Project Title: Establishing Critical Values of N and K for Grapevines

Project Leader: Dr. Larry E. Williams, Professor
Department of Viticulture and Enology, UC-Davis
Kearney Agriculture Center
9240 S. Riverbend Ave.
Parlier, CA 93648
Voice: 559-646-6558
FAX: 559-646-6593
e-mail: williams@uckac.edu

Summary:

Petioles were collected in three different vineyards at bloom, veraison and just prior to harvest. The Thompson Seedless vineyard was located at the Kearney Ag Center; the Chardonnay vineyard was located in the Carneros district of Napa Valley and the Cabernet Sauvignon vineyard near Oakville in the Napa Valley. Prior to bloom the following treatments were imposed: 1.) Vines that were not irrigated prior to bloom, 2.) Vines that were irrigated several times prior to bloom and 3.) Vines that were fertilized and then irrigated. Two fertilizer amounts were used in the Thompson Seedless (50 and 100 lbs. N per acre) and Cabernet (40 and 80 lbs. N per acre) vineyards while only one fertilizer amount was used in the Chardonnay vineyard (80 lbs. N per acre). The Non-irrigated treatment in the Thompson Seedless and Cabernet vineyards at veraison and pre-harvest consisted of vines in which irrigations were terminated two weeks prior to sampling. The Non-irrigated treatment in the Chardonnay vineyard was not irrigated all season long. Each treatment was replicated four times at the three locations.

At the bloom and veraison sample dates, petioles were collected at various times during the day; 0800, 1200 and 1600 hours. At veraison and prior to harvest petioles were also sampled before sunrise. On all three dates, petioles were taken from leaves exposed to direct sunlight and leaves that were in the shade at the time of sample. At bloom, petioles were also sampled from leaves opposite the cluster.

At the time this report was written not all of the petiole samples had been ground for nutrient analysis. In addition, none of the leaf, stem or clusters sampled from each treatment on each sample date had been ground. However, it was possible to analyze all petiole samples from one block at bloom, veraison and pre-harvest in the Thompson Seedless vineyard and all samples in one block at bloom and veraison in the Chardonnay and Cabernet vineyards.

Based upon the limited data reported on herein, several conclusions could be reached. As expected, N fertilizer application had a significant effect on petiole nitrate-N and total N at all three locations on all three, sample dates. The potassium nitrate fertilizer also significantly increased petiole K. Sampling leaves exposed to direct sunlight versus those taken from the shade had a significant effect on petiole nitrate-N

and K. At bloom, petiole nitrate-N was generally greater in the sunlit leaves compared to the shaded leaves. The petioles of sunlit leaves collected at veraison and pre-harvest, however, had lower nitrate-N and K values than the shaded leaves in all three vineyards. In addition, petioles collected from leaves opposite a cluster had lower values of nitrate-N and K at the three locations. Irrigation amount (no applied water vs. applied water) also affected petiole nutrient status. In general, non-irrigated vines had greater values of nitrate-N than the irrigated vines. The results indicate that leaf type and irrigation amount will affect petiole nutrient values. Whether time of day significantly affects petiole nutrient status awaits the analysis of additional replications at each location.

Objective:

The objective the first growing season was to determine how production practices and sampling procedures contributed to the variability in petiole nitrate-N, ammonia-N and total N and K of Thompson Seedless, Chardonnay and Cabernet Sauvignon grapevines and correlate N and K nutrient status of petioles sampled at bloom, veraison and just prior to harvest, with one another.

Experiments Conducted to Meet Above Objective:

Thompson Seedless, Chardonnay and Cabernet Sauvignon vines were used in the first year of the study (Table 1). Thompson Seedless vines were located at the Kearney Ag Center and the two wine grape cultivars (Chardonnay and Cabernet Sauvignon on the rootstock 5C) in the Napa Valley. At three phenological stages (bloom, veraison and just prior to harvest) petioles were collected three times during the day (Tables 2 to 4). The sampling times were 0730 to 0830 h, 1230 to1330 h (solar noon) and 1600 to 1700 h. Prior to harvest, no samples were taken at the 1600 h sampling time. At veraison and prior to harvest, petioles were also sampled before sunrise (predawn). On all sampling dates and times petioles were collected from leaves either in the shade or exposed to direct sunlight. Petioles were also sampled opposite a cluster at each sample time at bloom.

Prior to the bloom sample date, a cohort of vines was irrigated several times while another set had not been irrigated since budbreak. On the other two sample dates, the non-irrigated treatment received no applied water for at least two weeks before sampling (veraison and pre-harvest sample dates), except at Carneros, where the vines were not irrigated at any time during the growing season. At all three locations, a cohort of vines were fertilized with potassium nitrate prior to bloom, two amounts at Kearney and Oakville and one at Carneros (Table 1). Each irrigation and fertilization treatment was replicated four times at each location.

