2009

Sonoma County Water Agency: Vineyard Water Conservation Demonstration Project

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Contents

Executive Summary

An irrigation demonstration project was conducted at Hoot Owl Creek / Alexander Valley Vineyards during the 2009 growing season. The demonstration consisted of 6 non-replicated irrigation "treatments" illustrating 6 common practices used in drip irrigation of vineyards. Irrigation scheduling was conducted independently of the commercial practice being used in the surrounding vineyard block. Four of the treatments were initiated at the same time and a fifth treatment started one month after the others (based on plant-based measurements of water status). A fifth treatment was not irrigated at all, as the target level of plant water status was not reached at any time during the season.

The commercial level of irrigation for the growing season was 4 inches, while the four early-initiated irrigation treatments were irrigated with only 1.5 inches of water, on average. The fifth treatment was irrigated with only 0.6 inches of water and the sixth with no irrigation at all. **Relative to commercial practice, this represents approximately 60% savings for the four early treatments, 80% savings for the fifth treatment and 100% savings for the sixth treatment.**

Water savings relative to commercial practice arose largely by delaying the onset of irrigation for as long as possible. This is a practice that is particularly effective in climates with high levels of off-season (i.e. winter) rainfall, such as the California north coast wine growing region. Irrigation initiation occurred on August 10th in the demonstration block, while the commercial block was irrigated beginning on July 15th. It should be noted that the rainfall event that occurred in early May allowed for a late irrigation start. In fact, the commercial vineyard began its irrigation season three weeks later than usual for this reason.

Besides delaying the onset of irrigation, the use of soil moisture monitoring devices paired with frequent plant water status monitoring, allowed for efficient irrigation applications that further reduced irrigation needs for this demonstration vineyard.

The water savings summary is summarized below along with estimates of energy savings, energy cost savings and CO_2-equivalents of savings due to energy use reduction:

	Per Acre Savings				
Treatment #	**Gal./Acre**	**In./Acre**	**$/Acre**	**kWh/Acre**	**lbs. CO_2/Acre**
1 to 4	68015	2.5	$ 19.16	108	170
5	70767	3.3	$ 25.56	144	227
6	90763	4.0	$ 30.69	172	272

When extrapolated over the estimated 60,000 acres in the geographic region of interest (Russian River Basin), the estimated total savings were as follows:

Treatment #	Acre-ft.	$	kWh	Tons CO_2
1 to 4	12,524	$ 1,149,389	6,456,154	5,099
5	13,031	$ 1,533,796	8,615,377	6,804
6	16,713	$ 1,841,315	10,342,723	8,169

The irrigation treatments were accompanied by a reduction in yield. The commercial yield from the vineyard was 8.43 tons/acre. Treatments 1 to 4 reduced yield by approximately 13%, while treatment 5 reduced yield by 28%. The un-irrigated treatment 6 reduced yield by 42%. It is quite reasonable that small increases in the irrigation level will dramatically reduce impacts on the vineyard's productivity. These could be explored further in any subsequent demonstration projects.

A vineyard cooling demonstration project compared conventional impact sprinklers against an installation of newly-developed micro sprayers that have been successfully demonstrated in a Napa vineyard project. An uncooled control treatment was included to demonstrate that good canopy management and irrigation practices could reduce or eliminate the need for overhead sprinkler cooling of vineyards. The micro sprayer treatment was less effective in cooling the air and the clusters than was the impact sprinklers, but the impact sprinklers may have cooled the fruit excessively and the micro sprayers seemed to have cooled the fruit adequately. No damage to fruit was noted in any of the three treatments.

Water use from this demonstration can be summarized as follows (from six cooling events):

	Gal./Acre	In./Acre	$/Acre	kWh/Acre	lbs. CO_2/Acre
Impact Sprinklers	80,335	3.0	$22.63	127	150
Micro Sprayers	47,809	1.8	$13.47	76	89
	Net Savings per Acre (Relative to Impact Sprinklers)				
Micro Sprayers	32,526	1.2	$9.16	51	61
No Cooling	80,335	3	$23.63	127	150

The 2007 vineyard survey revealed that 13.8% of growers polled used overhead sprinklers to cool their vineyards during heat waves. Of an estimated 60,000 , vineyard acres in the Russian River basin, that represents an estimated 8,280 of sprinkler-cooled vineyards. This represents the following potential savings across all vineyards:

	Acre-ft.	$	kWH	Tons CO_2
Micro Sprayers	827	$75,852	426,066	252
No Cooling	2,041	$187,346	1,052,329	622

Project Execution and Results

Irrigation Demonstration

An irrigation demonstration project was conducted at Hoot Owl Creek / Alexander Valley Vineyards during the 2009 growing season. The demonstration was placed in a Cabernet Sauvignon Vineyard trained to a Scott-Henry trellis system on O39-16 rootstock. Row Spacing was 8 feet and vine spacing 6 feet. The demonstration consisted of 6 non-replicated irrigation "treatments" illustrating 6 common practices used in drip irrigation of vineyards. The irrigation scheduling was conducted by Mark Greenspan (viticulturist) of Advanced Viticulture and was based on current best practices, with some modifications per the individual treatments.

Treatments and Measurements

The treatments consisted of the following:

1) A single 1 gallon per hour (gph) emitter per vine (others had two ½ gph emitters installed per vine)
2) Relatively low volume irrigations conducted at relatively frequent intervals (other irrigation regimes were based on this schedule except for #3)
3) Relatively high volume irrigations conducted at relatively infrequent intervals (same intended volume as the other irrigation treatments but applied in a different manner)
4) Irrigation per #2, but during daytime hours (all others were irrigated at night)
5) Irrigation scheduling intended to maintain vines at approximately -13 bars of midday leaf water potential
6) Irrigation scheduling intended to maintain vines at approximately -15 bars of midday leaf water potential

Each treatment was applied to one row of grapevines. Treatment names were marked at the endposts and map was situated in the vineyard during the field demonstrations (**Figure 1**). Each treatment featured a 5 foot long AquaSpy soil moisture probe (which were donated by the company). Each probe contained 12 soil moisture sensors at 4 inch intervals. These sensors were connected to a Ranch Systems transceiver node, which provided the telemetry function for these sensors. (Real-time data were made available to the general public via the internet). For ease of interpretation, sensors within 1 foot intervals were averaged in the software for their visualization. Additionally, a flow gauge was installed in each irrigation line to measure current and accumulated flow and to notify the operator (Mark Greenspan) of any water flow (or lack thereof) that did not coincide with the scheduled irrigation events.

Irrigation events were controlled by the Ranch Systems network, with in-line water valves connected to an always-pressurized water source. Each treatment had its own valve connected to a Ranch Systems control and telemetry node. The irrigation events were scheduled by programming them through the Ranch Systems online software (accessible only by the operator).

Weekly measurements of vine water status (leaf water potential and stomatal conductance) were measured in each treatment using field instrumentation. The measurements were posted for access via the internet on Advanced Viticulture's web site.

A two-dimensional grid of soil moisture devices was installed below a drip emitter in the Short/Frequent irrigation treatment to obtain a picture of the vertical and horizontal extent of the wetted soil following an irrigation event. Eight soil moisture sensors (Watermark) were installed at 1, 2, and 3 foot depths right below an emitter, 9 inches laterally from an emitter and 18 inches laterally from an emitter (only 8 sensor ports were available, so the 1 foot depth was not included at the 18 lateral location). The Watermark sensors, which measure soil matric potential, were connected to two ēKo Pro nodes. The ēKo Pro nodes were used, along with sensors in the cooling demonstration project, to deliver data back to a central office location where data was made available via an internet connection.

At selected times, soil moisture profile data were extracted from the matric water potential measurements to construct profile plots of the two-dimensional soil moisture status. The results are discussed below and example plots appear in the Appendix.

Building on the concepts outlined in the vineyard water use best management practices (see Appendix), the emphasis was on the following aspects of irrigation management:

1) *Irrigation Initiation*: Begin the irrigation "season" as late as possible into the year by observing shoot elongation rates.
2) *Irrigation to match the root zone*: Explore soil and rooting patterns in each vineyard and adjust irrigation volumes to match the soil and root depth of the vineyard. Measurements of soil moisture within the soil profile provides a good means to achieve this goal.
3) *Water status monitoring*: Monitor vine water status (stress levels) and adjust irrigation intervals such that the vines operate in a water-use-efficient mode (i.e. partially closed stomata) while avoiding excessive stress.

Project Observations

Irrigation Initiation

Irrigation commenced per the decision of the viticulturist, primarily when shoot tips exhibited slowed or stopped growth (except for treatments #5 and #6). As vine water status measurements were already being made, values of about -11 bars of midday leaf water potential were being sought as a secondary guideline for the season's irrigation initiation.

A substantial rainfall event in early May delayed the normal onset of the irrigation season until August 10th, at which time shoot tips reached a slowing stage and midday leaf water potential had previously reached about -10 to -11 bars (**Figure 11**). Hence, total irrigation volume applied in 2009 was likely reduced below that of "normal" due to the late rainfall event. Nevertheless, it was instructive to demonstrate to growers that irrigation initiation

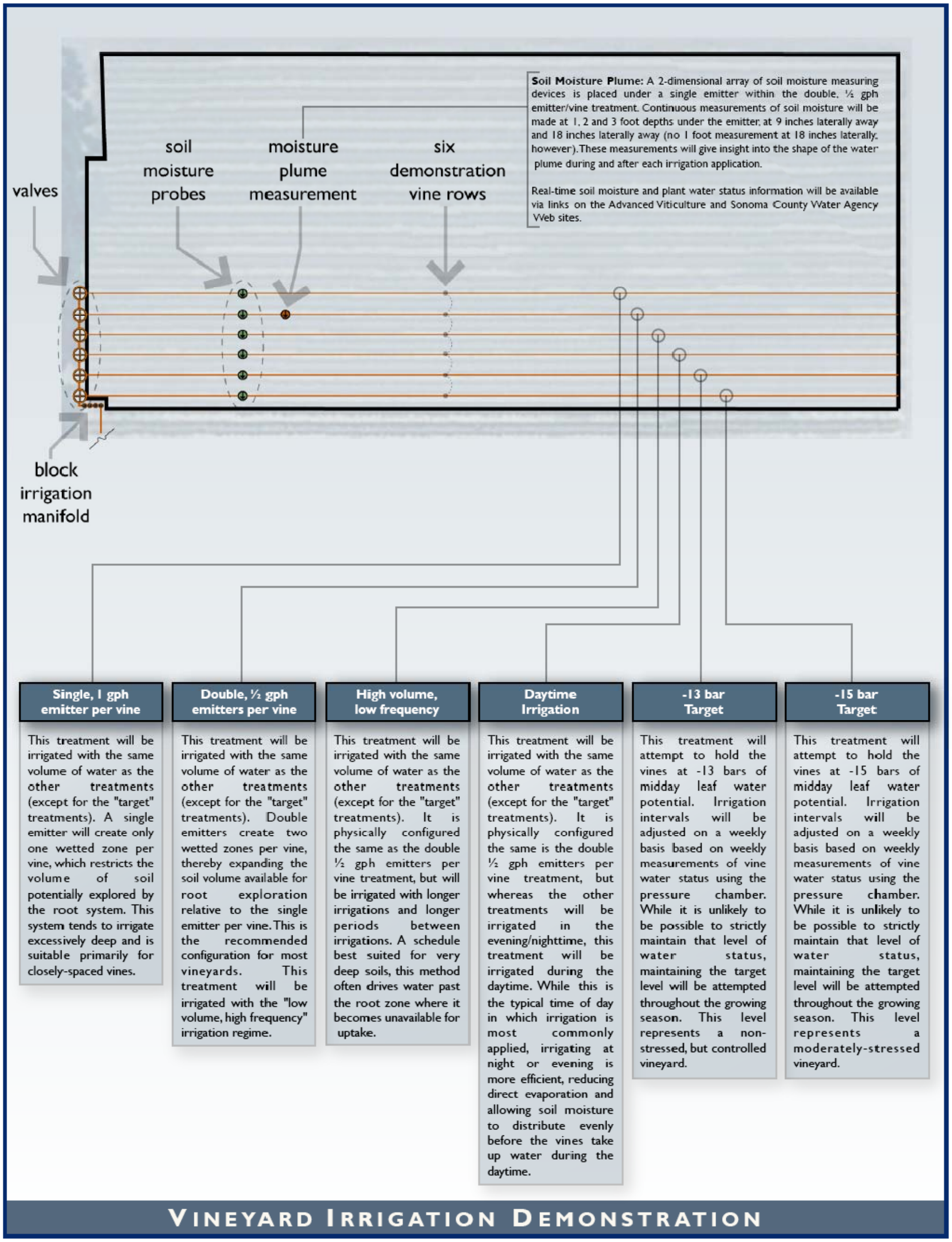


Figure 1: Treatment map and description for the irrigation demonstration. Water flow sensors were located at the same location as the soil moisture sensors. This document was provided to visitors at the demonstration field days.

does not need to be made during the same calendar time period each and every growing season.

Another message to growers about irrigation initiation is that drip irrigation, although the most efficient means to apply irrigation to vineyards, provides water to a very small proportion of the potentially-active root zone (water plume measurements appear later). Because the north coast typically receives ample winter and spring rainfall (even in a drought year) to provide ample soil moisture reserves for most vineyards until at least early summer, root systems will remain active within a relatively large volume of soil until drip irrigation commences. Once drip irrigation has begun, the root system tends to flourish in the wetted soil volume, to the detriment of the remainder of the root system. Within a relatively short amount of time (roughly two weeks), the root system morphs into one that is primarily active under the emitters. This creates a vineyard that is dependent upon drip irrigation during the remainder of the season. It also reduces the soil nutrient pool largely to the small wetted zone, thereby restricting uptake of nutrients from the larger soil reserve. For these reasons, it is beneficial to avoid drip irrigation until absolutely necessary to do so.

Irrigation to match the root zone

Once irrigation begins, it is important to irrigate with appropriate practices tailored to each vineyard. The primary variable is the depth of the root system. This was demonstrated using a backhoe pit, situated near and about the trunk of a typical vine in the vineyard. The root system was evaluated visually and the root system was determined to be approximately 3 feet deep (**Figure 2**). There were roots extending to 4 feet of depth, and perhaps even a few further down below the soil pit. Yet, the majority of the root system appeared to lie within the 3 foot soil depth. The soils at this location are alluvium, with a clay loam texture. There were no obvious impediments to root growth observed in the soil.

It was determined that, based on soil observations, that irrigation depth would be targeted to the 3 foot soil depth for the majority of the irrigation treatments, except for treatments #1 (single 1GPM emitter) and #3 (high volume, low frequency). The lateness of the irrigation season did not provide a long period of time for fine tuning of the irrigation scheduling, but some progress was made.

Accumulated irrigation volumes (gallons per vine) appears in **Figure 6**. Soil moisture profile charts appear in **Figure 3** through **Figure 5** for the six irrigation treatments. Initially, an irrigation volume of 2 gallons per vine was applied to treatments receiving irrigation. It was found that 2 gallons per vine provided insufficient moisture down to the 3 foot depth, so a second 2 gallon per vine irrigation was applied. It was found that a 4 to 5 gallon per vine irrigation application was sufficient to wet the soil down to 3 feet, with 5 gallons seen to be the most likely optimal volume. The soil moisture profile in the Low Volume/High Frequency treatment was used as the target for irrigation regime tuning. For most of the season, irrigation wetted down to 3 feet in that treatment, but did not penetrate any further down the profile. Irrigations were applied at weekly intervals. As the season progressed, the stomatal conductance values began to decline to levels that concerned the viticulturist, so irrigation intervals were shortened, as were the irrigation volumes. In retrospect, it would have been a better decision to maintain the same irrigation volume during that time, but to modify the irrigation regime by shortening the interval between irrigations by one or two days (i.e. 5 day irrigation intervals). The lower application volume reduced the depth of penetration of water, which was not necessary nor was it beneficial. Vine water status was not improved by this modification to the schedule.

The 1GPM emitter/vine treatment and the High Volume/Low Frequency treatment received nominally the same amount of water as the Low Volume/High Frequency treatment over time, though the water naturally had different wetting patterns. Irrigated along with treatment #2, the 1GPM emitter/vine treatment had water penetrate to deeper depths because the emitter output was twice as large as the other treatments. Water was concentrated in just one zone rather than split into two zones. As a result, the irrigation penetrated more deeply, regularly wetting the 40-48 inch depth and part of the 52-60 inch depth. In many vineyards (with shallower soils and rooting depths), this would have represented an inefficient way to irrigate. However, in these deep, heavy soils, this proved to be an effective irrigation alternative. Soil moisture declined after irrigation, even at the deeper depths, indicating that moisture was being taken up by the vines at all levels.

Likewise, the High Volume/Low Frequency irrigation treatment was irrigated with the same amount of water (nominally), but with twice the volume and twice the interval between irrigations. The higher volume of irrigation pushed water down to the 40-48 inch depth, but not to the 52-60 inch depth to a great extent. Once again, under many other vineyard conditions in the north coast, soils tend to be shallower and/or lighter, and optimal irrigation strategies may not include the deeper irrigation regimes.

The daytime irrigation treatment indicated that irrigation was penetrating down to the 40-48 inch depth. Since that treatment was irrigated similarly to the #2 treatment, there is no obvious reason why irrigation seemed to penetrate more deeply than the #2 treatment. On the contrary, it would seem that irrigation would not penetrate as deeply when irrigated during the daytime, since the vines are actively transpiring water during that time. It could have been a local soil feature that allowed water to penetrate more deeply in that particular location of soil moisture measurement. It also points out the fact that soil moisture measurements are inherently sensitive to placement in the soil.

The -13 bar treatment began irrigation on September 10th, one month after the 1-4 treatments. The -15 bar treatment never reached its threshold level of water stress, so was not irrigated at all during the 2009 growing season.

Figure 2: Examination and discussion of the vine's root zone during the demonstration field day on August 12th.

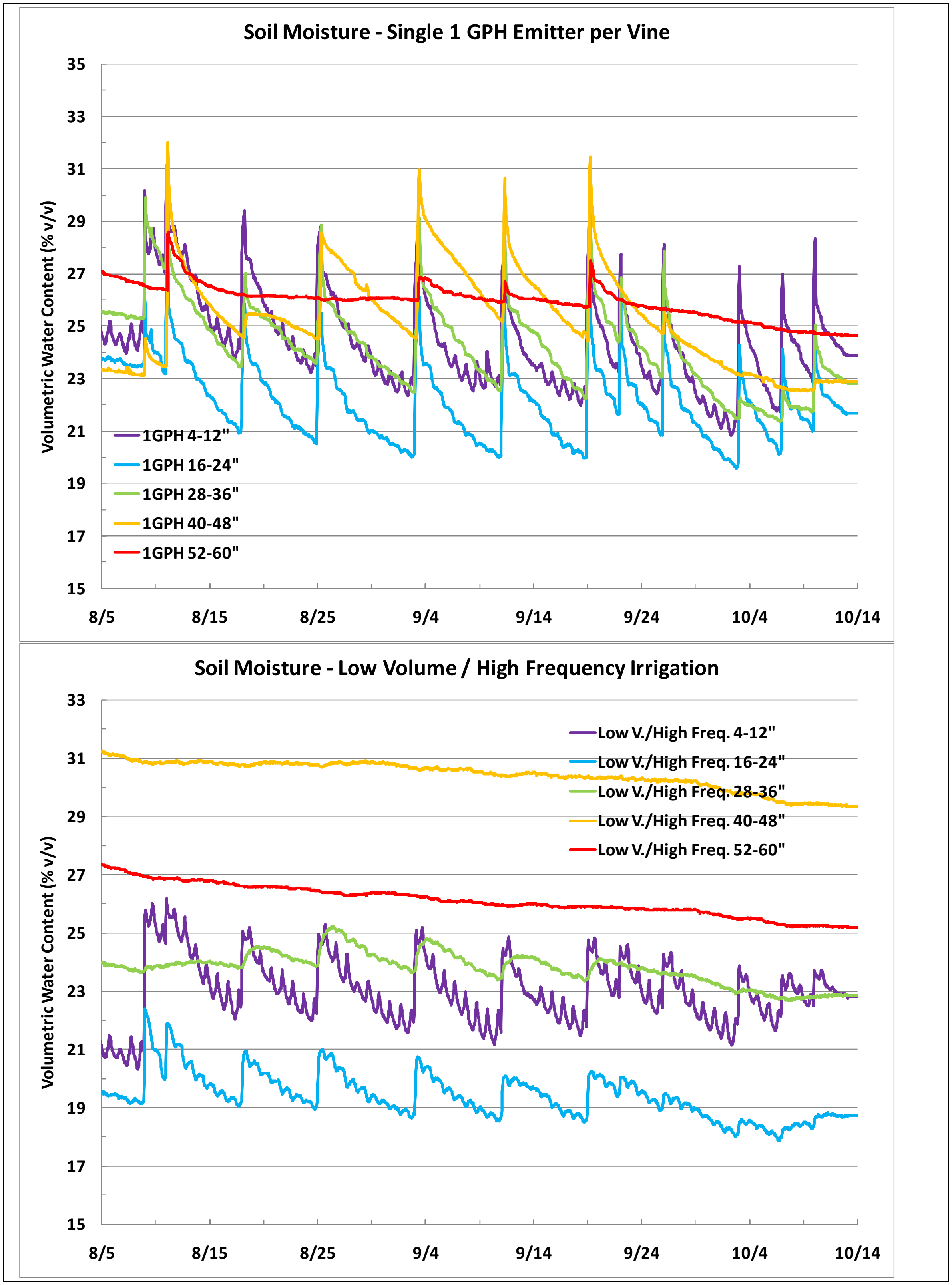


Figure 3: Volumetric water content of the soils below the emitter in the (1) Single 1GPH emitter per vine treatment and the (2) Low Volume/High Frequency irrigation application treatment.

