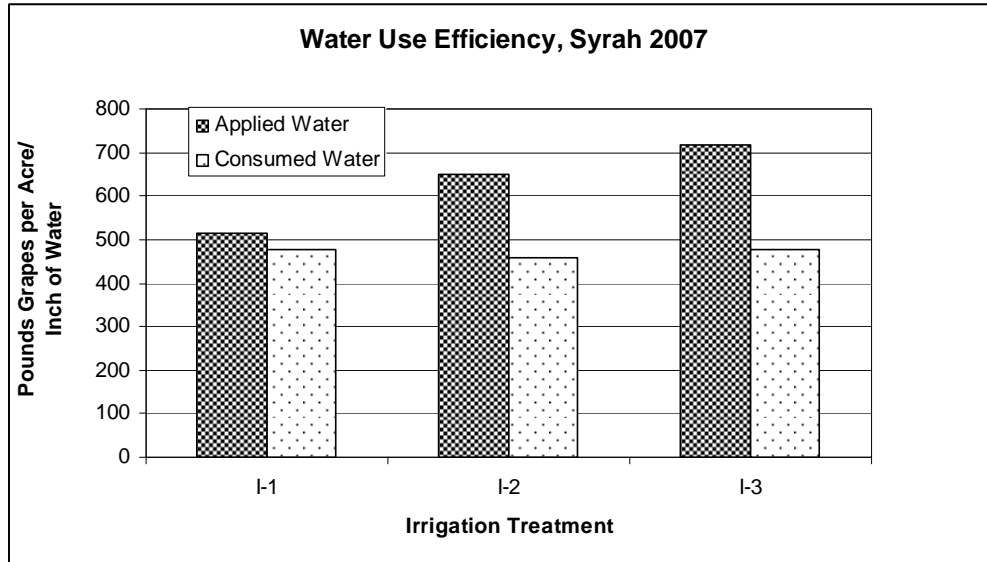
Fruit Quality:
One cluster from each vine (40 per treatment) was collected at each harvest and delivered to the laboratory for juice analysis. The fruit composition analysis was based on this sample. The juice sugar level significantly varied by irrigation and ºBrix treatments (Table 7). The highest ºBrix level occurred in irrigation treatments I-2 and I-3 both averaging 26.1 ºBrix followed by I-1 at 25.6 ºBrix across all ºBrix and spur treatments. Essentially, the full irrigation delayed sugar accumulation while the increase in

irrigation late in the season (I-2) had no effect on ºBrix level in comparison to the continual deficit treatment (I-3). Comparing the irrigation treatments across the Brix and spur treatments finds malic acid content, potassium content, and titratable acidity significantly higher in the full irrigation (I-1) than both deficit treatments (Table 8). Juice pH levels were significantly different from each other by irrigation treatment. The greater the amount of consumed water the higher resultant juice pH.

The ºBrix treatment targets were 24, 26, and 28 ºBrix. The actual averages were 24.4, 25.6, and 27.2. However, for year-to-year continuity the target ºBrix levels are used in this report. Comparing the ºBrix treatments across the irrigation and spur treatments finds a significant positive (increasing) relationship between ºBrix treatments and pH; and a negative (decreasing) relationship with titratable acidity as a function of increasing ºBrix. Malic acid content was significantly lower in the B-26 treatment in comparison to the B-24 and B-28 treatments. Potassium content was significantly different and negatively correlated with consumed water volume.

A significant difference between spur treatments was found to exist with S-18 highest at 26.1 ºBrix in contrast to 25.8 ºBrix in the S14 treatment.

Fruit Moisture, the percent moisture of the delivered fruit, was measured and found to be significantly different by irrigation and Brix treatments. The difference was only slight (however significant) between the I-1 treatment and the deficit treatments by an average of 1.2 %. As harvest time was delayed to achieve higher Brix levels, fruit moisture levels decreased significantly. The difference in moisture content from B-24 to B-26 was 1.5 % less and from B-24 to B-28, 3.3% less.

As mentioned, the titratable acidity was significantly higher in the full water I-1 treatment compared to the other irrigation treatments. Malic acid content was also significantly higher in the I-1 treatment. However, the tartaric acid levels were not significantly different among irrigation treatments leading to the ratio of tartaric to malic acid being significantly lower than the deficit treatments. The two deficit irrigation treatments were not significantly different from each other in TA, tartaric acid, malic acid, or the tartaric acid to malic acid ratio. Anthocyanins were found to be significantly different among Irrigation treatments with the highest amount in the lowest water consumption treatment and the lowest level of pigments or color or anthocyanins in the highest water consumption treatment.