At veraison, petioles of the Chardonnay and Cabernet vines were divided into three groups at the midday sample: 1.) Those analyzed using the standard petiole sampling procedure (i.e. the leaf was removed from the vine, the petiole detached from the blade and then dried), 2.) The leaf was removed from the vine with the blade and

petiole remaining intact. The leaves were placed in a bin and put in bright sunlight and allowed to dry naturally. 3.) Petioles were sampled by cutting both ends simultaneously with specially designed scissors. At each location and sample date, shoots were removed from the treatments vines and separated into leaves, stems and clusters.

The petioles and other vine organs were dried in a forced air oven at 70^{o}C for 48 h. The petioles collected on all dates and times were analyzed for total N, nitrate-N and K. The other vine organs will be analyzed for total N and K. Mineral nutrients will be analyzed either at the DANR Analytical Lab on the UC-Davis Campus or at a commercial laboratory.

Stomatal conductance and transpiration were measured several times at each location/sample date on leaves in the sun and shade with a LiCOR model 1600 diffusion porometer. Vine water status was determined by measuring leaf water potential with a pressure chamber. Measurements were taken on leaves in the sun and shade.

The experimental design was a completely randomized block. Analysis of variance (ANOVA) was conducted on the data and means separated using Duncan's multiple range test. Mean separation of several of the variables measured at a particular location on a particular calendar date utilized the time of day sample was taken as a replicate. Statistical analysis of the data can be found in the Appendix.

Summary of Major Research Accomplishments and Results:

Due to the date on which this at this report was written (the end of December 2001), all of the samples taken during the 2001 growing season could not be ground and analyzed for inclusion in this report. It should be pointed out that all the samples to be taken, as outlined in the proposal, were collected. Therefore, the data presented herein represent all three sampling dates for Thompson Seedless and the bloom and veraison sampling dates for Chardonnay and Cabernet. However, only one block was chosen for analysis at each site (the same block was analyzed for each sample date). Lastly, since the monies requested for project were less than asked for, it is not certain how many of the other samples may actually be analyzed for mineral nutrients in the future.

Bloom petiole samples were collected in the Thompson Seedless vineyard on May 7 2001 (Table 2). At each sample time on that date, petioles were collected from leaves exposed to direct solar radiation, those that were shaded within the canopy and those that were opposite a cluster (Table 5). The application of fertilizer (regardless of amount, 50 or 100 lbs of N per acre), significantly increased tissue petiole nitrate-N, total N and K. There were no differences between the two irrigation treatments or fertilizer treatments for the above-mentioned nutrients. There were no significant differences in total N or K among the three leaf types (sun/shade/opposite the cluster). There was a significant interaction regarding petiole nitrate-N. Vines that had been fertilized had higher nitrate-N values for the sun leaves than those petioles taken from the shade or opposite the cluster.

Thompson Seedless petiole nitrate-N values at veraison for the fertilized vines were less than those measured at bloom (Table 6). Shaded leaf petiole nitrate-N values for the vines that were not fertilized (irrigated and non-irrigated treatments) were generally higher that those measured at bloom. Vines fertilized with 100 lbs of N had significantly greater petiole N values than the other three treatments and the same was true for petiole K values. Only vines fertilized at the highest amount had significantly greater amounts of petiole nitrate-N in the shaded leaves than those leaves exposed to direct sunlight. There were significant differences between the sun and shaded leaves regarding petiole total N and K.

The Thompson Seedless petiole sample prior to harvest occurred on August 31 (Table 2). Petiole nitrate-N in the non-irrigated vines was generally higher than that in the irrigated vines, except for samples taken predawn (Table 7). For samples collected at 0800 and 1200 h, there were significant interactions among the main treatments (irrigated, non-irrigated, 50 lbs N and 100 lbs N) and leaves collected either in the sun or the shade. For potassium, vines that had been fertilized had higher K in the petioles regardless of whether the leaves were in the sun or the shade. Total petiole N was greater for the shade leaves of the 100 lb N fertilizer treatment. Lastly, petiole nitrate-N of sunlit leaves was greatest for the non-irrigated and 100 lb N fertilizer treatments, with the 100 lb N treatment having the highest petiole nitrate-N values for the shaded leaves.

Bloom time petiole samples for the Chardonnay vineyard in Carneros were collected on May 23 2001 (Table 3). The main treatments (irrigation, no irrigation and fertilizer) significantly affected petiole nitrate-N and total N but not K (Table 8). Petiole K was significantly affected by the type of leaf chosen, petioles opposite a cluster had lower K (1.73% K) compared to 2.32 and 2.22 % K for leaves in direct light and the shade, respectively. There was no effect of the main treatments on total N. Time of day had no significant effect on petiole nitrate-N, total N or K.