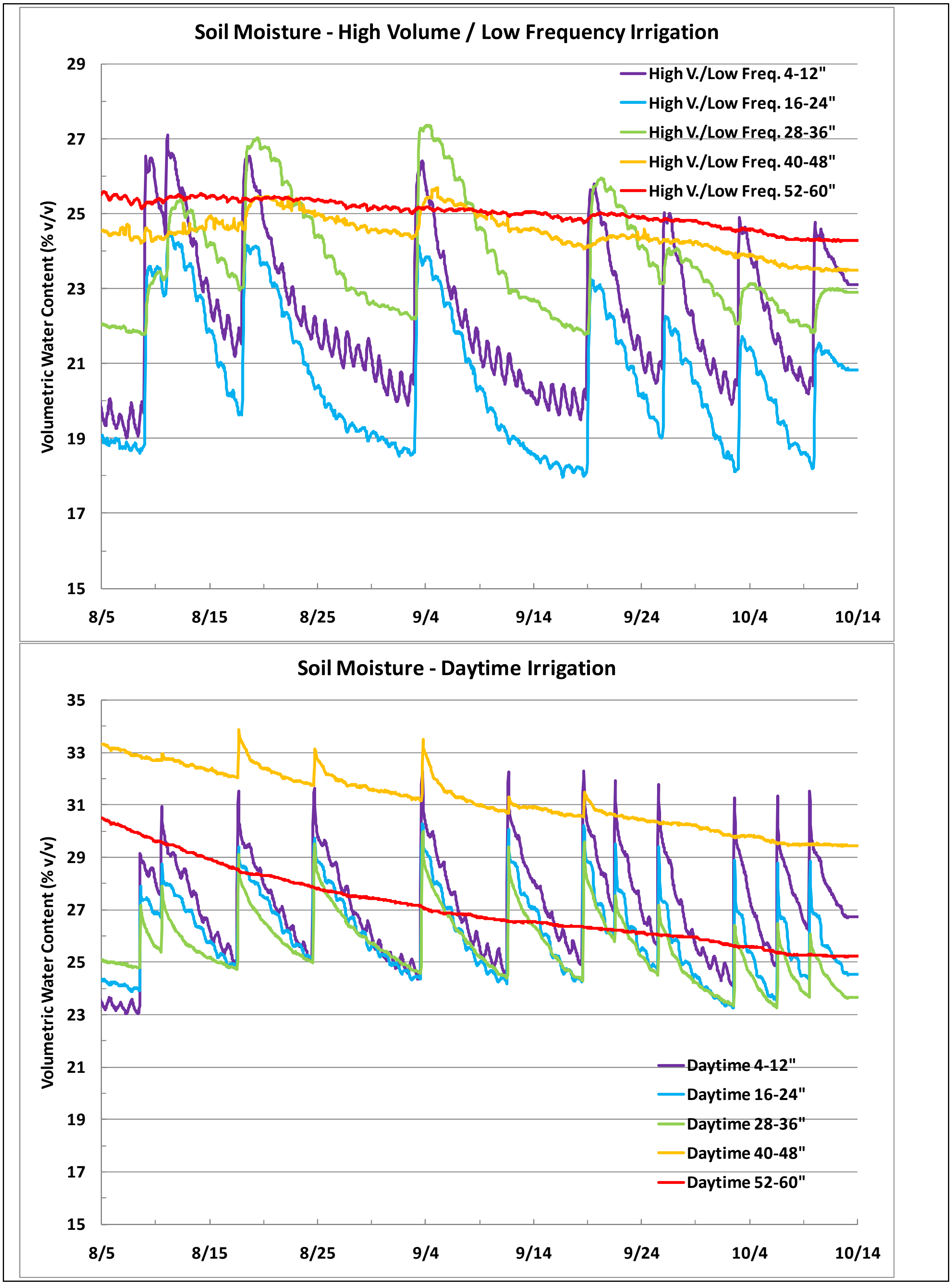
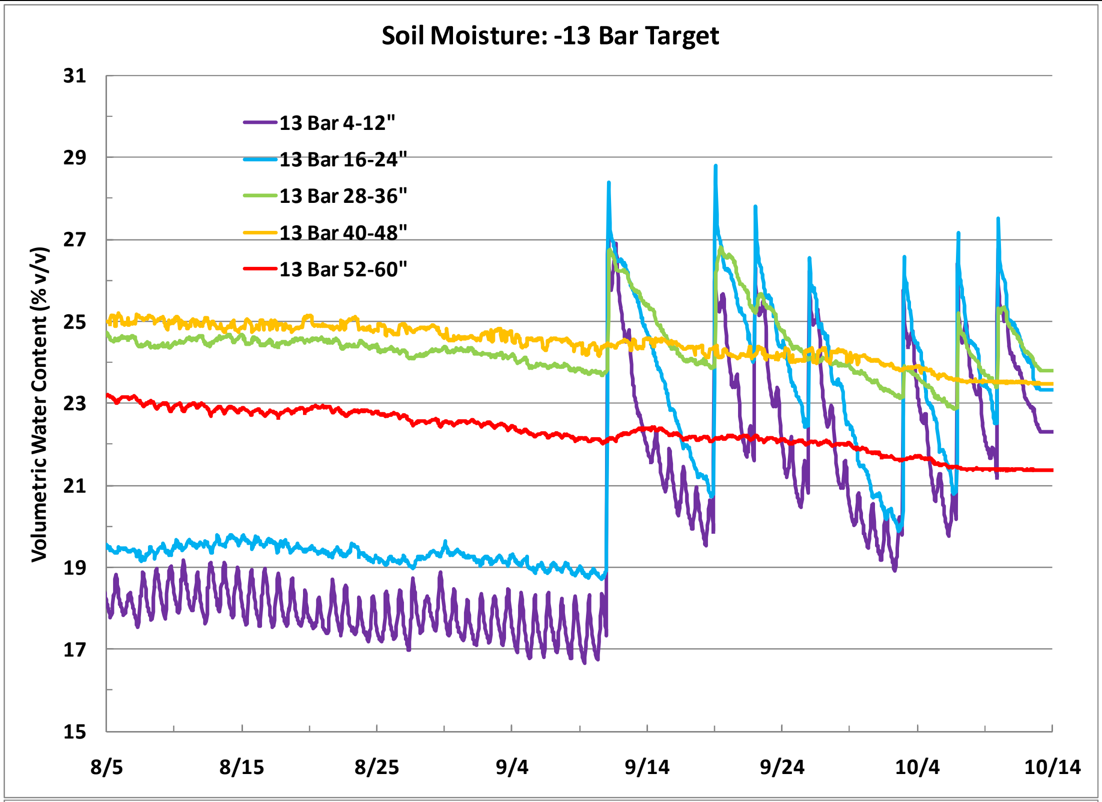


Figure 4: Volumetric water content of the soils below the emitter in the (3) High Volume/Low Frequency treatment and the (4) Daytime irrigation application treatment (irrigated per ttmt. #2).



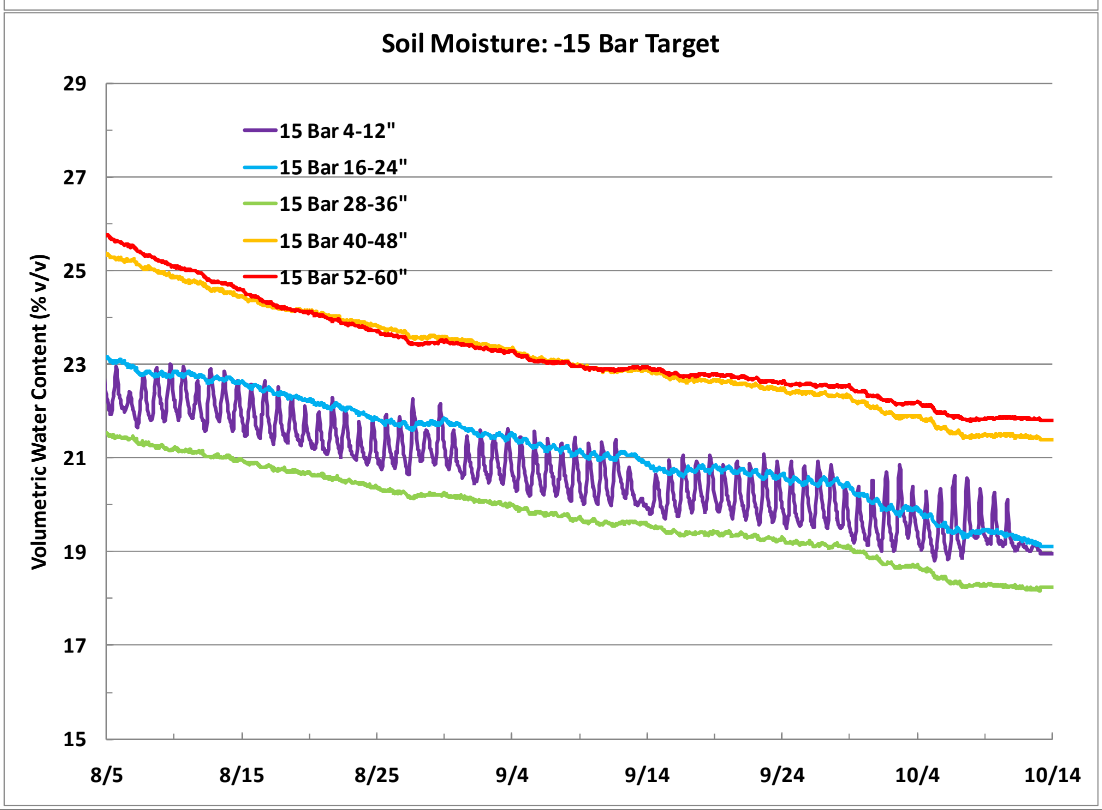


Figure 5: Volumetric water content of the soils below the emitter in the (5) -13 Bar Target treatment and the (6) -15 Bar Target irrigation treatment (which was never irrigated in 2009).

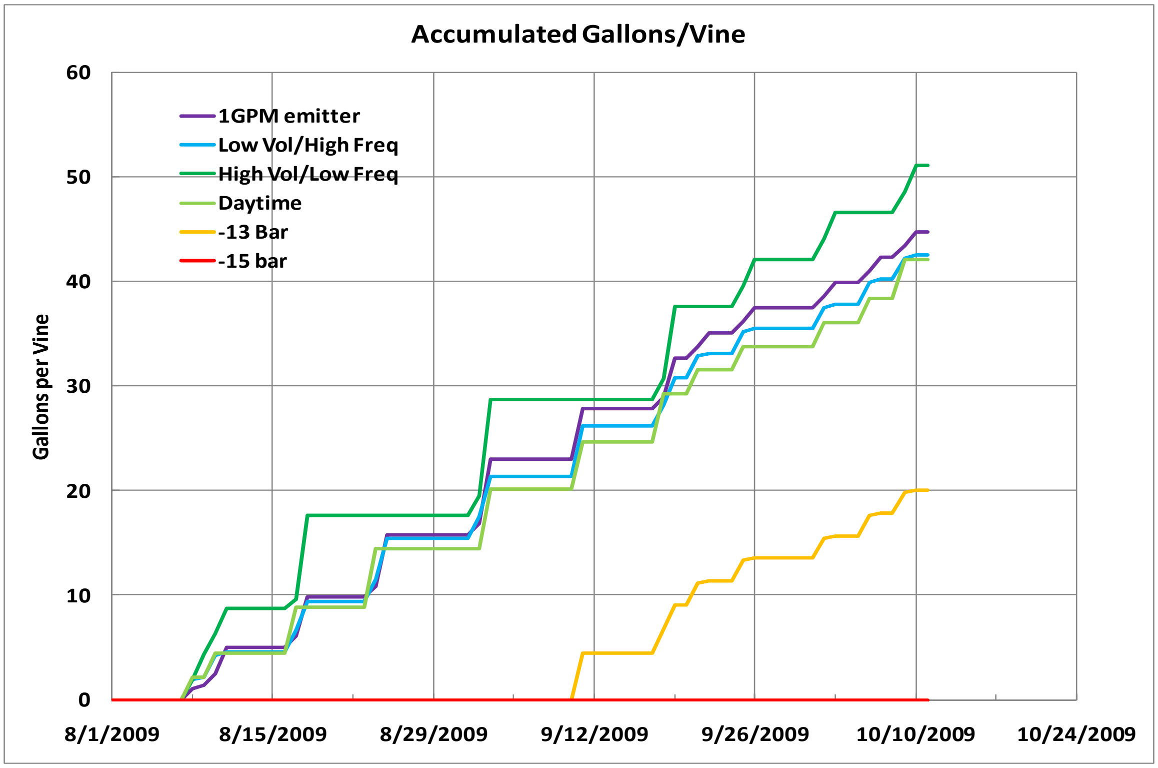


Figure 6: Accumulated irrigation volumes during the growing season for the six irrigation treatments

Soil Moisture Plume Measurement

As part of the demonstration project, a two-dimensional grid of soil moisture sensors were installed below and near a drip emitter to assess the depth and lateral extent of the wetting pattern following irrigation events. Sensors were placed at 12", 24" and 36" depths directly below a drip emitter and at the same depths 9 inches lateral distance from the same emitter. Additionally, sensors at 24" and 36" were placed 18 inches of lateral distance from the emitter (only 8 data logger ports were available so the 12" depth was not included at 18 inches lateral distance). From these data, wetting profiles were constructed using spatial interpolations of the measured data. Example profiles appear in **Figure 7** and in the Appendix. Soil moisture during the entire irrigation period is shown in **Figures 8-10**, for 0", 9" and 18" lateral distance from emitter, respectively.

It was found that the irrigation practice wetted soil down to the 3 foot depth, but not to saturation. Likewise, the moisture plume extended to the 9 inch lateral distance, but was sensed primarily at the 24 inch depth. Little soil moisture wetting occurred at 12 inch depth 9 inches laterally from the emitter. There was absolutely no wetting sensed 18 lateral inches from the emitter at any depth or at the 36" depth at 9 lateral inches. The limited size of the wetting pattern was very enlightening in that it represents a very small volume of wetted soil compared to the entire soil volume available to the vines (6 feet by 8 feet by 3 feet depth). Hence, drip irrigation, while an efficient delivery method, dramatically reduces the soil moisture pool available to the vines. Vine roots are very ephemeral in that they emerge and die or go dormant in a relatively short amount of time. Drip irrigation tends to shift the rooting patterns from the "natural" rain fed state into a confined soil volume, thus adding potential nutrient and water stresses on the vines. It is important to carry the message to growers that irrigation should be forestalled as late as possible into the growing season in order to mitigate the stresses induced from drip irrigation.

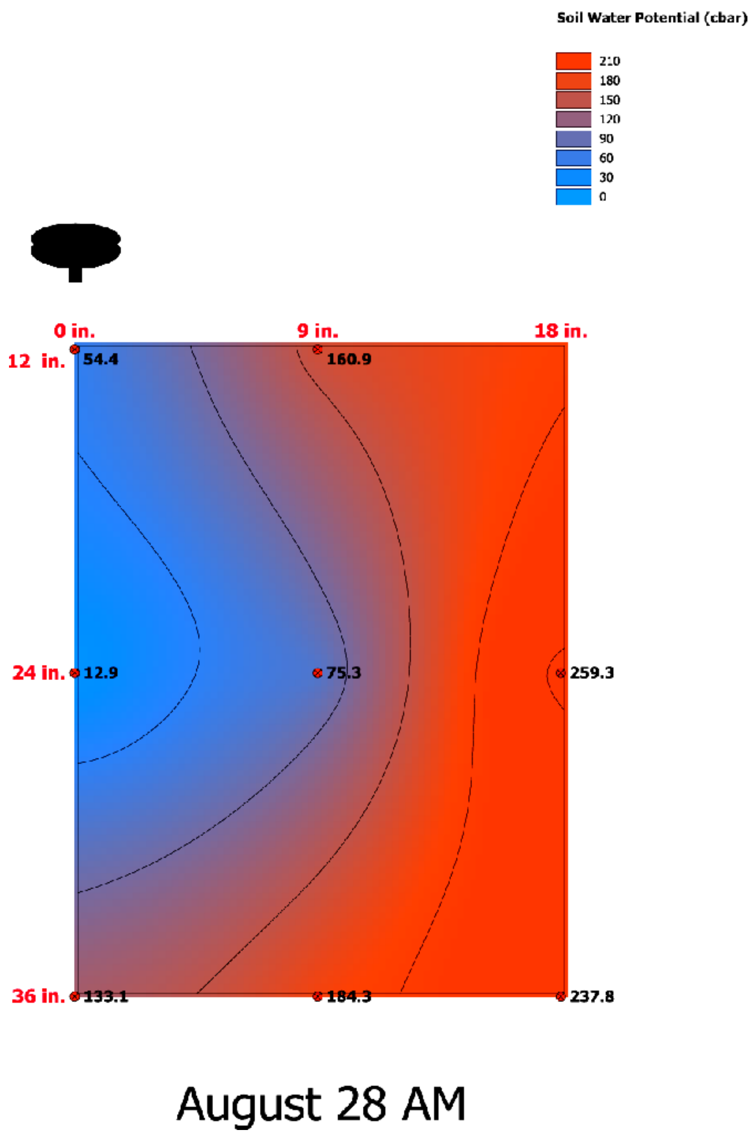


Figure 7: Example semi cross-section of the soil moisture pattern below an emitter following an irrigation application (after one day of redistribution). Values are in centibars of soil matric potential (lower values = more freely-available moisture). Upper level is 12 inches below the soil surface. For more profiles, see the appendix.