Comparing the maturity treatments, the B-26 is interesting in that TA (correlated to total acidity) was the lowest, along with Malic acid content was the lowest, while tartaric acid one of the highest; resulting in a tartaric to malic acid ratio of 3.3.Treatment In other words B-26 was significantly higher in tartaric to malic acid ratio compared to the other Brix treatments. Figure 5 shows this relationship by maturity treatment versus irrigation treatment. Each maturity treatment was significantly different from each other treatment in pH. The pH increased from 3.72 at B-24 to 4.02 at B-26 and even higher to 4.20 at B-28. The relationship of potassium and pH is very strong (Figure 6.) The correlation coefficient equals 0.97, indicating a relatively strong relationship between the variables

Table 7. Juice Analysis
2007 Syrah, Galt

Treatments	º Brix	pH	Potassium (mg/L)	TA (g/L)	Fruit Moisture (%)
Irrigation					
I-1	25.6 b[a]	3.89 c	2110 a	3.01 a	71.9 a
I-2	26.0 a	3.99 b	2050 b	2.37 b	70.9 b
I-3	26.2 a	4.05 a	2180 a	2.40 b	70.6 b
P =	0.0020	0.0000	0.00094	0.0000	0.0010
Brix					
24	24.4 c	3.72 c	1576 c	2.90 a	72.8 a
26	25.6 b	4.02 b	2096 b	2.27 c	71.3 b
28	27.8 a	4.20 a	2568 a	2.62 b	69.5 c
P =	0.0000	0.0000	0.0000	0.00	0.0000
Spurs					
14	25.8 b	3.99	2085	2.57	71.3
18	26.1 a	3.97	2076	2.63	71.0
P =	0.0077	0.2805	0.8151	0.3402	0.1520
Interactions					
Irr/Brix	NS	NS	NS	0.0013	NS
Irr/Spurs	0.0441	NS	NS	NS	NS
Brix/Spurs	NS	NS	NS	NS	NS

[a] *Different letters in the same column indicate significant differences as indicated by the stated p value using Duncan's means separation test.*

Table 8 Juice Analysis
2007 Syrah, Galt

Treatment	Tartaric Acid (mg/L)	Malic Acid (mg/L)	Tartaric:Malic Ratio	TA (g/L)	Anthocyanins (mg/g)
Irrigation					
I-1	4378	2143 a	2.1 b	3.01 a	1.06 c
I-2	4322	1709 b	2.9 a	2.37 b	1.24 b
I-3	4405	1620 b	3.1 a	2.40 b	1.33 a
P =	0.7137	0.0001	0.0000	0.0000	0.0000
Brix					
24	3787 b	1862 a	2.2 b	2.90 a	1.12 b
26	4581 a	1610 b	3.3 a	2.27 c	1.24 a
28	4716 a	2000 a	2.5 b	2.62 b	1.26 a
P =	0.0000	0.0013	0.0000	0.00	0.0001
Spurs					
14	4311	1832	2.6	2.57	1.19 b
18	4413	1817	2.7	2.63	1.23 a
P =	0.2339	0.8216	0.1808	0.3402	0.0496
Interactions					
Irr/Brix	0.0025	0.0064	0.0016	0.0013	NS
Irr/Spurs	NS	NS	NS	NS	NS
Brix/Spurs	NS	NS	NS	NS	NS

[a] *Different letters in the same column indicate significant differences as indicated by the stated p value using Duncan's means separation test.*