Bloom petiole analysis of the Cabernet vineyard presented here (Table 9) included all main treatments except the 40 lb N per acre treatment (Table 3). The fertilizer treatment significantly increased petiole nitrate-N and total N compared to the non-fertilized treatments (Table 9). The non-irrigated treatment had significantly lower petiole K than the other two main treatments. Leaf type significantly affected petiole K but not total N. Time of day had no significant effect on any of the mineral nutrients.

The water in the xylem of a plant is under tension and when an organ is removed, such as a leaf, much of the sap in the petiole is pulled into the blade. Therefore, at the veraison sampling dates for the Chardonnay and Cabernet grapevines petioles were also collected prior to sunrise (predawn) (Tables 10 and 11). Since leaf water potential is much higher prior to sunrise than after the sun has risen (Table 12), the column of water in the xylem would be under less tension and it is assumed more of the sap would remain in the petiole when sampled at this time.

The relative values of total N and K in the predawn Irrigated and Non-irrigated Chardonnay petiole sample treatments were similar to values of the same treatments

taken later in the day (Table 10). Values of nitrate-N for the Irrigated and Non-irrigated treatments were generally higher when measured later in the day when compared to predawn. The opposite was found for the predawn petiole nitrate-N samples of Thompson Seedless prior to harvest (Table 7). Predawn petiole nitrate-N samples for the fertilized Chardonnay treatment was almost 800 ppm while nitrate-N at 0800 hours was less (approximately 350 ppm). The shaded leaf petiole values of this treatment at 1200 and 1600 hours were greater than 950 ppm while those taken from sunlit leaves were much less. It would appear that even though the sky was overcast at 0800 hours, there was still enough light to reduce petiole nitrate-N values.

The petiole nitrate-N values measured throughout the day in the Cabernet vineyard were similar to one another for the Irrigated and Non-irrigated treatments (Table 11). In addition, there were no large differences between petioles taken from leaves in the sun or shade for these two treatments. For the fertilized vines' petioles, predawn and samples collected at 0800 hours were close to one another along with the sunlit leaf value taken at 1600 hours. Total N of the Fertilized treatment was significantly increased compared to the Irrigated and Non-irrigated treatments. There were no significant main, treatment effects on petiole K.

At the veraison sampling date, I found that when the leaf was removed from the shoot and the petiole then separated from the blade, there is little sap remaining in the petiole (this was after the petiole had been placed in a pressure chamber and then pressurized). Therefore, when the above procedure is used to obtain a petiole for nutrient analysis, the amount of sap remaining in the petiole is a function of the leaf's water status when sampled (i.e. whether the leaf is exposed to direct solar radiation or in the shade when sampled). This is a result of the fact that the water in the petiole of a leaf exposed to direct sunlight is under greater tension than a leaf in the shade (Table 12) due to higher rates of transpiration. When a petiole is cut at both ends simultaneously (using my specially designed scissors) this should prevent the sap from being pulled into the leaf blade (such occurs when leaves are sampled to measure leaf water potential). Accordingly, I found that the amount of sap expressed from the petiole by using the scissor method for sunlit leaves was much greater than even leaves sampled in the shade using the normal method. Thus, if the displacement of sap into the leaf blade has an effect on petiole nutrient analysis, then this method should illustrate its effect. In addition, the inclusion of two different irrigation treatments in the study should result in differing amounts of tension in their respective leaves.

Comparisons of the 'scissor cut' petioles with those obtained using the 'normal' technique were somewhat similar to one another in the Chardonnay vineyard (Table 13). Both methods illustrated that nitrate-N of sunlit leaf petioles was less than that in petioles of leaves collected in the shade. Since the petiole nitrate-N of the Cabernet Irrigated and Non-irrigated treatments were very low, little can be said of the comparisons between the two-petiole sampling techniques. However, the nitrate-N values of the 'scissor cut' petioles were only half that of petioles sampled the normal way for the Cabernet Fertilized treatment (Table 13).

The last sampling or post-sampling technique I used was to allow the leaf (blade and petiole still attached) to remain in the sun after it was detached. The rationale for this procedure was to allow any remaining sap in the petiole to be taken into the blade while transpiration proceeded (an attempt to pull any remaining sap in the petiole into the blade). The 'dry down' procedure appeared to increase petiole K values for Cabernet vines that were irrigated (Irrigated and 80 lbs N treatments) when compared to the 'normal' and 'scissor cut' methods (Table 13). This was not the case for the Chardonnay vines. The petiole nitrate-N values for the 'dry down' procedure were similar to those obtained by the 'normal' procedure for the Cabernet vines but not for the Chardonnay vines.

Outside Presentations of Research:

Since this project was just initiated during the 2001 growing season, I have not given any presentations of this research as of 27 December 2001.