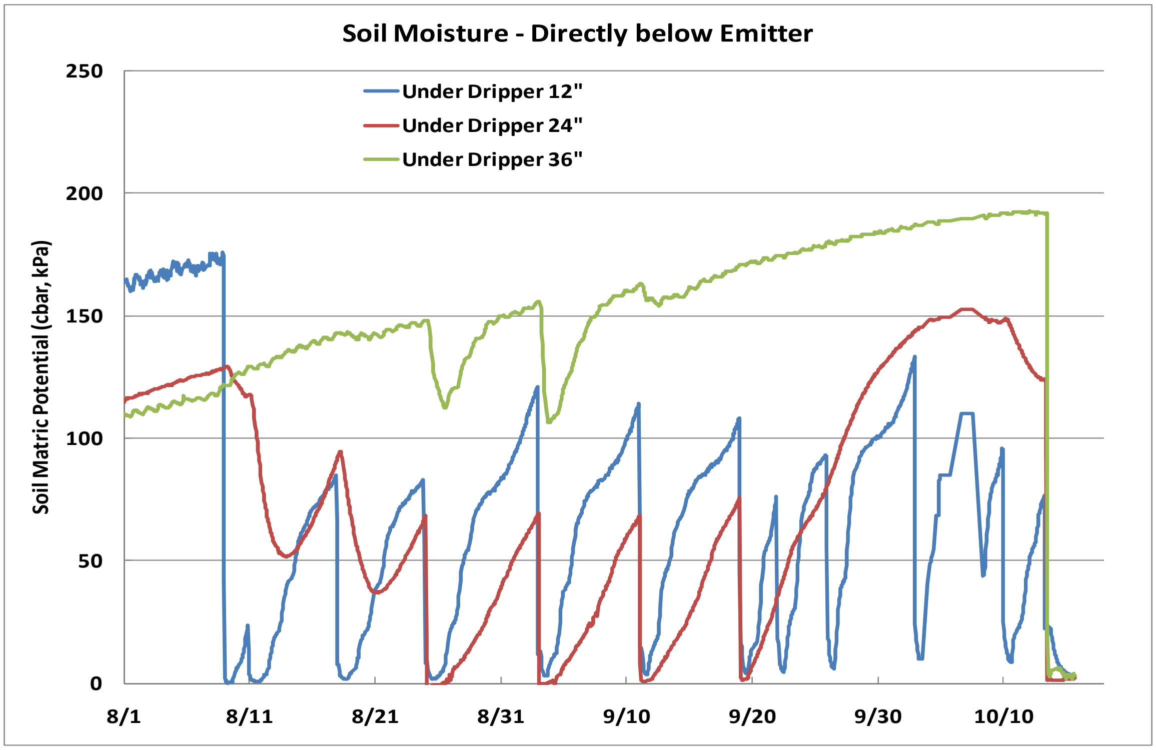


Figure 8: Soil moisture profile during the irrigation period of soil directly below a drip emitter. Values dropped to 0 cbars following the rain at the end of the period.

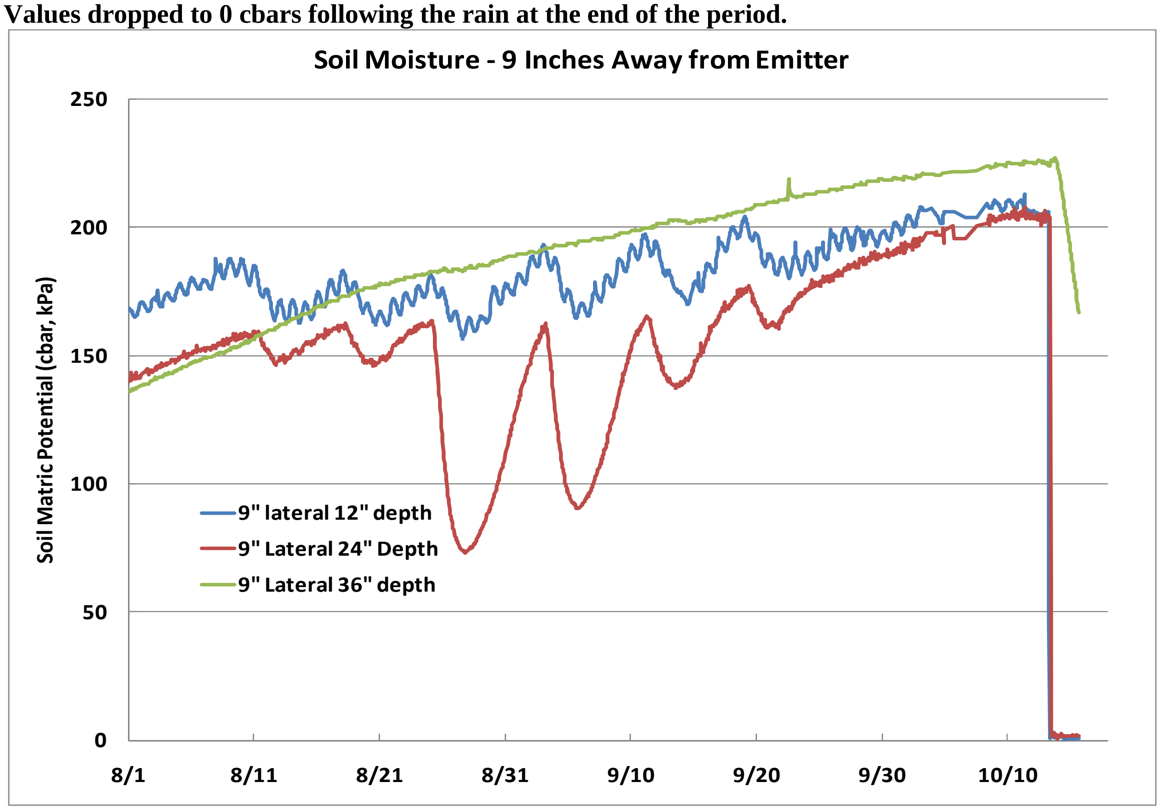


Figure 9: Soil moisture profile during the irrigation period of soil 9 inches laterally from a drip emitter.

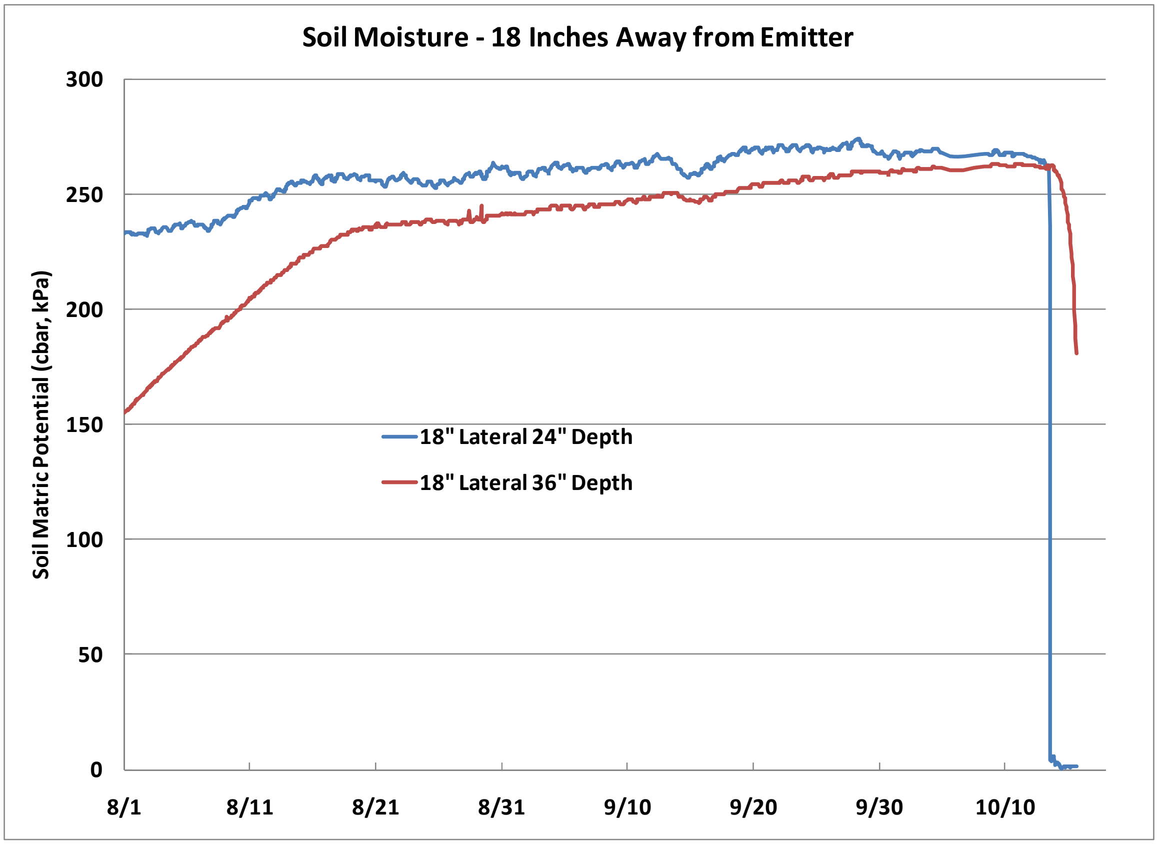


Figure 10: Soil moisture profile during the irrigation period of soil 18 inches laterally from a drip emitter.

Water status monitoring

Weekly measurements of vine water status were made throughout the season, from June through October and on days when irrigation was not being applied. In fact, an attempt was made to measure water status on the days prior to an irrigation event to best capture the stress levels between irrigations. Midday leaf water potential measurements (using the pressure chamber) appear in **Figure 11**. Note that more negative values of leaf water potential indicate more stress (i.e. lower energy state of water in the plant's xylem vessels). Data are displayed as two-period moving averages to reduce transient changes in measurements which distract from the overall trends.

With little exception, the leaf water potential values of the treatments did not reach excessive stress levels, with levels remaining above -15 bars. The lone exception was the daytime irrigation treatment, which had a period of time in which leaf water potential levels reached down below -15 bars to nearly -16 bars. It is most interesting to note that the -15 bar treatment, which did not receive any irrigation, did not get overly stressed during the measurement period. In fact, the level of water potential rose to about -12 bars towards the end of the season, which was somewhat lower than the levels measured in the irrigated treatments, except for the 1GPM emitter/vine treatment.

Midday leaf stomatal conductance values, as measured with the leaf porometer, are shown in **Figure 12**. Stomatal conductance values tend to exhibit greater variability than do leaf water potential values, although the variability amongst these measurements tended to decline as the season progressed. The tendency was that the short/frequent (i.e. Low Volume/High Frequency) treatment tended to have the highest stomatal conductance levels while the daytime irrigation treatment tended to have the lowest values. It is desirable for stomatal conductance levels to reach below 200 mmol m^{-2} s^{-1} since those levels indicate that stomata are acting to conserve water by partial closure. Levels below 100 mmol m^{-2} s^{-1} indicate excessive stress. Only two treatments (Long/Infrequent Irrigations and Daytime Irrigations) reached below the stressed level for more than one period of time.

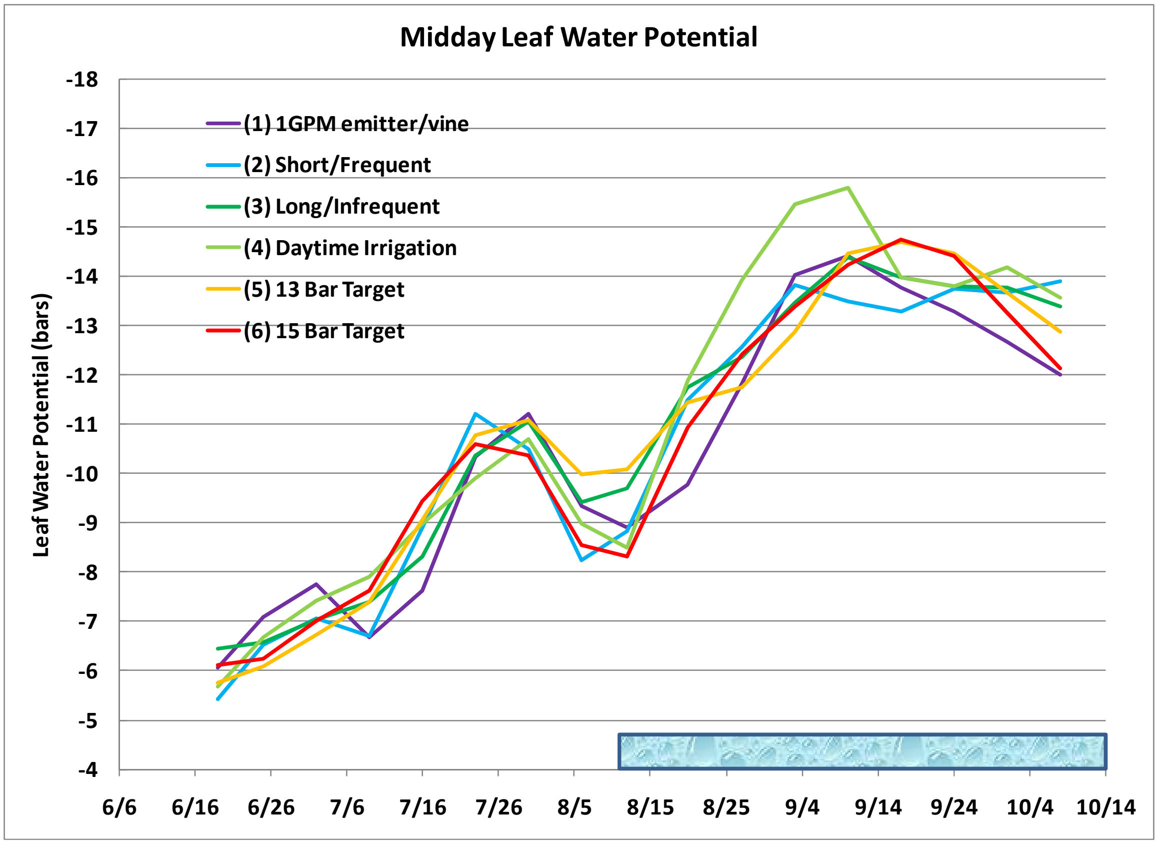


Figure 11: Midday leaf water potential measurements made at weekly intervals. Leaf water potential values above -10 bars indicates excessive water availability, between -10 and -12 bars indicates limited water resources, between -12 and -15 bars indicates moderate to mild water stress and below -15 bars indicates severe water stress. In order to improve clarity, values shown represent a 2-period moving average. Bar at the bottom indicates irrigation time period.

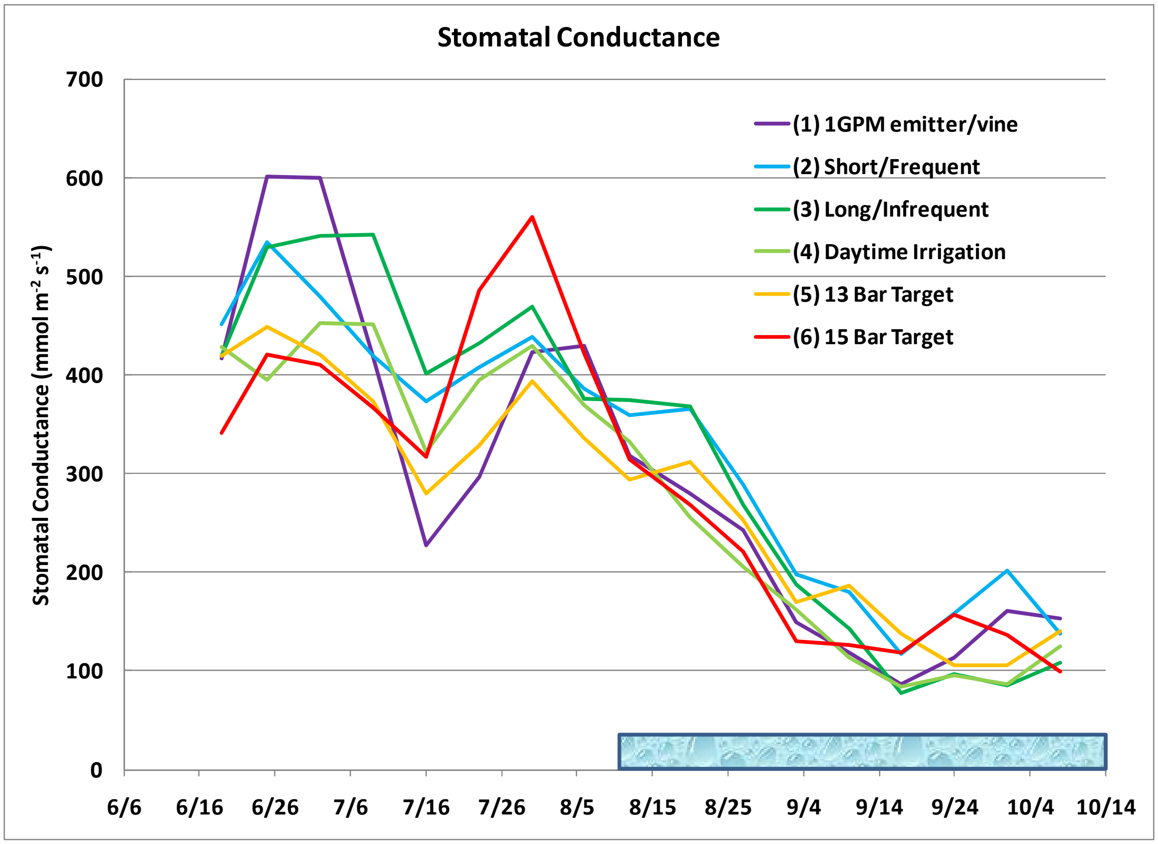


Figure 12: Midday stomatal conductance measurements made at weekly intervals. Values within 100 to 200 mmol m^{-2} s^{-1} indicate water-use-efficient conditions while those below 100 mmol m^{-2} s^{-1} indicate excessive water stress. In order to improve clarity, values shown represent a 2-period moving average. Bar at the bottom indicates irrigation time period.

Average values of both leaf water potential and stomatal conductance during the irrigation period (August 10 through October 10) appear in **Figure 13**. The average values are not highly different among the treatments with a few exceptions:

1) Daytime irrigation appears to be the most stressed, with the lowest (most negative) leaf water potential values and the lowest stomatal conductance values. This suggests that daytime irrigation is more stress-inducing to the vines than the other treatments, which were all irrigated during the night.
2) The Low Volume/High Frequency treatment had the highest stomatal conductance, although its leaf water potential was similar to the others (though not in the stressed levels). The higher stomatal conductance suggests that that irrigation regime was most effective at preventing vine stress.
3) The sing 1GPM Emitter/Vine treatment had similar stomatal conductance as the majority of the treatments, but tended to have higher (less negative) leaf water potential values, suggesting that soil moisture was more highly available to those vines.

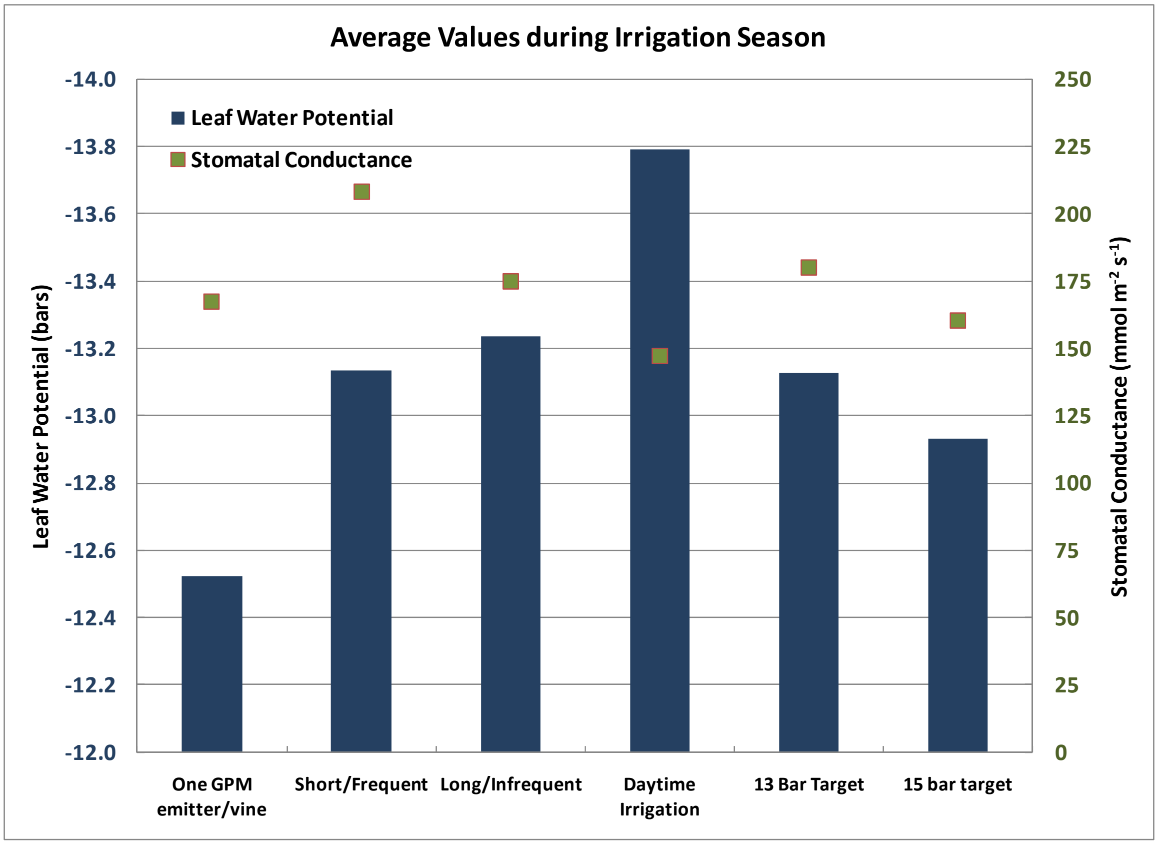


Figure 13: Average values of vine water status measurements made during the irrigation period (August 10 through October 10). More negative levels of leaf water potential indicate greater stress while lower levels of stomatal conductance indicate greater stress.