Figure 5. Tartaric to malic acid ratio by maturity treatments over irrigation treatment
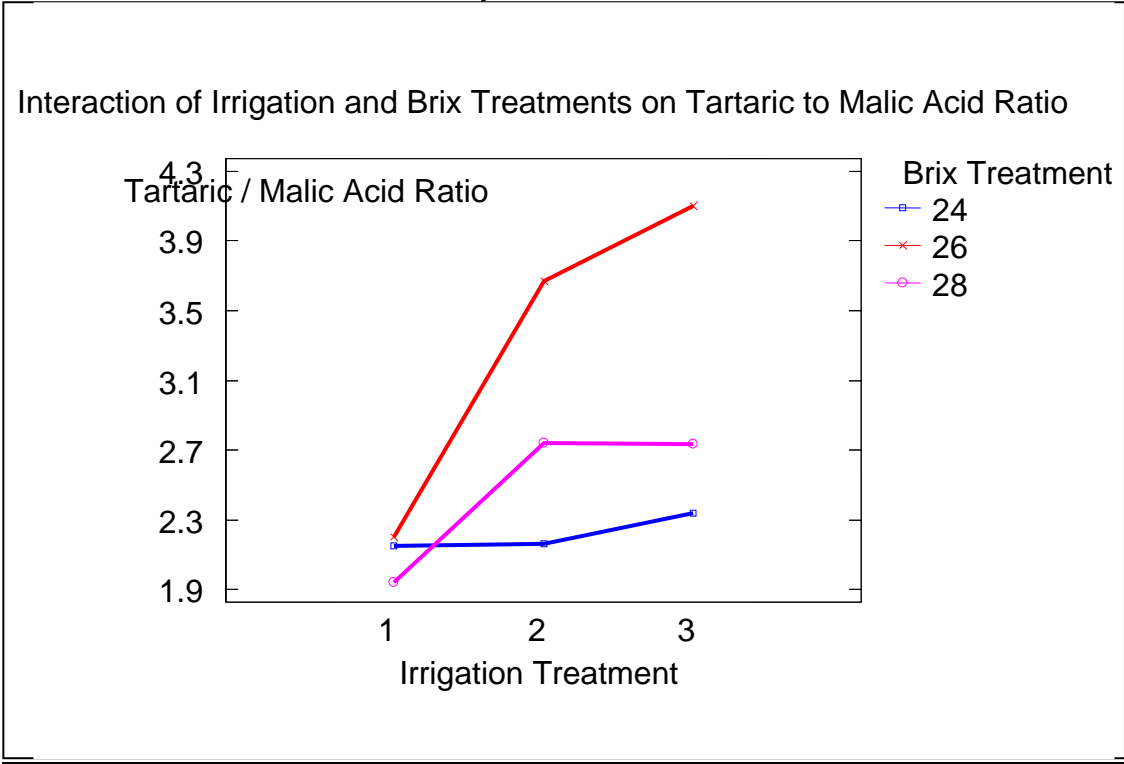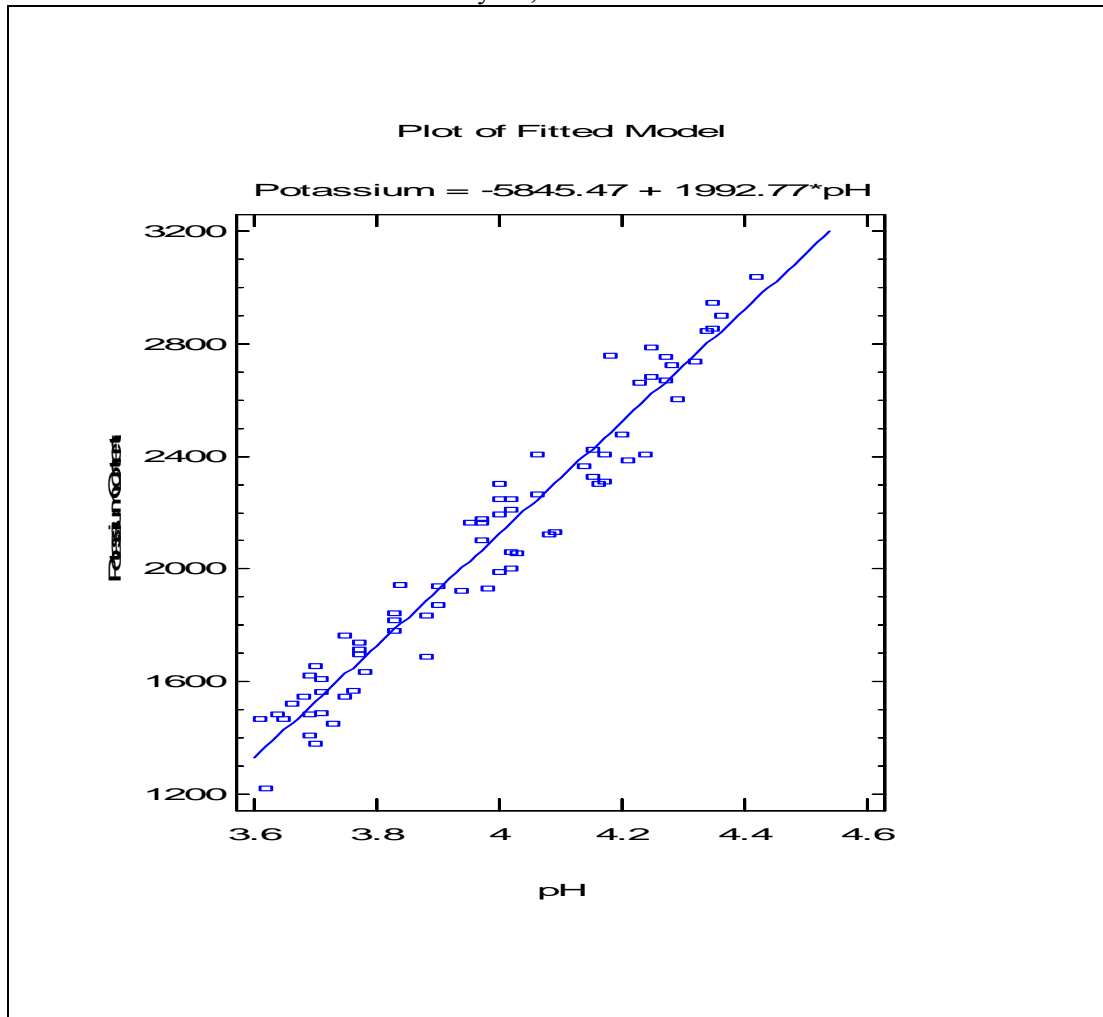Syrah 2007, Galt