Research Success Statements:

This research has the potential, once all samples are analyzed, to make grape growers cognizant of the fact that; cultural practices, leaf position, sampling technique, time of day samples are collected and weather conditions at the time of sample can affect the nutrient values measured in petioles. In addition, once leaf, stem and cluster N and K are analyzed; the relationship between petiole nutrient values and N and K in those tissues can be shown. This may then be used to establish new critical values of petiole tissue analysis that are independent of cultivar and/or rootstock. For example, an analysis of the relationship between petiole nitrate-N and total N resulted in a highly significant linear regression using data from all locations, dates, time of day and leaf type (sunlit or shaded) (Figure 1). It is anticipated that such may be found when leaf, stem and cluster N and K are correlated with petiole nitrate-N, total N or K.

It should be pointed out that conclusions drawn in portions of this report are based upon a limited amount of data. However, several generalizations can be drawn regarding what may influence the nutrient values of petioles. 1.) The type of leaf chosen to sample, whether it is in the sun, shade or opposite the cluster, will influence the values of nitrate-N and K. Sunlit leaves at bloom generally had higher values of petiole nitrate-N than either shaded leaves or leaves opposite the cluster. At veraison and prior to harvest, shaded leaves had greater values of petiole nitrate-N and K than sunlit leaves. 2.) Irrigation amount (when comparisons between the Irrigated and Non-irrigated treatments were made) had an effect on petiole nitrate-N and K late in the growing season. The irrigated treatment generally had lower values of nitrate-N and K when compared to the non-irrigated treatment. It is unknown at this time whether the water status of the vine is responsible for this effect. 3.) The three cultivars used in this study generally responded to the treatments and sampling differences similarly. 4.) Without further petiole analysis of more replicates, it is unknown whether time of day samples are collected or the contribution of the petiole's sap to the total nutrient within the petiole significantly affects nutrient

Funds Status:

The amount of money requested for this proposal was $33,945 while that allocated by the funding agencies was $25,000. To date, $24,537 has been spent or encumbered. Of that amount, $4,264 was used to analyze the petioles for the data presented in this report. The remainder of the monies was used for my technician's salary and benefits, for temporary summer help and travel expenses. There is no more money left over for the analysis any other samples. A request will be submitted for the next funding cycle to cover the expenses for additional petiole nutrient analyses of the 2001 growing season samples.

Table 1. Location, cultivar and irrigation and fertilization treatments used in the study during the 2001-growing season

Location	Cultivar	Irrigation Treatment[a]	Date of First Irrigation	Fertilizer Treatment[b]	Date Applied
Kearney	Thompson	Non-irrigated	na[c]	None	na
		Irrigated (100%)	April 23	None	na
		Irrigated (100%)	April 23	50 lbs	April 23
		Irrigated (100%)	April 23	100 lbs	April 23
Carneros	Chardonnay	Non-irrigated	na	na	na
		Irrigated (100%)	May 9	None	None
		Irrigated (100%)	May 9	80 lbs	May 9
Oakville	Cabernet	Non-irrigated	na	None	na
		Irrigated (50%)	May 10	None	na
		Irrigated (50%)	May 10	40 lbs	May 10
		Irrigated (50%)	May 10	80 lbs	May 10

[a] Irrigation treatment amounts were a percentage of estimated full ET.
[b] Fertilizer treatments were equivalent to pounds of total N per acre.
[c] Not applicable

Table 2. Phenological stage, date, time of day and leaf type of Thompson Seedless petioles sampled during the 2001-growing season at Kearney.

Phenological Stage	Calendar Date	Time of Day (h)	Leaf Type[a]
35% Bloom	May 7	0800	Sun
			Shade
			Opposite the Cluster
		1200	Sun
			Shade
			Opposite the Cluster
		1600	Sun
			Shade
			Opposite the Cluster
90% Veraison	July 12	0800	Sun
			Shade
		1200	Sun
			Shade
		1600	Sun
			Shade
Pre-harvest	August 31	Predawn	na
		0800	Sun
			Shade
		1300	Sun
			Shade

[a] Leaf type 'sun', 'shade', or 'opposite the cluster' refers to leaves that when sampled were fully exposed to solar radiation, the majority of the leaf blade was shaded, or sampled opposite the cluster along the shoot, respectively. Leaves were randomly sampled within the canopy at predawn.

Table 3. Phenological stage, date, time of day and leaf type of Chardonnay petioles sampled during the 2001-growing season at Carneros.

Phenological Stage	Calendar Date	Time of Day (h)	Leaf Type[a]
98% Bloom	May 23	0800	Sun
			Shade
			Opposite the Cluster
		1200	Sun
			Shade
			Opposite the Cluster
		1600	Sun
			Shade
			Opposite the Cluster
70% Veraison	July 25	Predawn	na
		0800	Overcast
		1200	Sun
			Shade
		1600	Sun
			Shade
Pre-harvest	September 5	Predawn	na
		0800	Overcast
		1300	Sun
			Shade

[a] Leaf type 'sun', 'shade', or 'opposite the cluster' refers to leaves that when sampled were fully exposed to solar radiation, the majority of the leaf blade was shaded, or sampled opposite the cluster along the shoot, respectively. Leaves were randomly sampled within the canopy at predawn or when it was overcast

Table 4. Phenological stage, date, time of day and leaf type of Cabernet Sauvignon petioles sampled during the 2001-growing season at Oakville.