<u>Net Water Applications and Savings from Commercial Practice</u>

Irrigation volume accumulation patterns are shown in **Figure 11** and total irrigation volumes are shown in **Figure 14**. Also shown in Figure 14 is the total volume of water applied to the block outside of the demonstration project, as scheduled by the vineyard manager. The vineyard manager is well-informed of best irrigation management practices and, indeed, the volume of water applied in this block (120 gallons per vine or 4 inches) was not excessive per the standard practice for Alexander Valley (about 6 inches). Using soil moisture monitoring devices and plant water status monitoring devices, irrigation volumes in the demonstration project were markedly lower than the commercial practice, with about 45-50 gallons per vine or 1.5 inches. The -13 bar treatment was even less, at about 20 gallons per vine, or 0.6 inches. **This represents a savings of about 60% from standard practice for treatments #1-4, 80% savings for the -13 bar treatment and 100% savings from the -15 bar treatment** (**Figure 15**).

Water savings relative to commercial practice arose largely by delaying the onset of irrigation for as long as possible. This is a practice that is particularly effective in climates with high levels of off-season (i.e. winter) rainfall, such as the California north coast wine growing region. Irrigation initiation occurred on August 10th in the demonstration block, while the commercial block was irrigated beginning on July 15th. It should be noted that the rainfall event that occurred in early May allowed for a late irrigation start. In fact, the commercial vineyard began its irrigation season three weeks later than usual for this reason.

Besides delaying the onset of irrigation, the use of soil moisture monitoring devices paired with frequent plant water status monitoring, allowed for efficient irrigation applications that further reduced irrigation needs for this demonstration vineyard.

Energy costs for pumping were $30.69/acre (172 kWh) for the commercial irrigation practice versus and average of $11.53/acre (65 kWh) for irrigation treatments #1-4.

The water savings summary is summarized below along with estimates of energy savings, energy cost savings and CO_2-equivalents of savings due to energy use reduction[1]:

	Per Acre Savings					
Treatment #	Gal./Acre	In./Acre		$/Acre	kWh/Acre	lbs. CO_2/Acre
1 to 4	68015	2.5	$	19.16	108	170
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When extrapolated over the nominally 60,000 acres in the geographic region of interest (Russian River Basin), the potential totals are as follows:

Treatment #	Acre-ft.		$	kWH	Tons CO_2
1 to 4	12,524	$	1,149,389	6,456,154	5,099
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6	16,713	$	1,841,315	10,342,723	8,169

The lower irrigation levels relative to commercial irrigation did, however, have an impact on yield (**Figure 16**). Yield estimates were made from the demonstration treatments by harvesting and weighing 6 contiguous vines from each treatment and extrapolating those yield values to an acre basis. The commercial yield from the demonstration block was 8.43 tons per acre. Yield from treatments #1-4 averaged 7.33 tons per acre, representing a yield loss of approximately 13%. The -13 bar treatment yielded 6.1 tons/acre (28% yield loss) while the dry farmed -15 bar treatment yielded 4.9 tons/acre (42% yield loss).

[1] 0.718 kg CO_2 per kWH electricity per US EPA

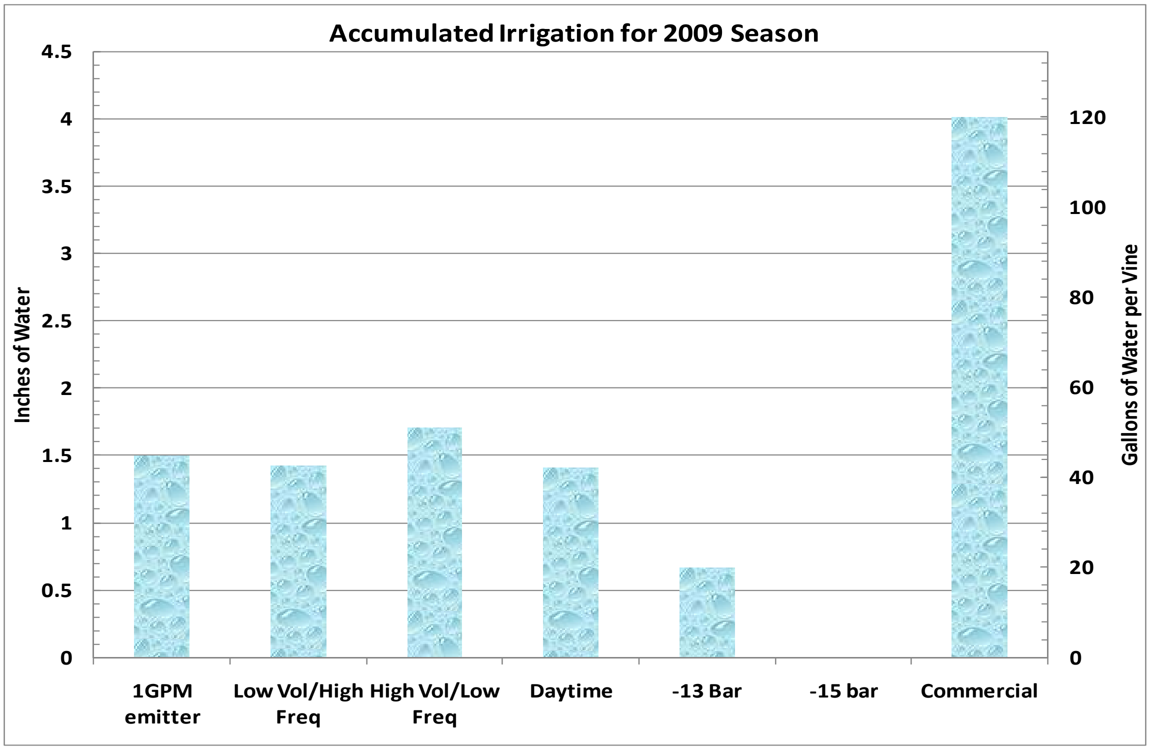


Figure 14: Accumulated irrigation for the 2009 growing season for the six irrigation treatments along with the commercial irrigation volume applied per the vineyard manager.

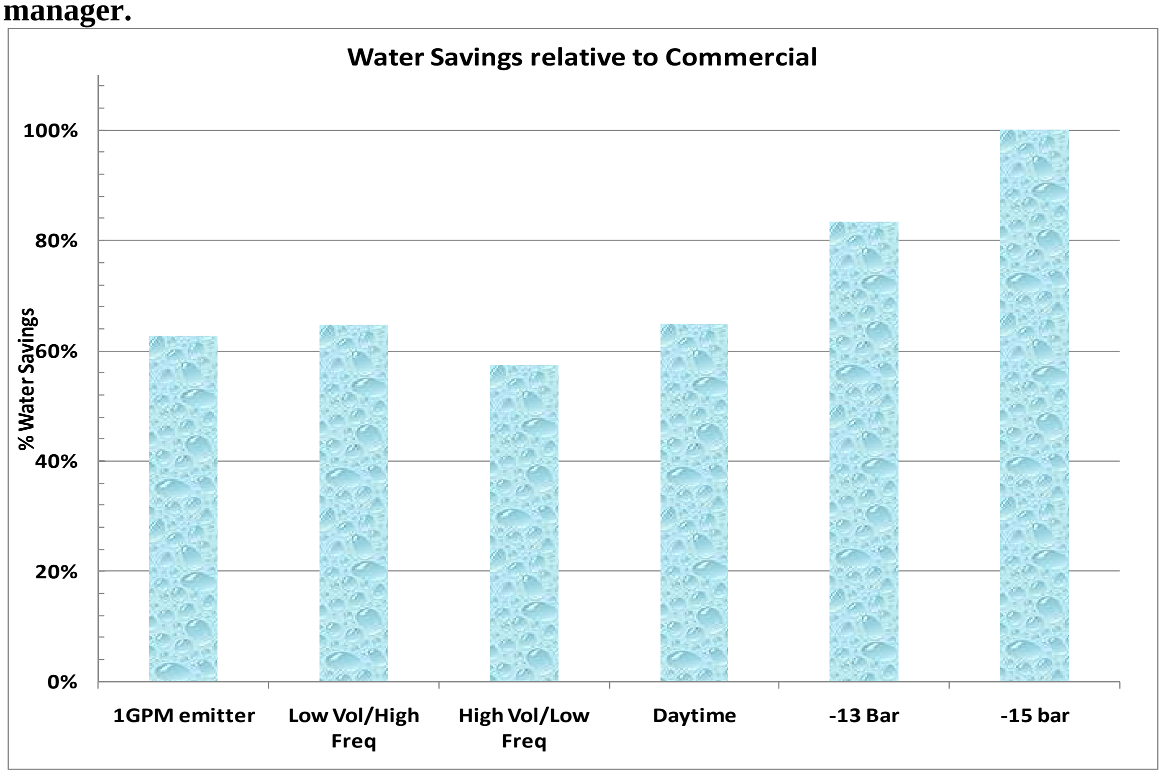


Figure 15: Percent water savings of each treatment relative to commercial irrigation practice.

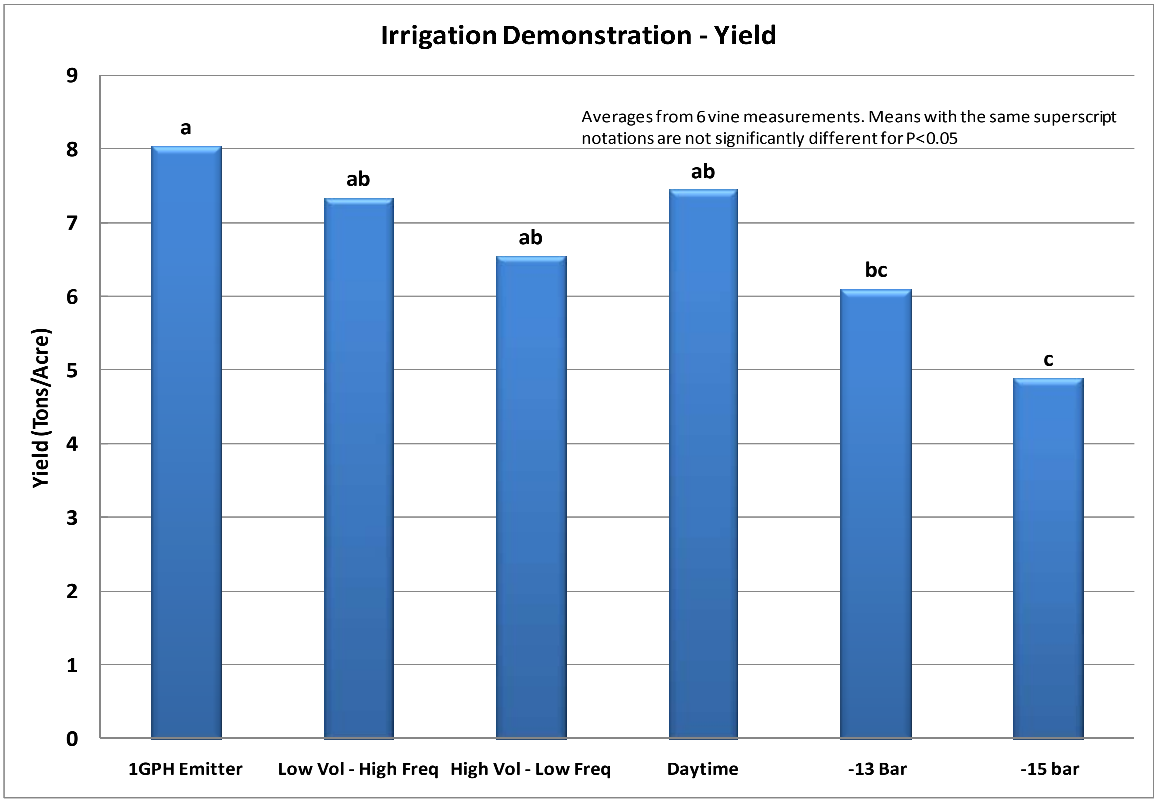


Figure 16: Yield estimate (based on a six-vine harvest from each treatment) for each irrigation treatment.

It is suggested that, if this demonstration is to continue for another season, that the overall level of irrigation be increased slightly in an attempt to produce similar yields to commercial with the expectation that less irrigation will be applied nonetheless.

Note on potential quality differences

Wines were not made from the treatments so it was useful that some sensorial evaluation be done on the fruit before harvest. The fruit was tasted by the viticulturist (Mark Greenspan), who scored the fruit in five separate categories, all of which pertained to levels of ripeness in the fruit (**Figure 17**).

The ripest characters were observed in the -13 bar and -15 bar target treatments (i.e. those that received the least irrigation. The other treatments lagged in ripe flavors, though the daytime irrigated treatment (which seemed to have the most water stress of all the treatments) had slightly elevated ripeness than treatments #1 through 3. Treatments #1 through 3 had slight traces of vegetative character, while treatments #4 through 6 had no vegetative flavors. Tannins were softest in the two treatments that were irrigated the least (-13 and -15 bar target treatments).

For completeness, fruit chemistry was analyzed on fruit at the end of September and beginning of October. The results exhibited no consistent and understandable trends, and thus are included only in the appendix. However, Brix levels were higher in the lesser-irrigated treatments and also in the daytime irrigation treatment. Also, titratable acidity levels were lowest in the daytime irrigation treatment and highest in the single 1GPM emitter/vine treatment. Note that these measurements were taken weeks before actual harvest of the fruit, of which harvest was delayed by inclement weather.

Treatment	Flavor Development	Overripe	Seeds	Tannin	Vegetative Character
(1) One GPM emitter/vine	2 - Almost developed	0 - No overripe character	0 - All brown	1 - Slightly coarse	1 - Mostly non-vegetal
(2) Short/Frequent	2 - Almost developed	0 - No overripe character	0 - All brown	2 - Coarse and/or astringent	1 - Mostly non-vegetal
(3) Long/Infrequent	2 - Almost developed	0 - No overripe character	0 - All brown	2 - Coarse and/or astringent	1 - Mostly non-vegetal
(4) Daytime Irrigation	1 - Fully developed but subdued	0 - No overripe character	0 - All brown	1 - Slightly coarse	0 - Non-vegetal
(5) 13 Bar Target	0 - Fully developed and rich	0 - No overripe character	0 - All brown	0 - Soft and ripe	0 - Non-vegetal
(6) 15 bar target	0 - Fully developed and rich	0 - No overripe character	0 - All brown	0 - Soft and ripe	0 - Non-vegetal
Potential Scoring Range	**0-4**	**0-4**	**0-4**	**0-3**	**0-3**

Figure 17: Fruit sensory components, as assessed on October 21, 2009 (prior to harvest). The fruit was tasted by the viticulturist using a standardized scale of fruit sensory assessment. Range of possible values appears in the bottom row.

Vineyard Cooling Demonstration

Project Description

The vineyard cooling demonstration portion of the project was intended to demonstrate two methods of vine and fruit cooling during high-heat events compared to that of an uncooled control treatment. This demonstration was conducted in a Merlot Block trained to Scott-Henry trellis system and on O39-16 rootstock. Spacing was 8 feet between rows and 6 feet between vines. There were two cooled treatments, consisting of standard overhead impact sprinklers at 25 per acre (nominally 55 gallons per minute per acre) and micro sprayers at one per vine (908 per acre, nominally 16.7 gallons per minute per acre) (**Figure 18**). The systems were activated when air temperatures (outside of the treatment areas) reached 99°F and were deactivated when temperatures fell below that level (or before evening, whichever came first). System activation was automated using the Ranch Systems network.

Figure 18: Impact sprinkler (left) and micro-sprayer (right)

The demonstration layout (**Figure 19**) consisted of a one acre plot cooled by impact sprinklers. A one-acre buffer was left between that plot and the one acre micro-sprayer plot. To the west of that plot was the larger control plot, which received no cooling.

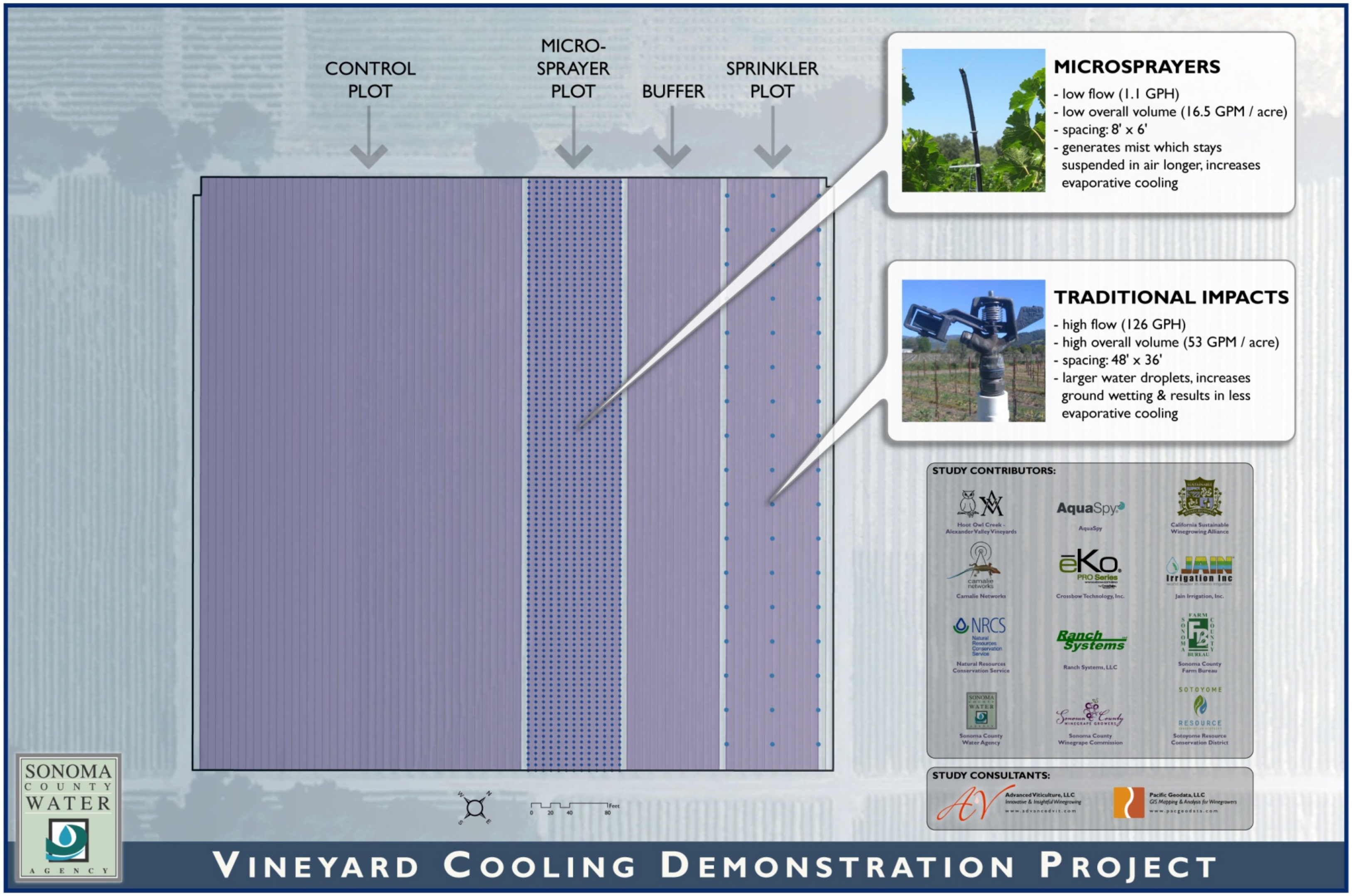


Figure 19: Layout of vineyard cooling demonstration

Project Results

Example cooling patterns of air temperature are shown in **Figure 20** for two cooling events separated by a day without cooling. It is clear that both treatments had an effect of cooling the air temperature in the treatment blocks relative to the uncontrolled treatment. It is also apparent that the impact sprinkler treatment cooled the air more than the micro sprayer treatment. Likewise, the impact sprinkler increased the air relative humidity by a much greater amount than the micro-sprayers, and the elevated humidity persisted into the nighttime (**Figure 21**).