Interaction of Irrigation and Brix Treatments on Tartaric to Malic Acid Ratio

Tartaric / Malic Acid Ratio

Brix Treatment
24
26
28

Irrigation Treatment

Figure 6. Fitted relationship of potassium content and pH of the juice
Syrah, 2007 Galt

Plot of Fitted Model

Potassium = -5845.47 + 1992.77*pH

Summary
Three levels of fruit maturity were compared across three different irrigation strategies in a region III/IV
Syrah vineyard for a fourth season Significant differences in level of water stress were found between all
treatments as measured by seasonal average midday leaf water potential. Irrigation treatment I-2 which
received additional water after veraison at 19º Brix in contrast to treatment I-3 improved vine water
relations significantly throughout the remainder of the season. Water consumption was also significantly
different among all irrigation treatments. The deficit irrigation treatments I-2 and I-3 consumed 68% and
51% of the full potential consumptive use treatment I-1. Both the deficit irrigation treatments resulted in
higher water use efficiency compared to the full water treatment as a function of applied water. When
compared as total consumed water the water use efficiencies were similar between all irrigation
treatments.

Significant yield reductions did occur with deficit irrigation. Yield reductions, compared to full water (I-
1) treatment, were; I-2 at 35% less yield and I-3 at 49% less. The mitigating effect of additional irrigation
as harvest approached (I-2) was to reduce yield loss due to deficit irrigation somewhat.

The deficit irrigation treatment I-2 received 5.2 inches of irrigation water more than the I-3 vines as harvest approached. This strategy resulted in a significantly higher in yield than the I-3 treatment of continual deficit treatment. Yield component analysis using simple regression revealed fruit load differences explain 79.1% of the differences in yield while berry size explains 41.3%. The same irrigation treatments were imposed in the 2004 through the 2006 season, which explains the increased cluster number and fruit load in the full irrigation treatment (I-1). The number of clusters per vine was significantly reduced by 28 % in the continual deficit treatment 1-3 when compared to the other treatments. Irrigation treatment I-2 cluster number was also significantly reduced from the full water treatment (I-1) by 14%.

Significant yield reductions were also found between Brix treatments across irrigation and spur treatments. There was no significant reduction in yield between B-26 and B-28 treatments. The yield reduction from B- 24 to the later two maturity treatments was 11 %. The yield reduction was due to both reduced fruit load and berry size. No interaction between irrigation and Brix or spur treatments were found to exist.

The mitigating effect of adding crop load by pruning to 30% more spurs was to increase yield by 9% across all irrigation and Brix treatments.

The juice sugar level did significantly vary by irrigation and Brix treatments. The highest Brix level was found in irrigation treatment I-2 and I-3 averaging 26.1 Brix followed by I-1 at 25.6 Brix across all Brix and spur treatments. Essentially the full irrigation delayed sugar accumulation, while the increase in irrigation late in the season (I-2) had no effect relative to the continual deficit treatment. Comparing the irrigation treatments across the Brix and spur treatments finds potassium content, titratable acidity and pH to be significantly higher in the full irrigation (I-1) versus both deficit treatments.

Brix treatments compared across the irrigation and spur treatments shows a significant positive (increasing) relationship between Brix treatments and pH

Deficit irrigation techniques and extended maturation (or delayed harvest) strategies each reduce yield over time as a result of decreased fruit load from fewer clusters and smaller berries. However, the deficit strategy I-2 significantly improved yield over the continual deficit treatment I-3. The strategy of increasing fruit load by pruning to leave 30% more primary buds also looks promising to recover some of the yield loss while vine balance seems not to have been effected; no significant delay in harvest was found; and changes in Juice components were minimal.