Phenological Stage	Calendar Date	Time of Day (h)	Leaf Type[a]
98% Bloom	May 24	0800	Sun
			Shade
			Opposite the Cluster
		1200	Sun
			Shade
			Opposite the Cluster
		1600	Sun
			Shade
			Opposite the Cluster
70% Veraison	July 26	Predawn	na
		0800	Overcast
		1200	Sun
			Shade
		1600	Sun
			Shade
Pre-harvest	September 6	Predawn	na
		0800	Overcast
		1300	Sun
			Shade

[a] Leaf type 'sun', 'shade', or 'opposite the cluster' refers to leaves that when sampled were fully exposed to solar radiation, the majority of the leaf blade was shaded, or sampled opposite the cluster along the shoot, respectively. Leaves were randomly sampled within the canopy at predawn or when it was overcast

Table 5. Effects of treatment, time of day and leaf type on **Thompson Seedless** petiole nitrate-N, total N and potassium at **bloom**. All samples were taken in Block II. Values are expressed on a dry weight basis. Other information as found in Tables 1 and 2.

Time of Day	Treatment	Leaf Type	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
0800	Irrigated	Sun	26	0.79	2.0
		Shade	40	0.68	1.9
		Cluster	35	0.73	2.1
	Non-Irr.	Sun	92	0.80	2.1
		Shade	72	0.73	2.1
		Cluster	64	0.74	2.0
	50 lbs. N	Sun	2840	1.45	2.7
		Shade	1940	1.22	2.3
		Cluster	2230	1.26	2.3
	100 lbs. N	Sun	3395	1.59	2.5
		Shade	2471	1.26	2.2
		Cluster	2190	1.22	2.3
1200	Irrigated	Sun	61	0.63	2.1
		Shade	41	0.62	1.9
		Cluster	31	0.73	2.0
	Non-Irr.	Sun	49	0.71	2.0
		Shade	53	0.66	1.8
		Cluster	87	0.73	2.0
	50 lbs. N	Sun	2342	1.33	2.6
		Shade	1881	1.13	2.3
		Cluster	2163	1.32	2.2
	100 lbs. N	Sun	3391	1.56	2.6
		Shade	2332	1.29	2.2
		Cluster	2299	1.28	2.4
1600	Irrigated	Sun	85	0.77	2.0
		Shade	21	0.62	1.7
		Cluster	40	0.70	2.1
	Non-Irr.	Sun	65	0.78	2.4
		Shade	54	0.63	2.1
		Cluster	37	0.73	1.9
	50 lbs. N	Sun	3136	1.57	2.7
		Shade	2848	1.30	2.6
		Cluster	2674	1.38	2.4
	100 lbs. N	Sun	3184	1.62	2.5
		Shade	2795	1.34	2.3
		Cluster	3175	1.37	2.7

Table 6. Effects of treatment, time of day and leaf type on **Thompson Seedless** petiole nitrate-N, total N and potassium at **veraison**. All samples were from Block II. Other information as found in Tables 1, 2 and 5.

Time of Day	Treatment	Leaf Type	$NO_3 - N$	Total N	K
(h)			(ppm)	(%)	(%)
0800	Irrigated	Sun	70	0.58	1.5
		Shade	273	0.56	2.0
	Non-Irr.	Sun	93	0.56	1.7
		Shade	254	0.58	2.1
	50 lbs. N	Sun	51	0.56	1.8
		Shade	288	0.61	2.4
	100 lbs. N	Sun	550	0.70	1.7
		Shade	1251	0.83	2.2
1200	Irrigated	Sun	113	0.52	1.9
		Shade	125	0.52	1.8
	Non-Irr.	Sun	138	0.53	1.7
		Shade	143	0.53	1.8
	50 lbs. N	Sun	55	0.48	2.3
		Shade	173	0.54	2.2
	100 lbs. N	Sun	539	0.61	2.0
		Shade	832	0.66	2.1
1600	Irrigated	Sun	58	0.52	1.7
		Shade	61	0.54	2.1
	Non-Irr.	Sun	65	0.51	1.8
		Shade	179	0.53	2.1
	50 lbs. N	Sun	34	0.50	1.8
		Shade	432	0.65	2.2
	100 lbs. N	Sun	418	0.60	2.0
		Shade	1276	0.76	2.5

Table 7. Effect of treatment, time of day and leaf type on **Thompson Seedless** petiole nitrate-N, total N and potassium **prior to harvest**. All samples were from Block II. Other information as found in Tables 1, 2 and 5.