The 2009 growing season was relatively mild compared to a typical season's weather. Only 9 heat events triggered cooling during the ripening period. Two of those events occurred when the impact sprinkler's valve controller was not functional. Those two days were eliminated from the data analyses. Average cooling power of each treatment is shown in **Figure 22**, which was corrected for natural temperature variations observed during times without cooling system activations. The impact sprinkler system cooled the air by about 10.5°F relative to the control while the micro sprayer system cooled the air by about 6°F.

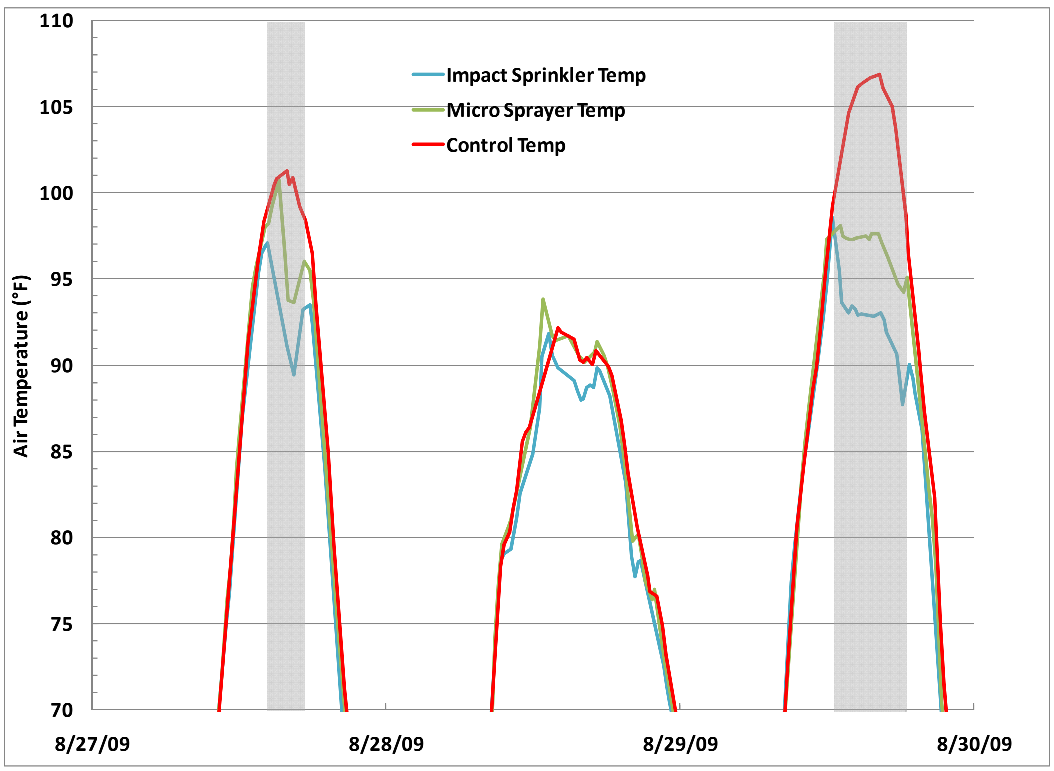


Figure 20: Example cooling events showing air temperatures of the control (uncooled), micro sprayer and impact sprinkler treatments during two cooling events separated by a day without cooling events. Active cooling is shown by the gray shading.

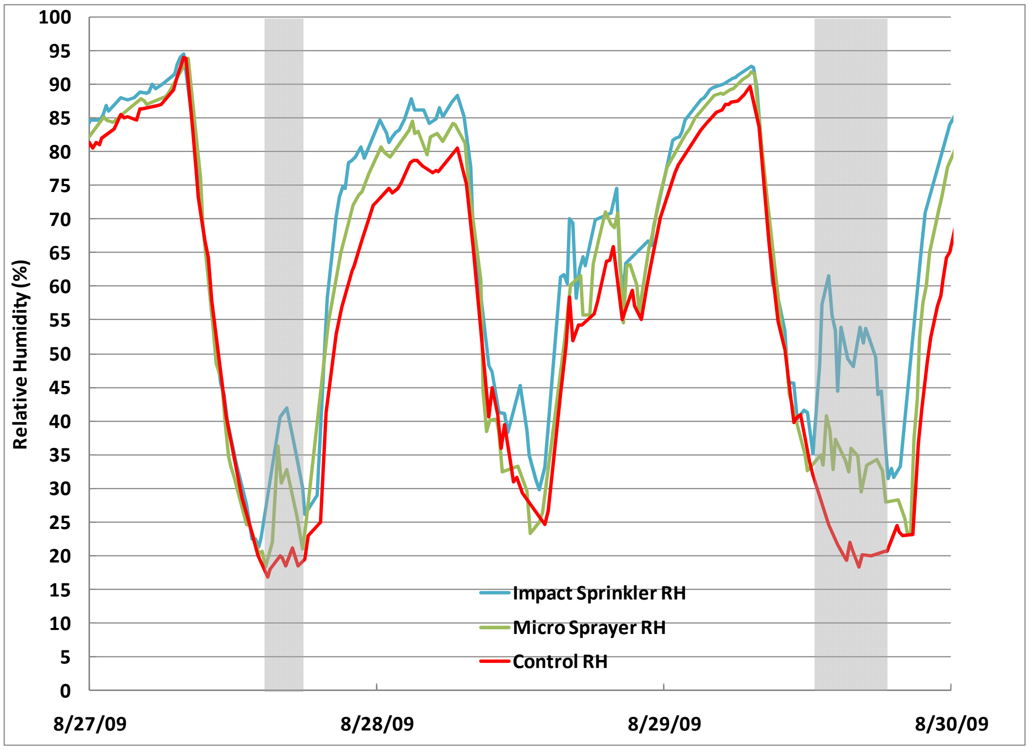


Figure 21: Example cooling events showing air relative humidity of the control (uncooled), micro sprayer and impact sprinkler treatments during two cooling events separated by a day without cooling events. Active cooling is shown by the gray shading.

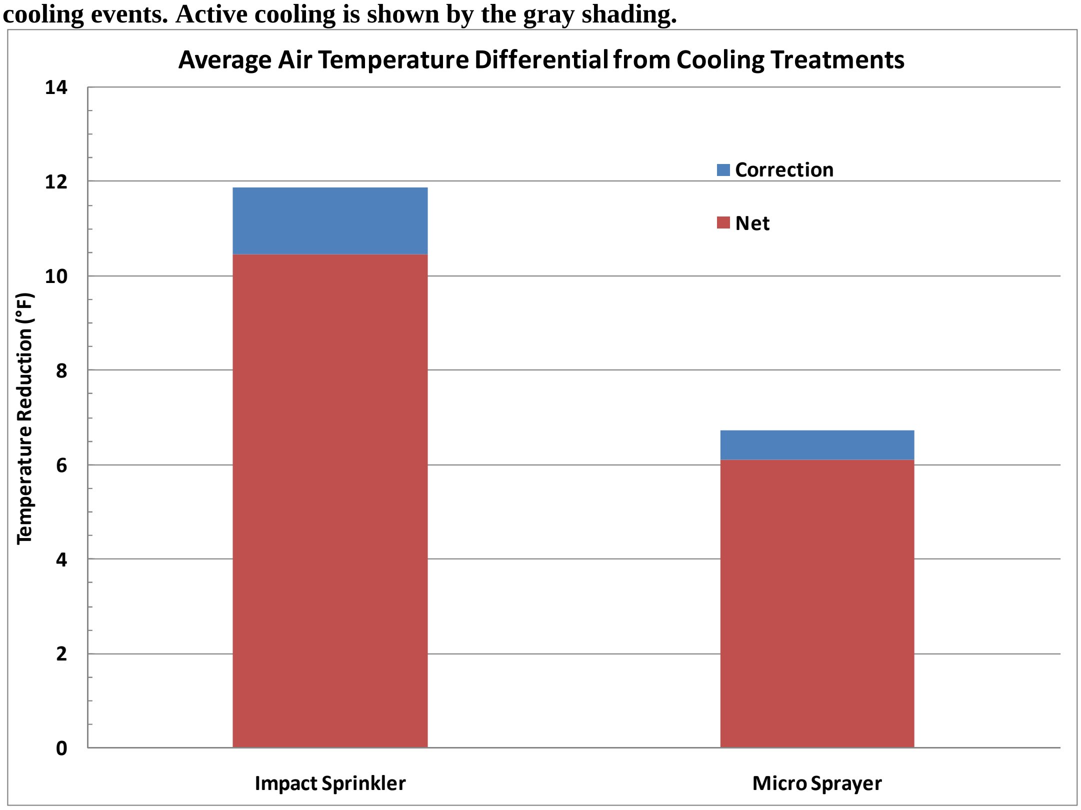


Figure 22: Average air temperature reduction, relative to the control, of the two cooling treatments. Corrections are shown for the natural temperature gradient that existed in the vineyard block.

Figure 23: Photos of clusters with temperature sensors in place.

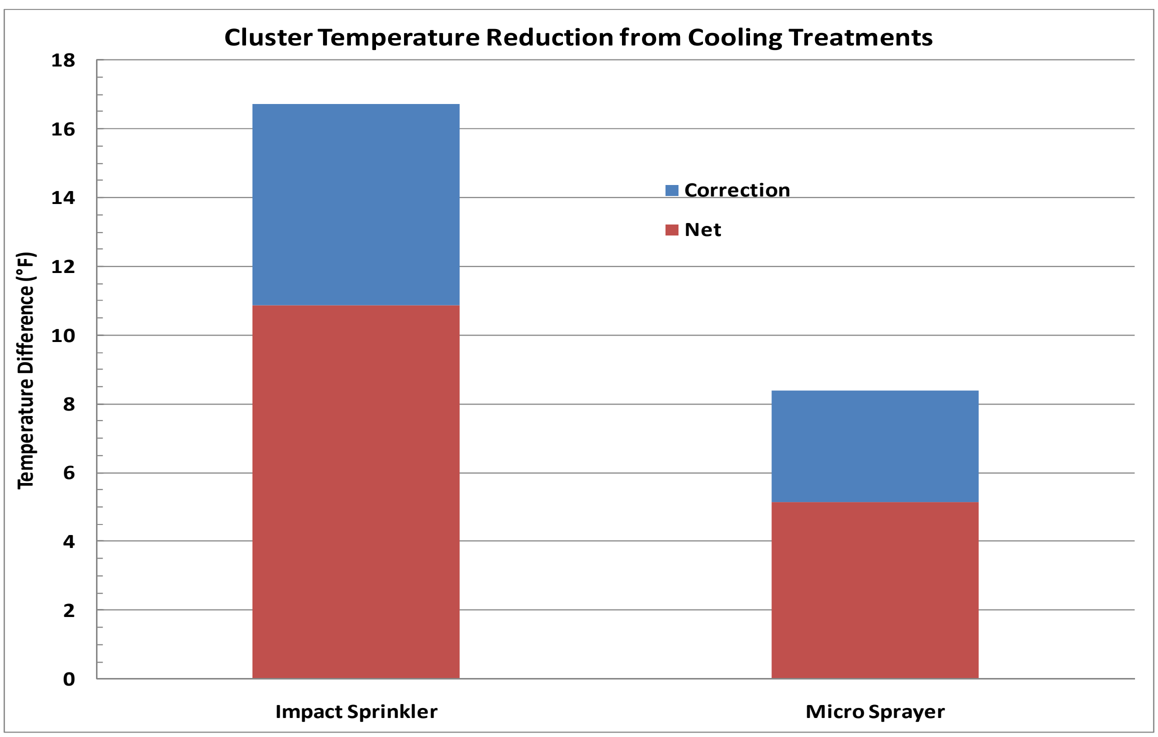


Figure 24: Average cluster temperature reduction, relative to the control, of the two cooling treatments. Corrections are shown for the natural temperature differences measured in the clusters under uncooled conditions.

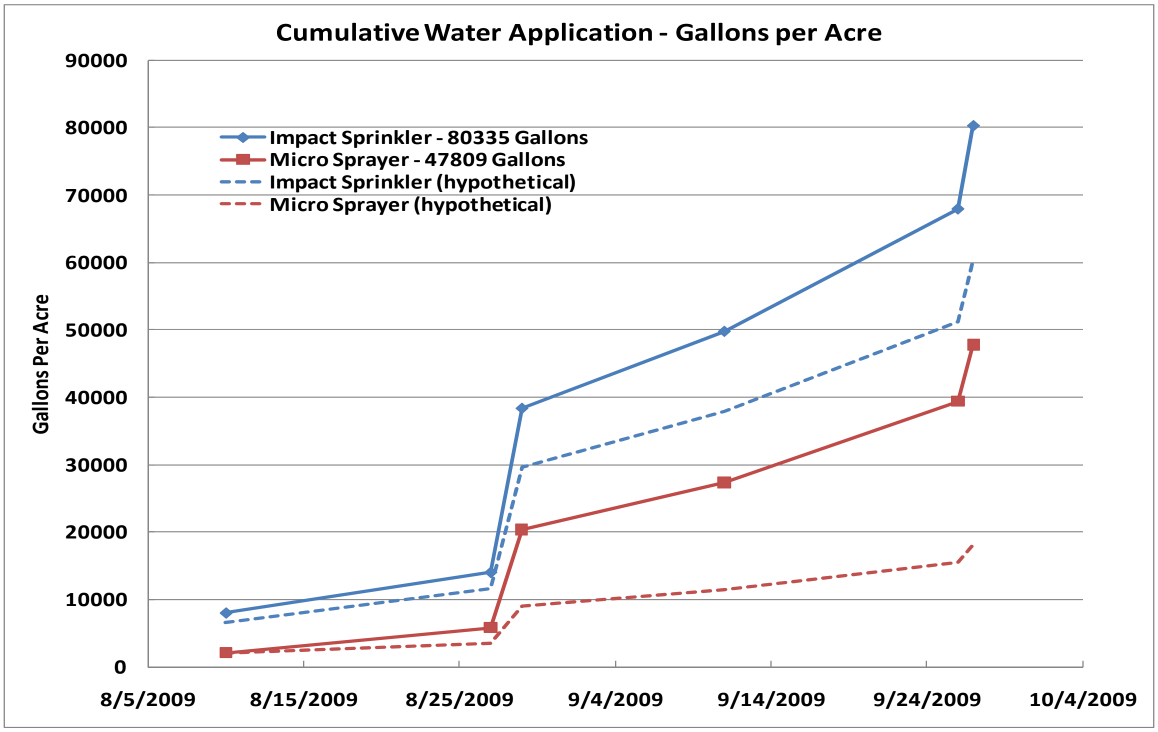


Figure 25: Cumulative water application volumes for the two cooling treatments. Theoretical levels (based on design parameters and hours of operation) are shown along with measured levels, which were much higher than theoretical.

Temperature sensors were also installed in three clusters within each of the cooling blocks to determine the effects on the clusters themselves (**Figure 23**). Because cluster temperatures varied considerably due to sensor placement, cluster size and density, etc., the average cluster temperature differences under non-cooled conditions were subtracted from the average measured values of fruit temperatures during cooling events (**Figure 24**). The impact sprinkler treatment cooled the clusters, on average, almost 11 degrees below the uncooled control while the micro sprayer treatment cooled the clusters 5 degrees below the control. While the micro spray treatment was less effective in cooling the clusters, in fact, the impact sprinkler cooling may have been excessive and more than was necessary to avoid fruit damage due to heat.

The measured volumes of water use differed considerably from that of the nominal theoretical values (**Figure 25**). For the impact sprinklers, flow from only one of the sprinkler devices was measured and the acreage rate computed by multiplying by the number of units per acre. There could have been error introduced by the limited sample size. It is possible that this was the case with the micro sprayers, but in that case one whole vine row was measured, comprising one-ninth of an acre, which would be much less prone to error. The likely cause for the discrepancy between theoretical and actual flow rate for the micro sprayer treatment was probably leaks in the system where the riser tubes were inserted into the drip hose, leaks from the emitters themselves and/or leaks caused by field operations. Whatever the case, it is probable that this system requires further engineering before being amenable to commercial implementation. Nevertheless, the micro sprayer system's water usage represented a 40% savings of water relative to the impact sprinkler's water usage.

Water Conservation

Water use from this demonstration can be summarized as follows (from six cooling events):

	Gal./Acre	In./Acre	$/Acre	kWh/Acre	lbs. CO_2/Acre
Impact Sprinklers	80,335	3.0	$22.63	127	201
Micro Sprayers	47,809	1.8	$13.47	76	119
	Net Savings per Acre (Relative to Impact Sprinklers)				
Micro Sprayers	32,526	1.2	$9.16	51	81
No Cooling	80,335	3	$23.63	127	201

The 2007 vineyard survey revealed that 13.8% of growers polled used overhead sprinklers to cool their vineyards during heat waves. Of an estimated 60,000 vineyard acres in the Russian River basin, that represents an estimated 8,280 of sprinkler-cooled vineyards. This represents the following potential savings across all vineyards:

	Acre-ft.	$	kWH	Tons CO_2
Micro Sprayers	827	$75,852	426,066	337
No Cooling	2,041	$187,346	1,052,329	831

Fruit Composition

There was not a strong, consistent effect of the cooling treatments on fruit composition. Much of the differences between treatments may have been due to relative levels of hydration, of which the uncooled control appeared to be slightly less than the cooled treatments (though fruit was still completely intact).

Brix (**Figure 26**) rose rapidly at the end of the season in the uncooled control treatment, while Brix of the remaining two treatments remained relatively unchanged and at low values. The pH of the uncooled treatment was lower than that of the cooled treatments (**Figure 27**). Titratable acidity tended to be higher in the mister (micro sprayer) treatment, though there is little reason that it should have (warmer fruit metabolizes malic acid more rapidly than cooler fruit) (**Figure 28**).

Also difficult to explain is the lower levels of polymeric anthocyanin (anthocyanin pigment bound to tannin molecules) in the micro sprayer treatment (**Figure 29**). Levels rose in the other two treatments in early October, but failed to do so in the micro sprayer treatment. Total anthocyanin pigment concentration was highest in the uncooled control (**Figure 30**), the treatment which was also highest in total tannins (**Figure 31**). Finally, fruit catechin, found mostly in the seeds and thought to be an indicator of ripeness, was highest in the uncooled control treatment (**Figure 32**).

Fruit compositional analysis was not very useful in determining whether or not there was any potential enological benefit from the cooling treatments. All-in-all, there was little to suggest than either of the two cooling treatments would benefit wine quality, though experimental wines would be the best means by which this could be determined.