Time of Day	Treatment	Leaf Type[a]	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
Predawn	Irrigated	na	281	0.51	1.1
	Non-Irr.	na	321	0.44	1.0
	50 lbs. N	na	34	0.43	1.4
	100 lbs. N	na	418	0.52	1.3
0800	Irrigated	Sun	70	0.43	0.7
		Shade	11	0.45	1.2
	Non-Irr.	Sun	217	0.48	0.7
		Shade	256	0.49	1.1
	50 lbs. N	Sun	20	0.46	1.4
		Shade	127	0.45	1.7
	100 lbs. N	Sun	178	0.47	1.2
		Shade	900	0.60	1.8
1200	Irrigated	Sun	36	0.44	1.0
		Shade	89	0.47	1.3
	Non-Irr.	Sun	200	0.50	0.7
		Shade	220	0.48	1.1
	50 lbs. N	Sun	42	0.46	1.2
		Shade	141	0.51	1.8
	100 lbs. N	Sun	161	0.50	1.3
		Shade	740	0.63	1.9

[a] Leaf petioles were collected from throughout the canopy at predawn.

Table 8. Effects of treatment, time of day and leaf type on **Chardonnay** petiole nitrate-N, total N and potassium at **bloom**. All samples were from Block III. Values are expressed on a dry weight basis. Other information as found in Tables 1 and 3.

Time of Day	Treatment	Leaf Type	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
0800	Irrigated	Sun	95	1.12	2.4
		Shade	146	1.02	2.3
		Cluster	93	0.79	1.9
	Non-Irr.	Sun	202	1.11	2.2
		Shade	244	0.92	2.2
		Cluster	314	0.89	1.8
	80 lbs. N	Sun	1077	1.46	2.5
		Shade	1393	1.27	2.3
		Cluster	661	1.03	1.7
1200	Irrigated	Sun	132	1.15	2.3
		Shade	162	1.00	2.3
		Cluster	233	0.91	1.7
	Non-Irr.	Sun	265	1.01	2.2
		Shade	321	0.95	2.1
		Cluster	311	0.88	1.9
	80 lbs. N	Sun	925	1.20	2.4
		Shade	2002	1.39	2.2
		Cluster	912	1.00	1.8
1600	Irrigated	Sun	126	1.02	2.3
		Shade	197	0.97	2.1
		Cluster	187	1.17	1.5
	Non-Irr.	Sun	146	0.94	2.1
		Shade	274	0.94	2.1
		Cluster	279	0.85	2.0
	80 lbs. N	Sun	1229	1.26	2.5
		Shade	2232	1.46	2.4
		Cluster	1758	1.81	1.3

Table 9. Effects of treatment, time of day and leaf type on **Cabernet Sauvignon** petiole nitrate-nitrogen, total nitrogen and potassium at **bloom**. All samples were from Block I. Values are expressed on a dry weight basis. Other information as found in Tables 1 and 4.

Time of Day	Treatment	Leaf Type	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
0800	Irrigated	Sun	214	0.89	3.3
		Shade	306	0.78	3.1
		Cluster	75	0.59	3.0
	Non-Irr.	Sun	35	0.80	2.9
		Shade	248	0.83	3.1
		Cluster	40	0.62	2.6
	80 lbs. N	Sun	2919	1.42	3.3
		Shade	2910	1.34	3.1
		Cluster	1976	0.95	2.9
1200	Irrigated	Sun	501	1.00	3.6
		Shade	509	0.78	3.1
		Cluster	414	0.68	3.1
	Non-Irr.	Sun	255	0.95	2.8
		Shade	219	0.71	2.7
		Cluster	111	0.61	2.8
	80 lbs. N	Sun	3917	1.64	3.3
		Shade	3959	1.43	3.2
		Cluster	2954	1.07	2.9
1600	Irrigated	Sun	236	0.75	3.2
		Shade	410	0.76	3.1
		Cluster	29	0.60	3.1
	Non-Irr.	Sun	244	0.76	3.0
		Shade	77	0.70	2.6
		Cluster	76	0.62	2.6
	80 lbs. N	Sun	3678	1.42	3.2
		Shade	3844	1.38	3.2
		Cluster	2775	1.04	2.9

Table 10. Effects of treatment, time of day and leaf type on **Chardonnay** petiole nitrate-N, total N and potassium at **veraison**. All samples were from Block III. Other information as found in Tables 1 and 3.

Time of Day	Treatment	Leaf Type[a]	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
Predawn	Irrigated	na	8	0.51	2.92
	Non-Irr.	na	46	0.51	3.12
	80 lbs. N	na	796	0.63	3.06
0800	Irrigated	na	13	0.48	2.72
	Non-Irr.	na	80	0.50	3.08
	80 lbs. N	na	358	0.56	2.63
1200	Irrigated	Sun	29	0.50	2.75
		Shade	16	0.50	2.69
	Non-Irr.	Sun	121	0.54	3.21
		Shade	135	0.54	2.91
	80 lbs. N	Sun	223	0.56	2.95
		Shade	977	0.68	2.79
1600	Irrigated	Sun	40	0.51	2.85
		Shade	16	0.48	3.05
	Non-Irr.	Sun	83	0.54	2.79
		Shade	103	0.52	3.10
	80 lbs. N	Sun	275	0.56	2.99
		Shade	940	0.63	2.70

[a] Leaf petioles were collected from throughout the canopy at predawn and 0800 hours. It was overcast at 0800 hours.

Table 11. Effects of treatment, time of day and leaf type on **Cabernet Sauvignon** petiole nitrate-N, total N and potassium at **veraison**. All samples were from Block I. Other information as found in Tables 1 and 4.

Time of Day	Treatment	Leaf Type[a]	NO_3 - N	Total N	K
(h)			(ppm)	(%)	(%)
Pre-dawn	Irrigated	na	14	0.40	4.40
	Non-Irr.	na	10	0.40	3.79
	80 lbs. N	na	400	0.48	3.91
0800	Irrigated	na	8	0.41	3.98
	Non-Irr.	na	7	0.39	3.49
	80 lbs. N	na	406	0.51	2.85
1200	Irrigated	Sun	7	0.40	3.51
		Shade	9	0.41	3.61
	Non-Irr.	Sun	3	0.41	3.15
		Shade	7	0.41	3.85
	80 lbs. N	Sun	230	0.48	3.30
		Shade	486	0.50	3.73
1600	Irrigated	Sun	7	0.41	3.71
		Shade	21	0.42	3.49
	Non-Irr.	Sun	43	0.41	3.73
		Shade	7	0.43	3.36
	80 lbs. N	Sun	370	0.48	3.38
		Shade	534	0.51	3.31

[a] Leaf petioles were collected from throughout the canopy at predawn and 0800 hours. It was overcast at 0800 hours.

Table 12. The effect of irrigation treatment (irrigated vs. non-irrigated) and leaf type (sunlit vs. shaded) on leaf water potential (Ψ_l) of three cultivars at three different growth stages. Each value is the mean of at least three individual leaf replicates. Values are expressed in MPa.

Cultivar	Growth Stage	Time of Day (h)	--------Irrigated--------		-----Non-Irrigated-----	
			Sunlit Ψ_l	Shaded Ψ_l	Sunlit Ψ_l	Shaded Ψ_l
Thompson	Bloom	1300	-0.76		-0.96	
	Veraison	1300	-0.81	-0.60	-1.36	-1.25
	Pre-harvest	Predawn	-0.03		-0.16	
		0830	-0.33	-0.16	-0.46	-0.32
		1300	-0.86	-0.63	-1.11	-0.88
Chardonnay	Bloom	0900	-0.47		-0.61	
		1300	-0.73		-0.97	
		1700	-0.60		-0.81	
	Veraison	0800[a]	-0.16		-0.35	
		1300	-0.65	-0.49	-1.14	-0.97
		1630	-0.78	-0.51	-1.22	-1.02
	Pre-harvest	0800[a]	-0.17		-0.57	
		1200	-1.21	-1.10	-1.38	-1.25
Cabernet	Bloom	0800	-0.42		-0.52	
		1200	-0.70		-1.04	
		1600	-0.95		-1.14	
	Veraison	0800[a]	-0.19		-0.40	
		1300	-0.97	-0.83	-1.23	-1.03
		1600	-1.08	-0.98	-1.33	-1.23
	Pre-harvest	0800[a]	-0.14		-0.43	
		1330	-1.09	-0.94	-1.30	-1.25

[a] The sky was overcast on these dates at the 0800 hour measurement period. Therefore, leaves were randomly sampled at that time, they were not separated into sunlit and shade.

Table 13. The effect of the method of collecting the petioles or the treatment of the leaf blade and petiole after their removal from the shoot. Data were collected in the **Chardonnay** (Char) and **Cabernet** (Cab) vineyards at **veraison** at **1200 hours**.

Cultivar/ Treatment	Method[a]	Leaf Type	Nitrate N (ppm)	Total N (% dry wt.)	K (% dry wt.)
Char/Non-irr	Normal	Sun	121	0.54	3.21
		Shade	135	0.54	2.91
	Scissor Cut	Sun	111	0.54	3.30
		Shade	105	0.52	3.19
	Dry Down	Sun	48	0.51	3.41
		Shade	185	0.54	3.47
Char/80 lbs N	Normal	Sun	223	0.56	2.95
		Shade	977	0.68	2.79
	Scissor Cut	Sun	326	0.61	2.57
		Shade	562	0.59	2.99
	Dry Down	Sun	--	--	--
		Shade	548	0.60	2.97
Cab/Irrigated	Normal	Sun	7	0.40	3.51
		Shade	9	0.41	3.61
	Scissor Cut	Sun	7	0.42	3.29
		Shade	14	0.40	3.67
	Dry Down	Sun	12	0.41	4.09
		Shade	11	0.39	4.35
Cab/Non-irr	Normal	Sun	3	0.41	3.15
		Shade	7	0.41	3.85
	Scissor Cut	Sun	6	0.40	2.82
		Shade	10	0.40	3.82
	Dry Down	Sun	8	0.39	3.19
		Shade	3	0.40	3.80
Cab/80 lbs N	Normal	Sun	230	0.48	3.30
		Shade	486	0.50	3.73
	Scissor Cut	Sun	118	0.46	3.74
		Shade	257	0.44	3.76
	Dry Down	Sun	296	0.45	4.07
		Shade	484	0.47	4.40