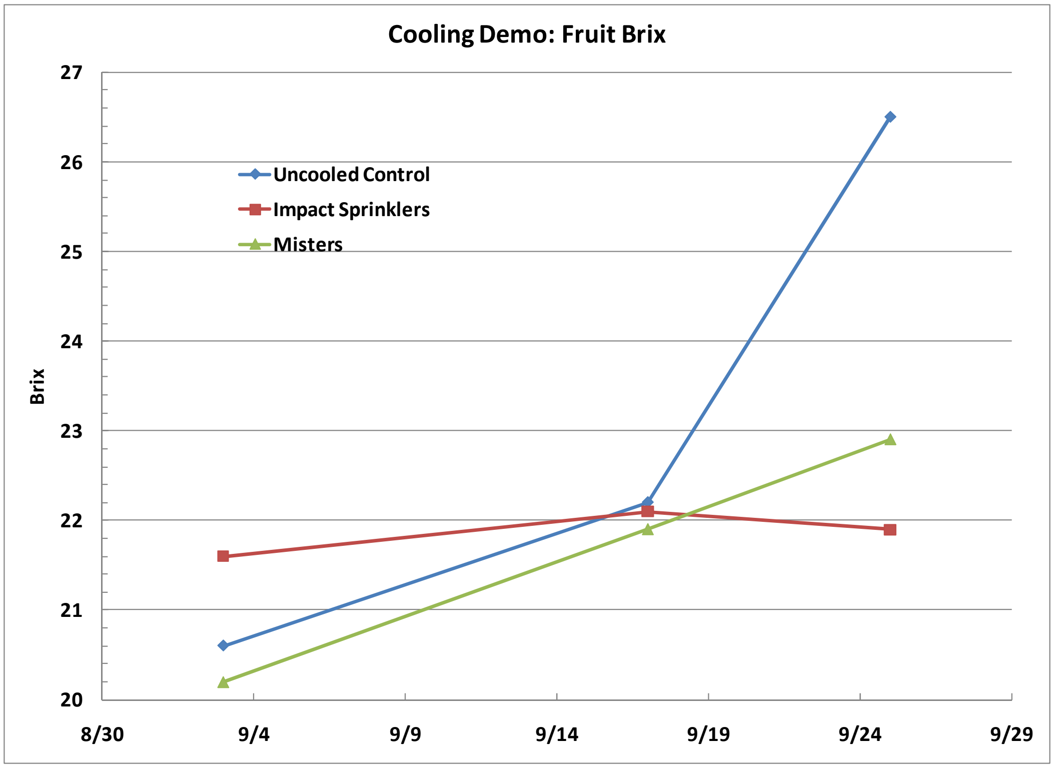


Figure 26: Brix (% soluble solids) of fruit at three sampling periods of time for the cooling demonstration project.

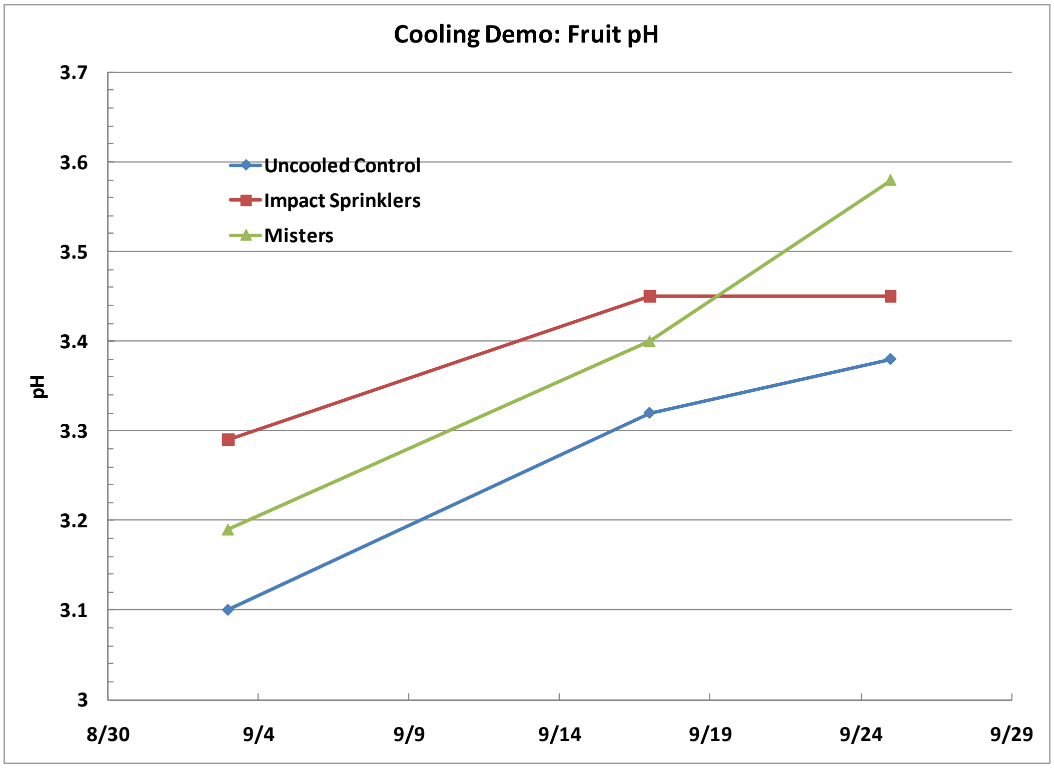


Figure 27: Fruit pH at three sampling periods of time for the cooling demonstration project.

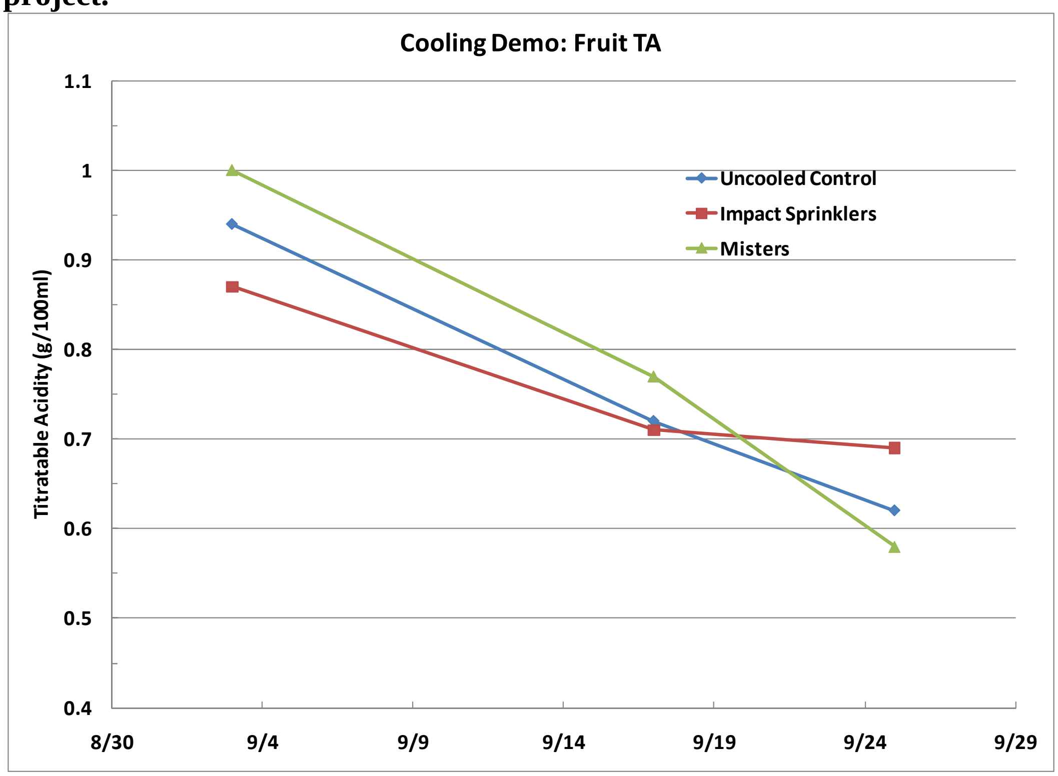


Figure 28: Titratable acidity of fruit at three sampling periods of time for the cooling demonstration project.

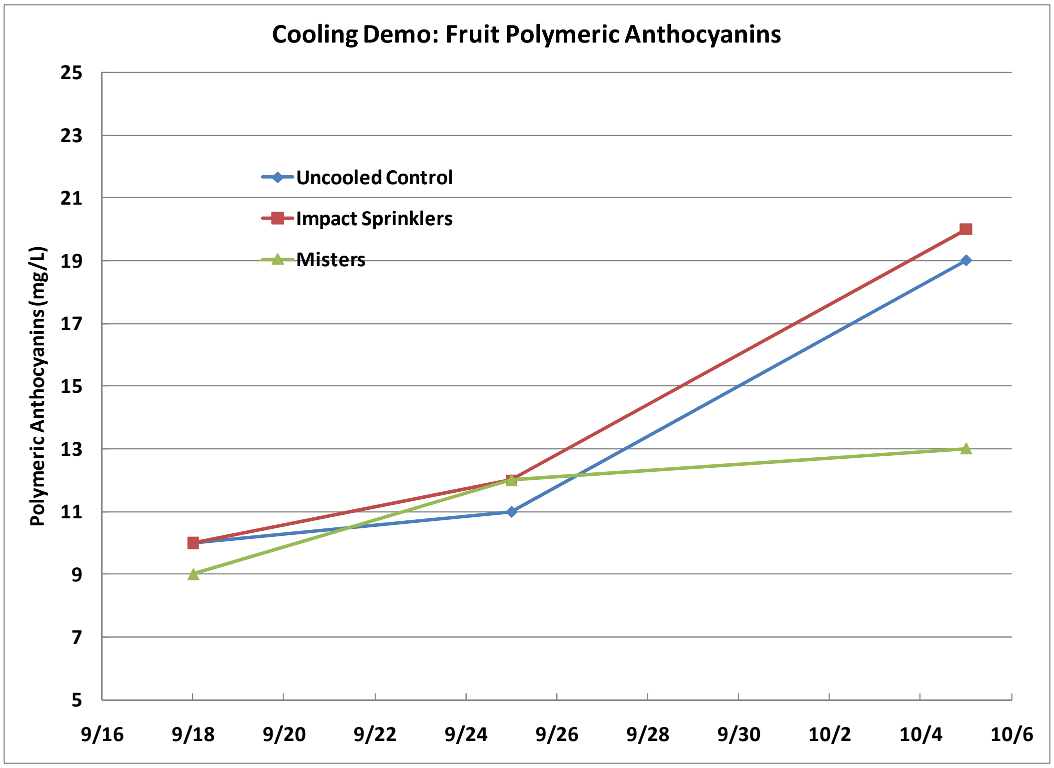


Figure 29: Polymeric anthocyanins (i.e. tannin-linked) of fruit at three sampling periods of time for the cooling demonstration project.

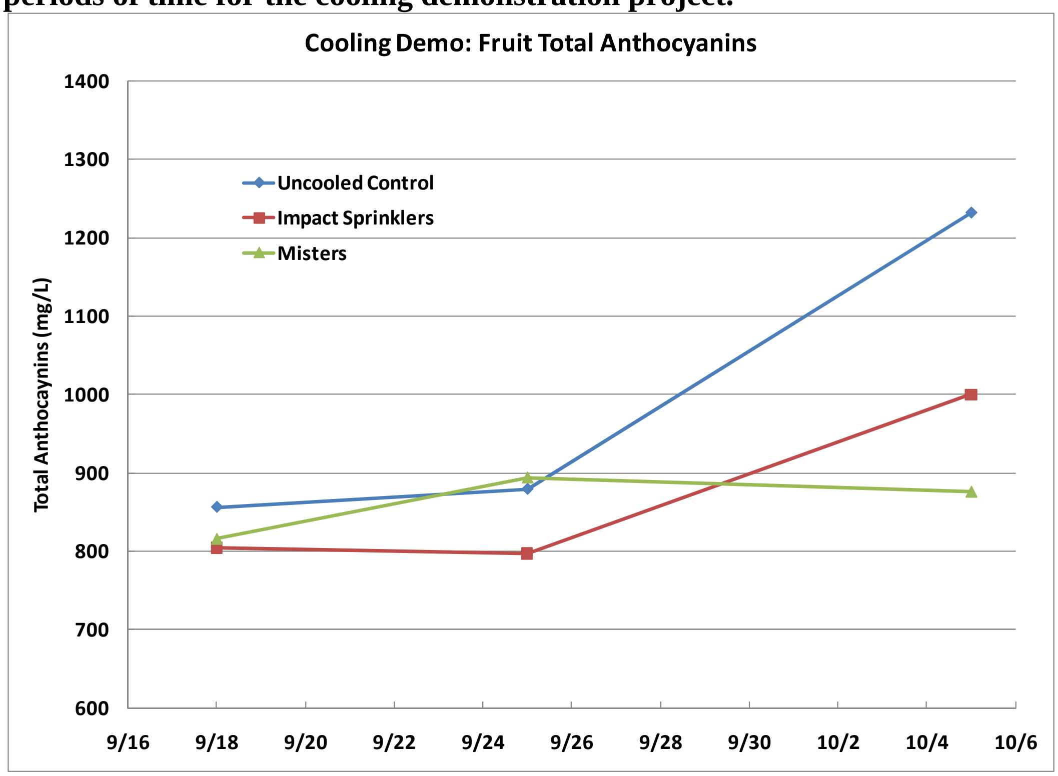


Figure 30: Total anthocyanins of fruit at three sampling periods of time for the cooling demonstration project.

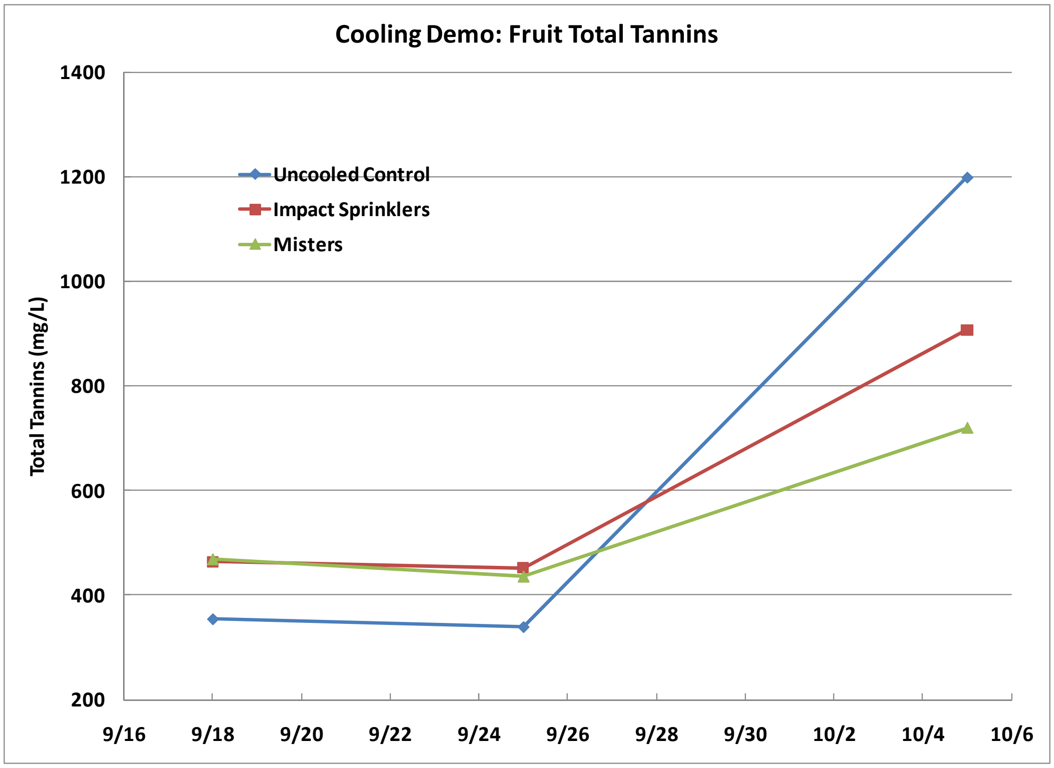


Figure 31: Total tannin of fruit at three sampling periods of time for the cooling demonstration project.

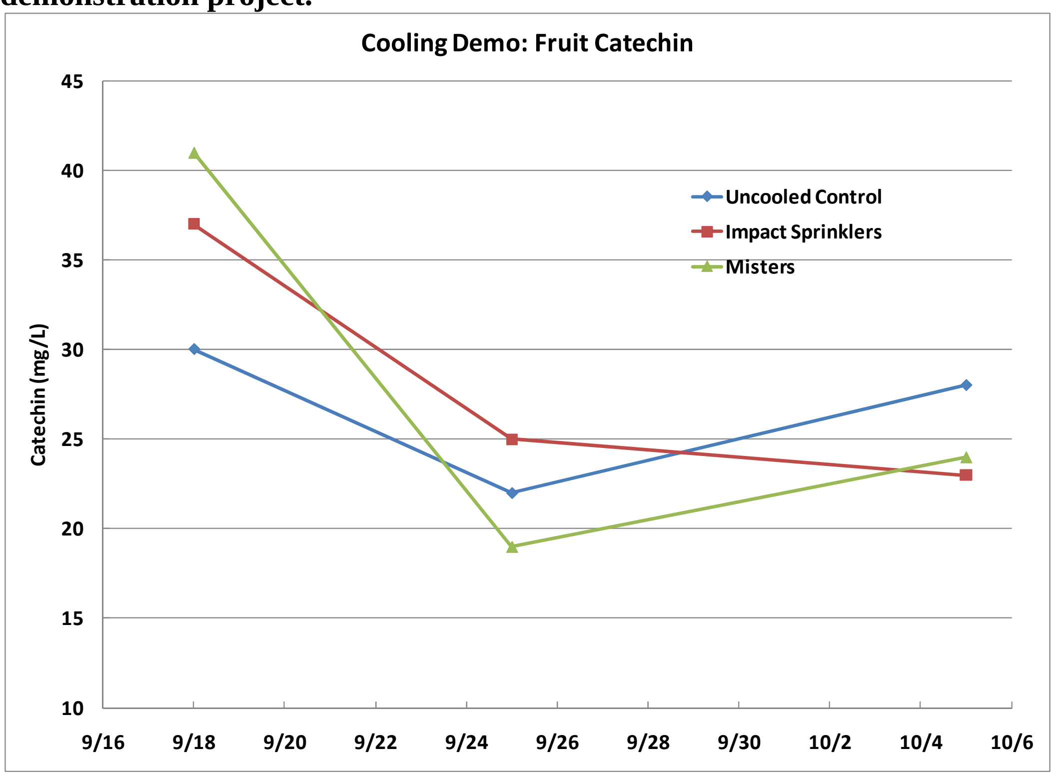
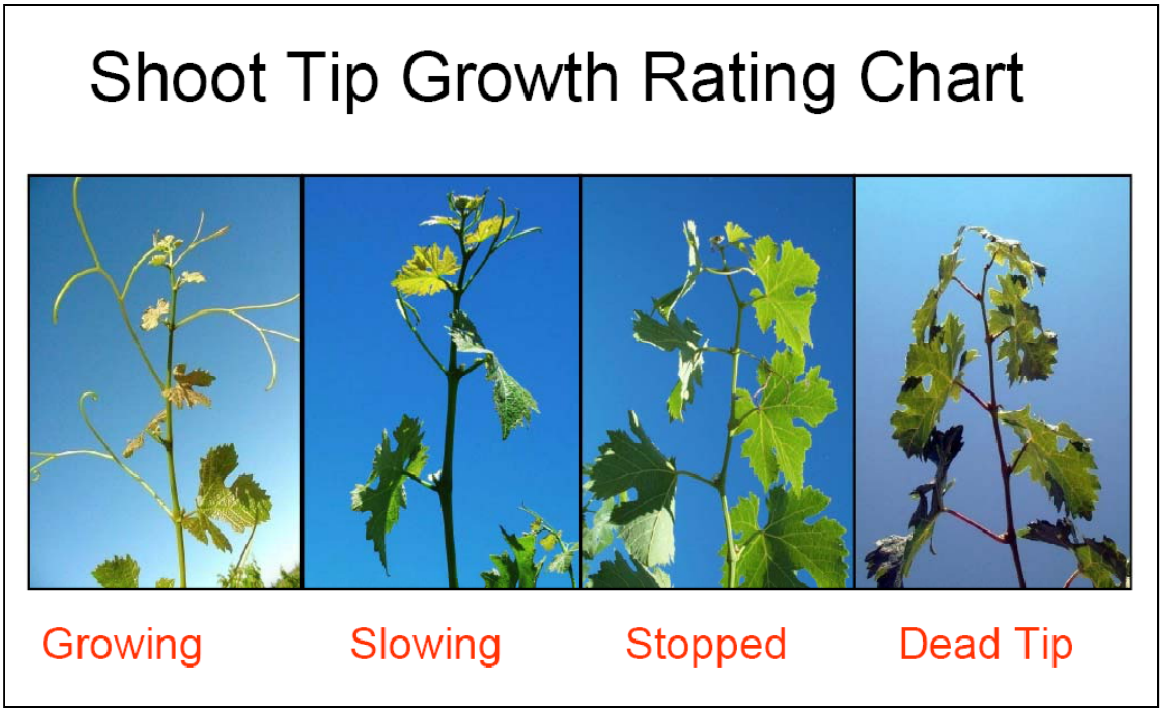


Figure 32: Catechin of fruit at three sampling periods of time for the cooling demonstration project.