[a] '**Normal**' refers to removal of the leaf blade and petiole from the shoot and then detaching the petiole from the blade; '**Scissor cut**' refers to cutting both end of the the petiole simultaneously; '**Dry Down**' refers to removal of the leaf blade and petiole from the shoot and placing them in the sun for two hours prior to detaching the petiole from the blade.

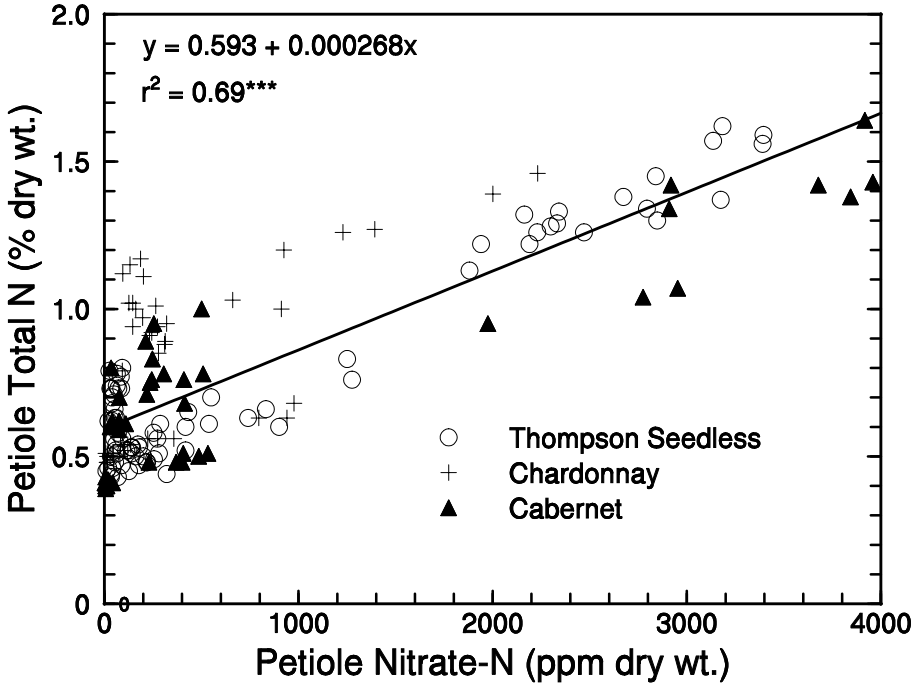

Figure 1. The relationship between petiole nitrate-N and petiole total N for three cultivars.

Appendix

Sources of significant ($P < 0.05$) differences for nitrate N (NO_3), total N (TN) and potassium (K) in petioles of Thompson Seedless at the Kearney Ag Center at bloom, veraison and prior to harvest and at Carneros (Chardonnay) and Oakville (Cabernet Sauvignon) at bloom and interactions. Treatments (Treatment or Treat) included vines that were irrigated or not irrigated or irrigated and fertilized with potassium nitrate fertilizer. Leaf type (or Leaf) included petioles from leaves that were exposed to direct sunlight, from leaves in the shade or from leaves opposite a cluster (at the bloom sample date only) at the time of sampling.

Location	Growth Stage	Nutrient	Source	*P*
Kearney	Bloom	$N0_3$	Treat x Leaf	0.02
		TN / K	Treatment	<0.0001
	Veraison	NO_3	Treat x Leaf	0.0147
		TN	Treatment	0.0001
			Leaf Type	0.0146
		K	Treatment	0.0308
			Leaf Type	0.001
	Harvest	NO_3	Treat x Leaf	<0.0001
		TN	Treatment	0.0005
			Leaf Type	0.0028
		K	Treatment	0.0085
			Leaf Type	0.02
Carneros	Bloom	NO_3	Treatment	<0.0001
			Leaf Type	0.0392
			Treat x Leaf	0.041
		TN	Treatment	0.0007
		K	Leaf Type	<0.0001
			Treat x Leaf	0.0122
Oakville	Bloom	NO_3	Treatment	<0.0001
		TN	Treatment	0.001
		K	Treatment	0.001
			Leaf Type	0.025