APPENDIX:

Shoot Tip Rating Chart

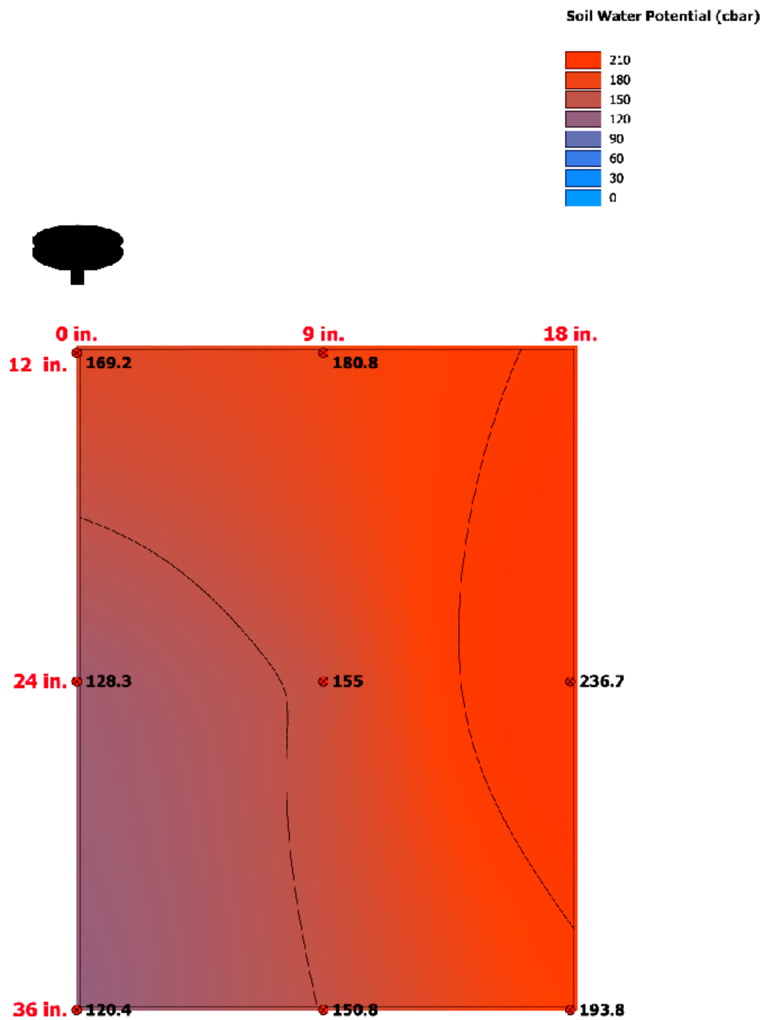


Shoot tip growth identification guide that was made available to the grower public at events and via Advanced Viticulture's website. Growers were advised to avoid commencing the irrigation cycle until shoot tips were either slowing or stopped.

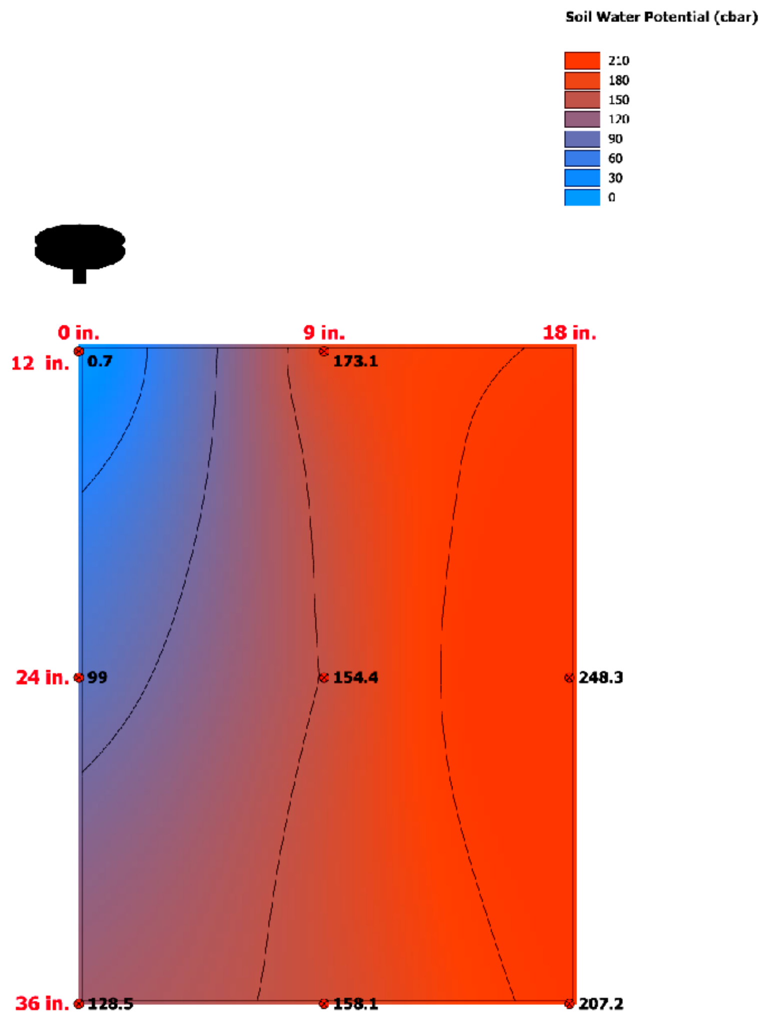
Soil Moisture Plume Examples

The following charts are examples of soil moisture plume patterns, as measured by a grid of soil matric potential sensors (Watermark) and spatially interpolated using a Kriging routine. The sensors were located at 1, 2 and 3 foot depths, at lateral distances of 0, 9 and 18 inches from the emitter drip zone. The 1 foot depth sensor was not included at 18 lateral inches since only 8 sensor ports were available. Note that lower values of soil matric potential indicate a higher water content (i.e. more easily-extractable water). The contours are at 50 cbar (50 kPa) intervals and are included for better visualization of the shape of the water plume.

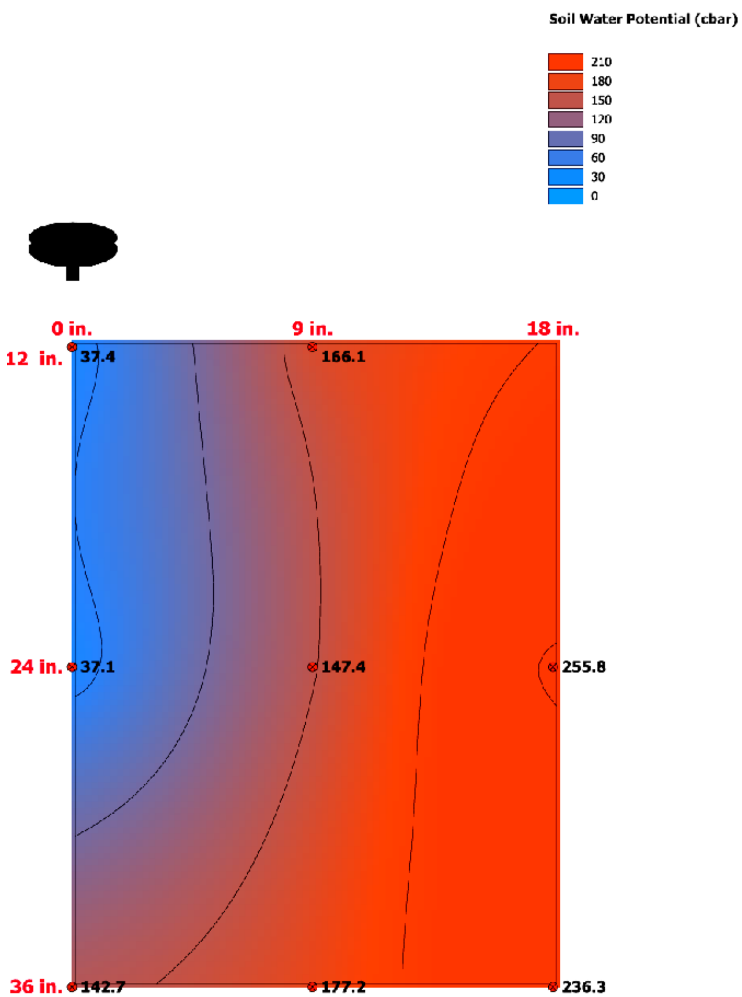
Note that the August 8 measurement preceded any irrigation applications.



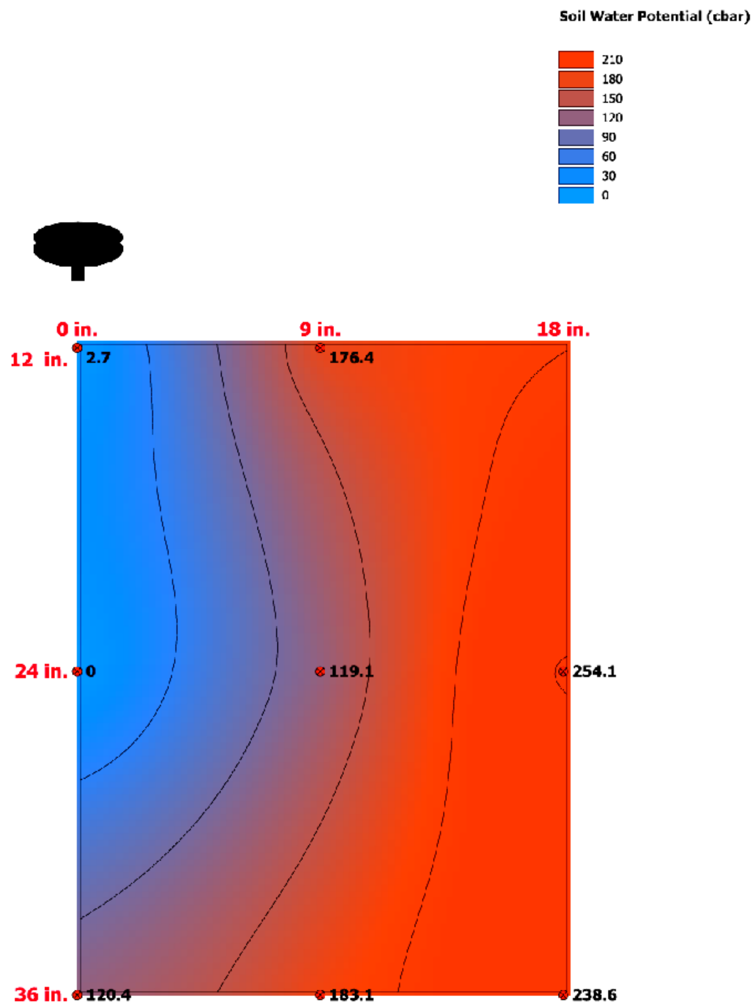
August 8



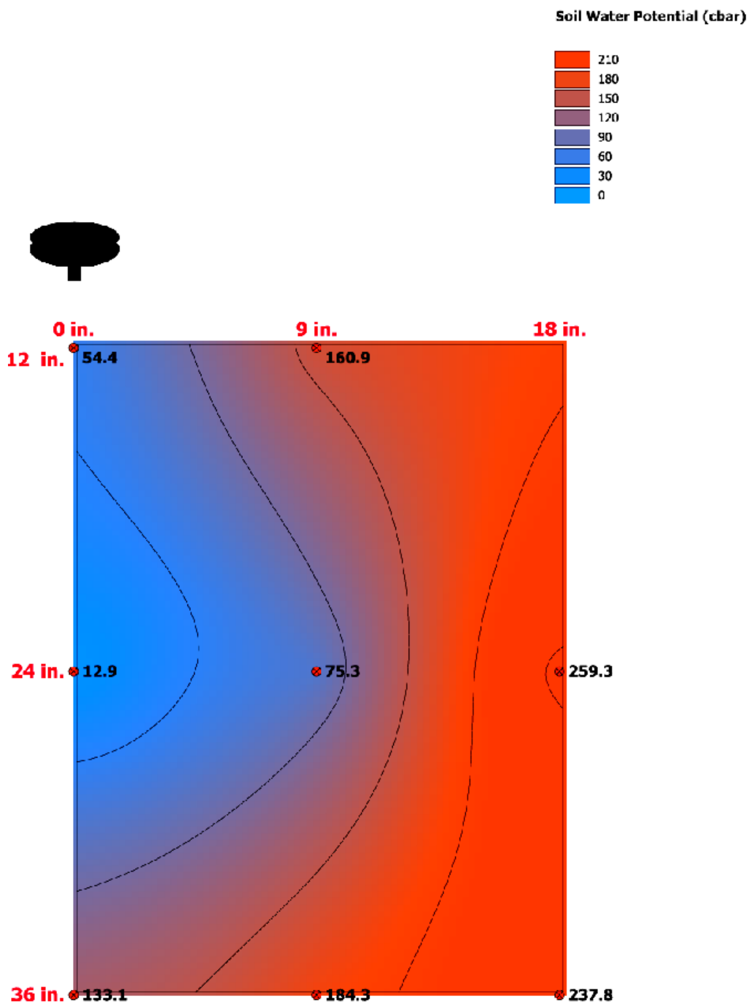
August 11



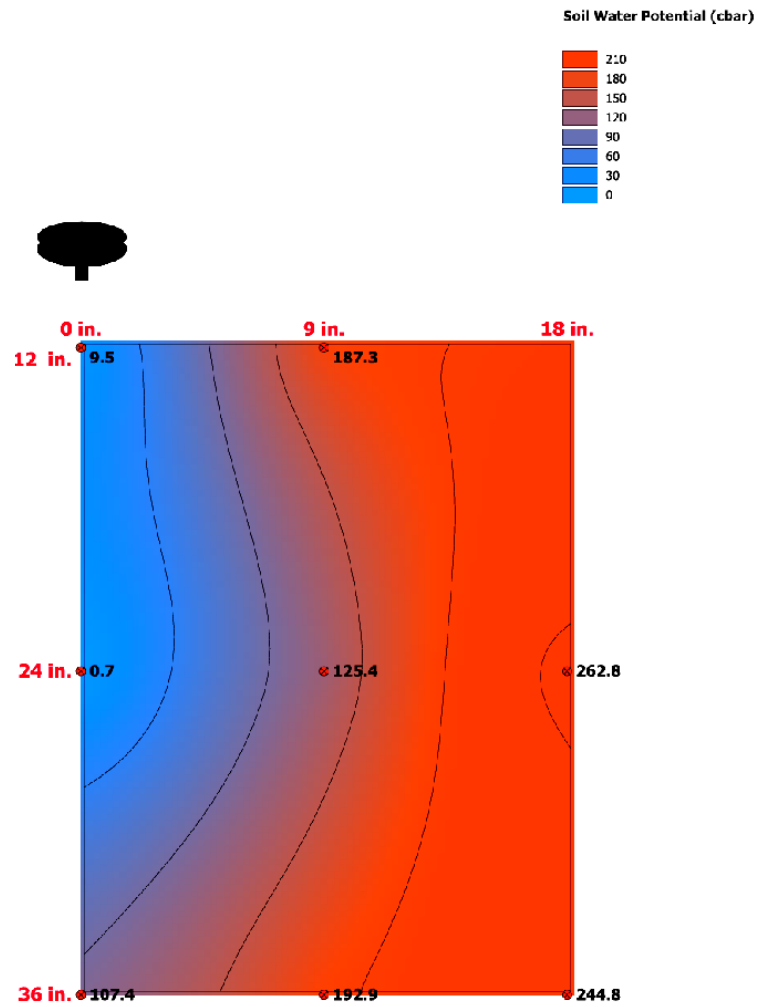
August 20



August 26 AM



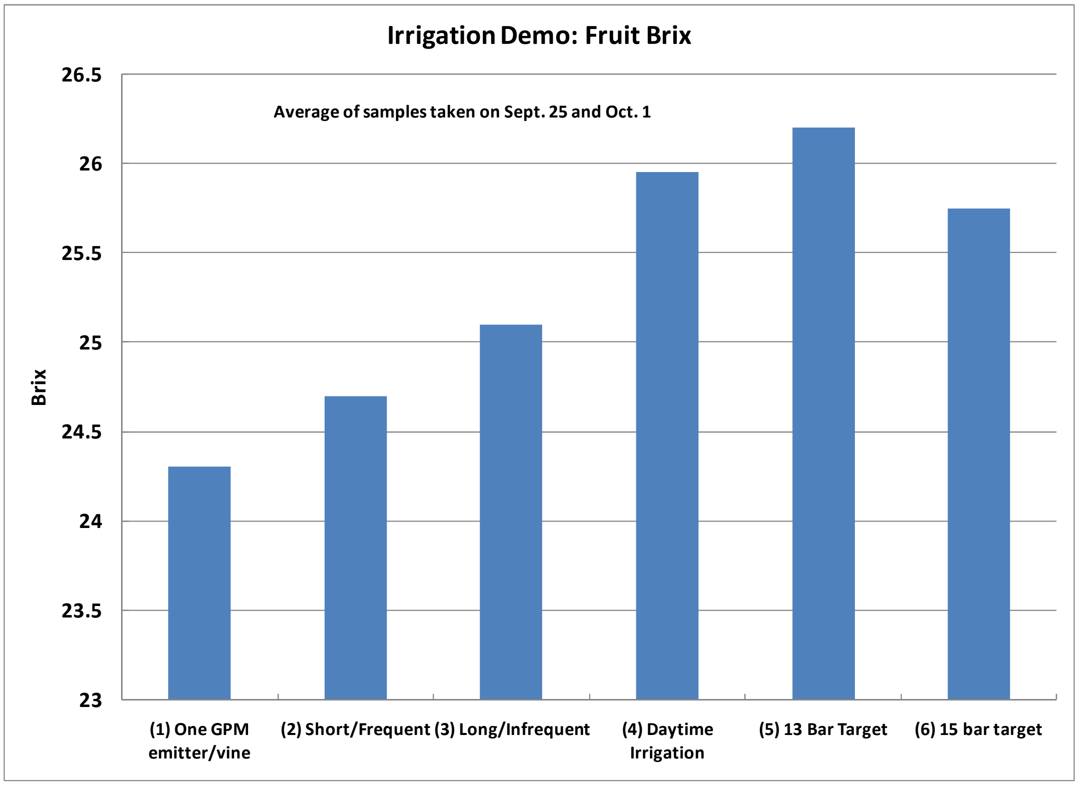
August 28 AM

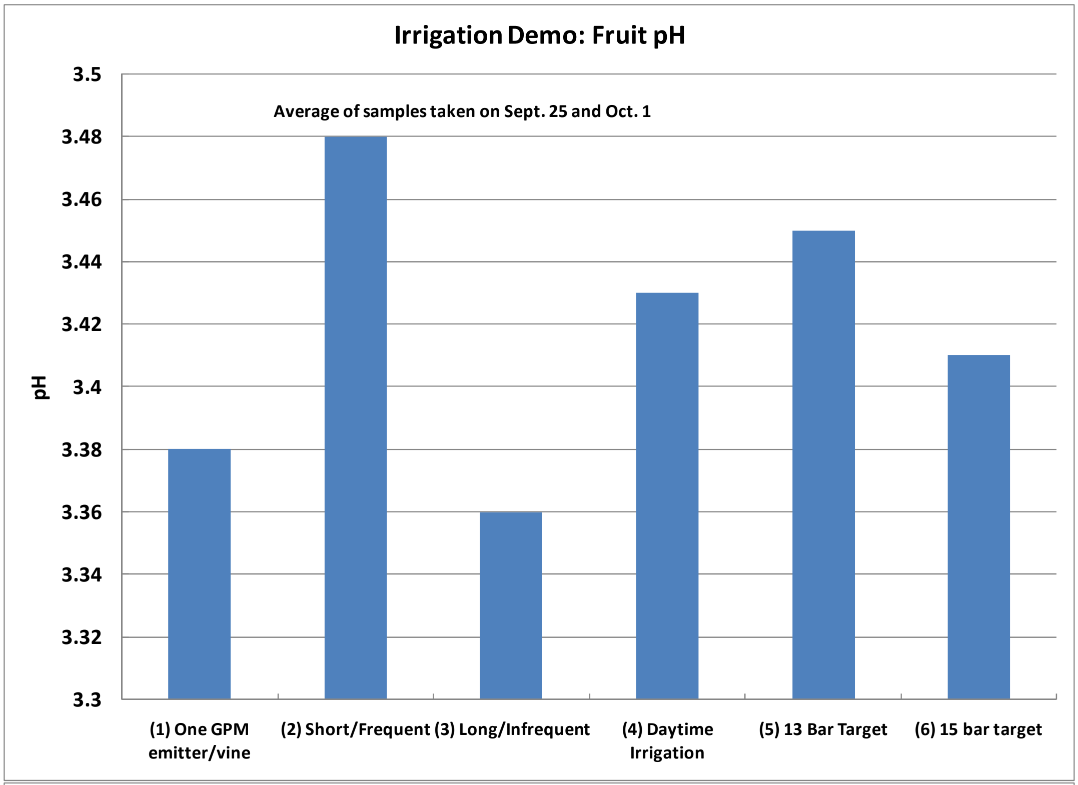


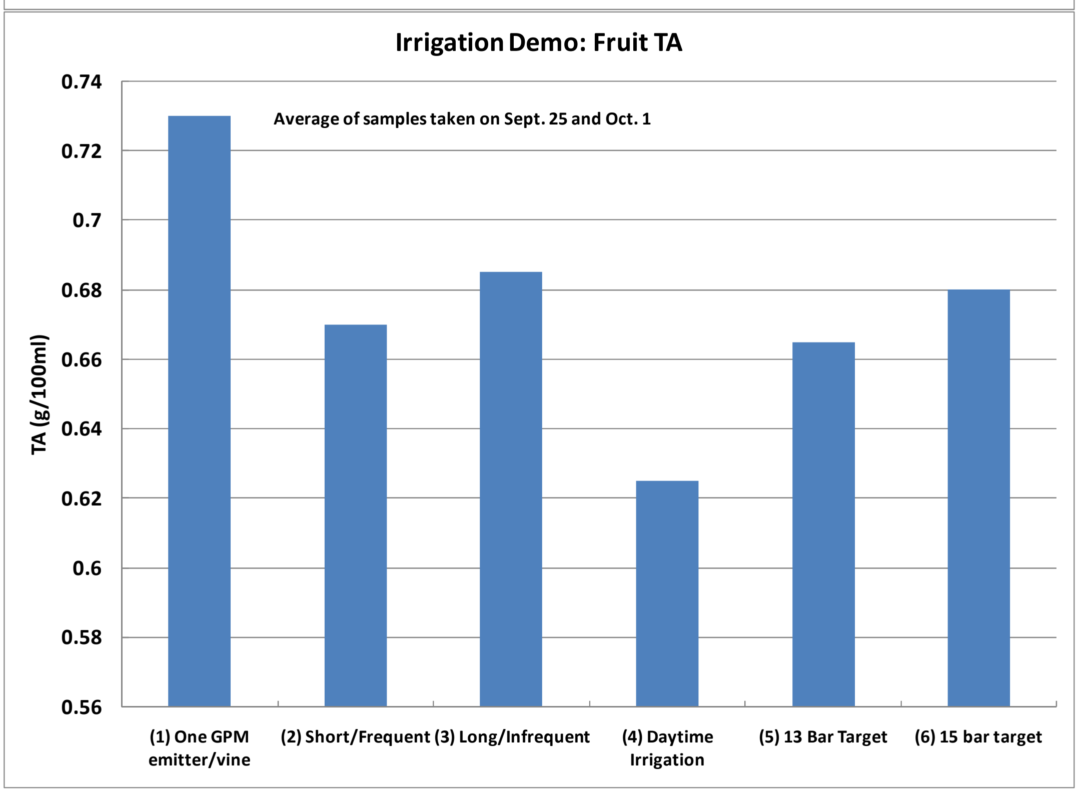
September 4

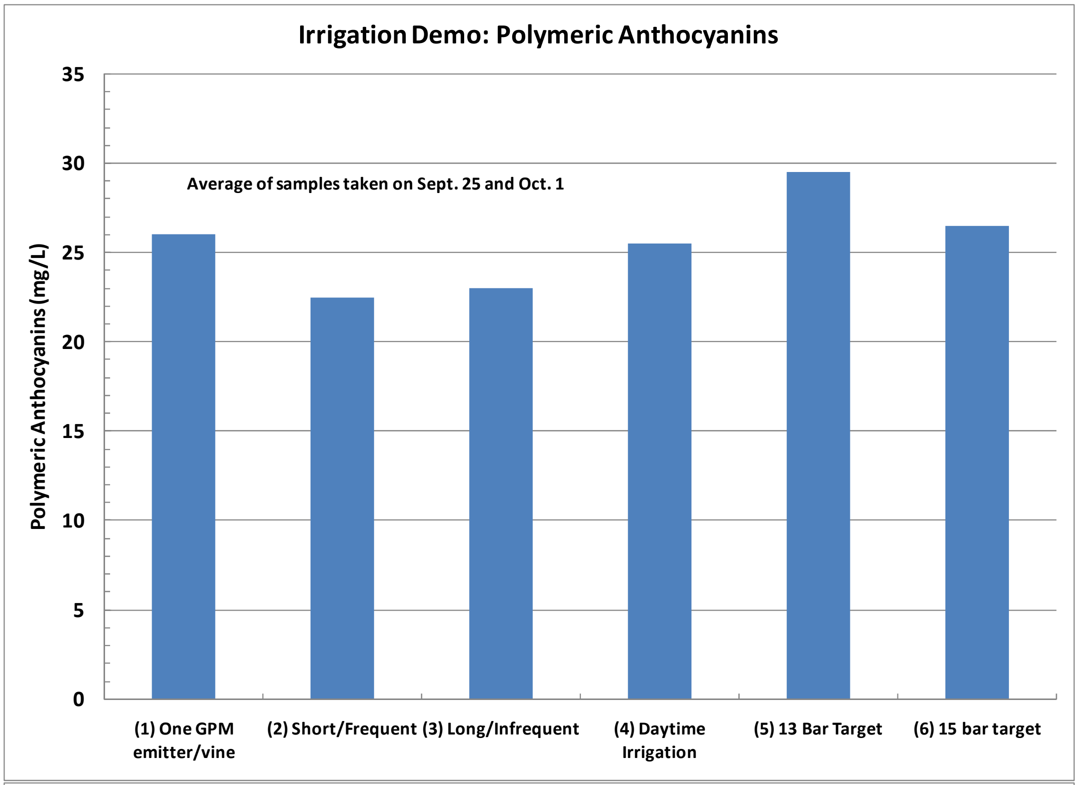
Fruit Chemistry Plots from Irrigation Demonstration

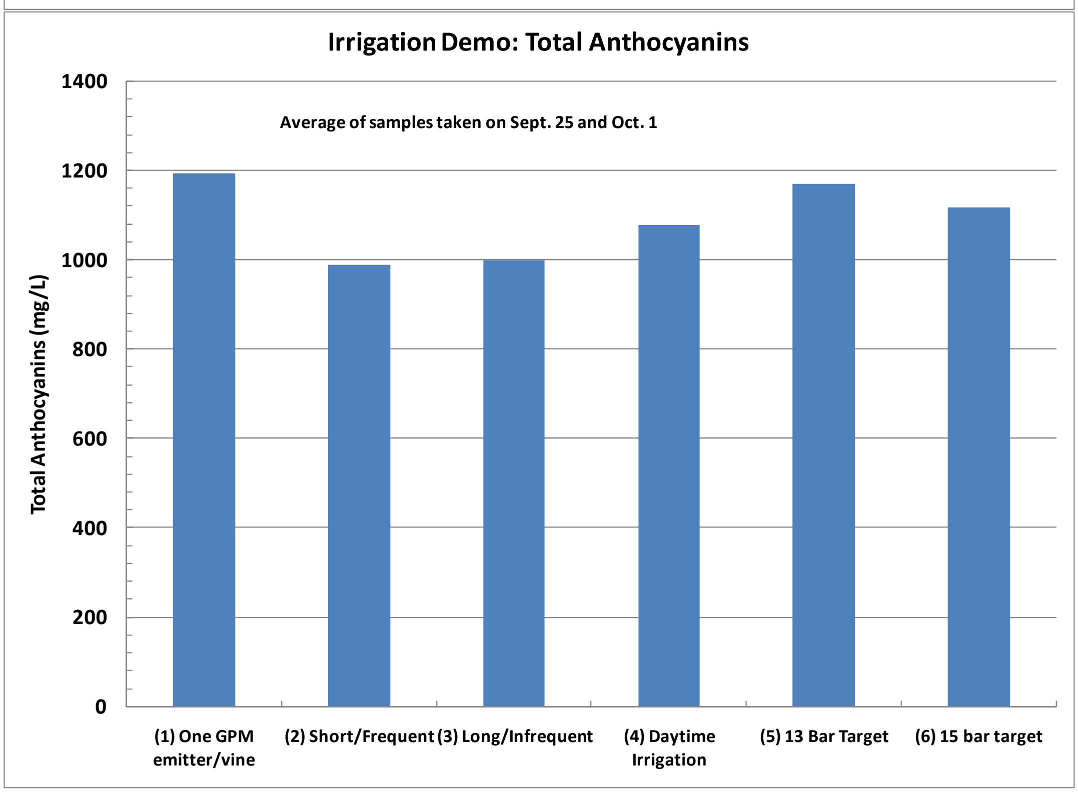
These plots are included here for reference, though there were no apparent lessons learned from these measurements.

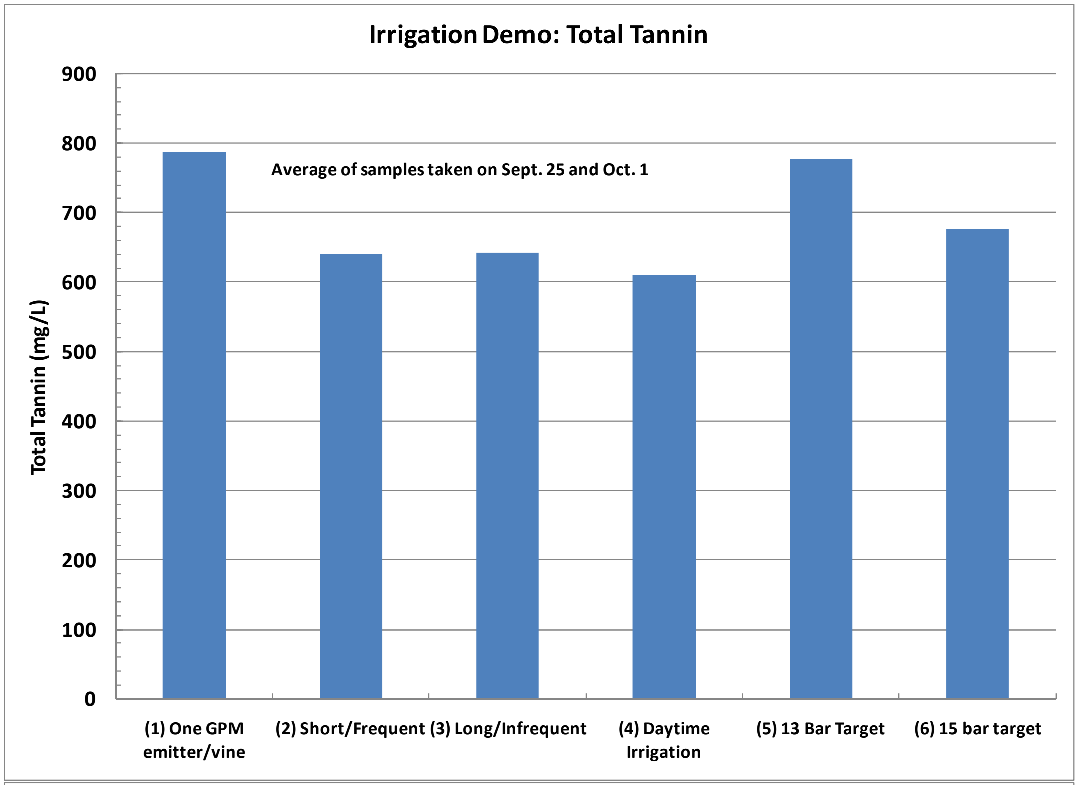


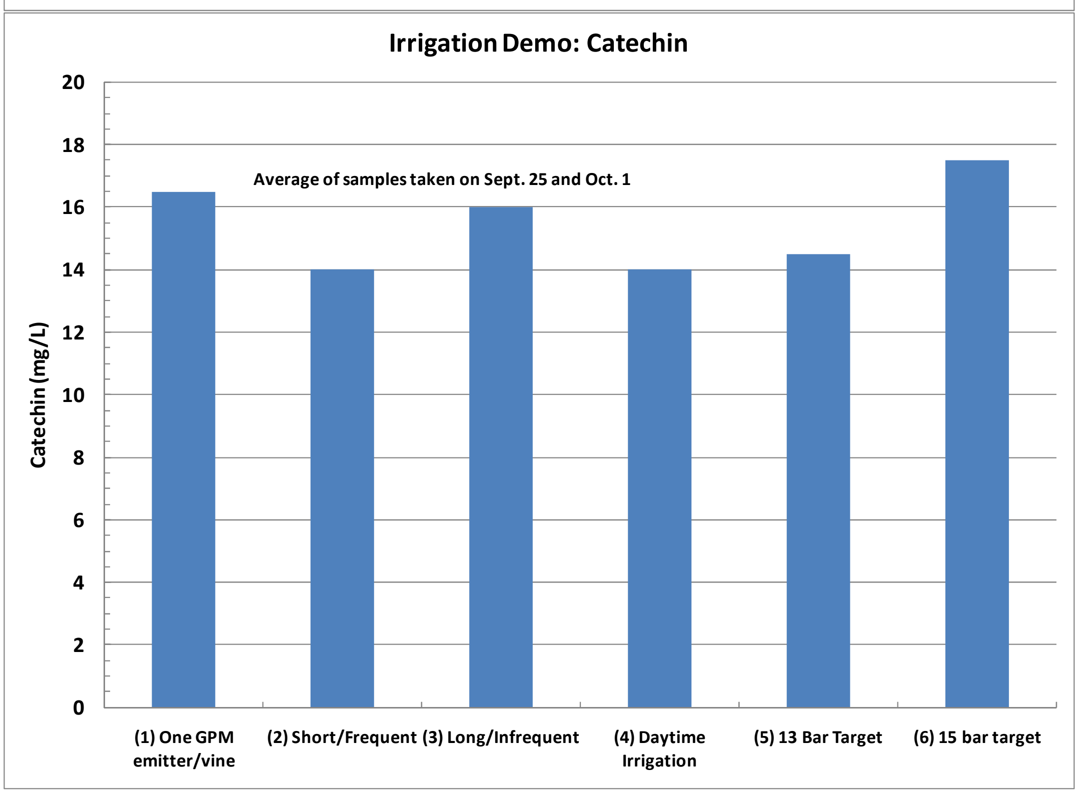

Irrigation Demo: Fruit pH
Average of samples taken on Sept. 25 and Oct. 1
pH
3.5
3.48
3.46
3.44
3.42
3.4
3.38
3.36
3.34
3.32
3.3
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target


Irrigation Demo: Fruit TA
Average of samples taken on Sept. 25 and Oct. 1
TA (g/100ml)
0.74
0.72
0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target


Irrigation Demo: Polymeric Anthocyanins
Average of samples taken on Sept. 25 and Oct. 1
Polymeric Anthocyanins (mg/L)
35
30
25
20
15
10
5
0
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target


Irrigation Demo: Total Anthocyanins
Average of samples taken on Sept. 25 and Oct. 1
Total Anthocyanins (mg/L)
1400
1200
1000
800
600
400
200
0
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target


Irrigation Demo: Total Tannin
Average of samples taken on Sept. 25 and Oct. 1
Total Tannin (mg/L)
900
800
700
600
500
400
300
200
100
0
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target


Irrigation Demo: Catechin
Average of samples taken on Sept. 25 and Oct. 1
Catechin (mg/L)
20
18
16
14
12
10
8
6
4
2
0
(1) One GPM emitter/vine
(2) Short/Frequent
(3) Long/Infrequent
(4) Daytime Irrigation
(5) 13 Bar Target
(6) 15 bar target

North Coast Vineyard Water Management: Best Management Practices

- **Reduce irrigation water usage**
  - **Irrigation avoidance:**
    - Don't start to irrigate too early in the season (wait until shoots stop growing before irrigating – assuming that shoots reach proper length before stopping)
    - Manage cover crop to minimize its competition (closely mowing is best option); disk in if absolutely necessary to maximize water conservation
    - **Limit use of overhead sprinklers for cooling:**
      - Leave some leaves and laterals to protect fruit from direct sunlight.
      - Leave one side of VSP loose to shade fruit.
      - North or northeast row orientations are less sensitive to heat stress than east-west oriented rows.
      - Limit or eliminate late-season sulfur and horticultural oil applications – these materials promote leaf and fruit burn during hot weather.
      - Increase trigger temperature for start-up of system.
      - Apply overhead sprinklers in pulses. Allow for evaporation between cycles. Less than 50% duty cycle should be effective.
      - Reduce system pressure for this purpose. Use just enough pressure to get sprinklers to turn.
      - Install a system of low-volume "misting-type" spray heads, instead of impact sprinklers.
  - **Irrigation reduction:**
    - Smaller vines use less water – leaf area transpires water. Begin irrigation later in the season and hedge vines to constrain canopy.
    - Restrain the use of nitrogen fertilizers that induce vegetative growth of vines
    - In most cases, short & frequent drip irrigation is much better than large, infrequent applications – may allow for less overall water application.
    - Install additional drip tubes to selectively irrigate weaker zones in the vineyard earlier in the season without irrigating the entire vineyard block.
    - As above, install a second drip tube to irrigate soil zones with lower total available water holding capacity on a more frequent basis than zones with higher total available water holding capacity.
    - Use soil moisture devices in weakest soils of each block to discover how long irrigation may be applied before water is wasted (i.e. moving past root zone). Soil moisture devices can also help to

determine length of intervals between applications, by observing the drying pattern.
- Employ a moderate deficit irrigation program while monitoring soil and/or vine water status. Vine water status monitoring (using a pressure chamber or Porometer) is highly desirable, since soil moisture instruments are not easily calibrated.
- **Reduce post-harvest irrigation:**
  - Refrain from using overhead sprinklers for irrigation of vines.
  - Use drip irrigation for post-harvest fertigation and irrigation of the vines.
  - Vine irrigation is not necessary if vines are in senescence. Irrigate only if leaves are green following harvest. Some fertilizers (e.g. potassium and micronutrients) may be applied if vines are not active, but do not apply nitrogen if vines are senescing.
  - Use overhead irrigation only for shallow irrigation of cover crop seeds. Consult local farm advisor for best practices for cover crops.
  - Use permanent (self re-seeding or perennial) cover crop to avoid re-seeding every fall.

- **Improve system and irrigation efficiency:**
  - Perform frequent (at least once per week) and repetitive inspections of drip laterals and emitters, valves, filters, etc. Look for leaks in the system. Repair any leaks immediately.
  - Perform system uniformity evaluations at least once per season using timed collection of water output in catch cans. Less than 65% uniformity triggers system flush.
  - Reduce height of drip emitters where possible to reduce evaporative losses from splashing.
  - Apply mulch under the vines (or under drip emitters) to reduce surface evaporation – use caution with mulch cover, however, if voles are a potential pest problem
  - Nighttime irrigation is more efficient than daytime irrigation.
  - Apply short and frequent irrigation applications (as mentioned above).
  - Monitoring vine water status will allow for decisions regarding whether improved efficiency will allow for an overall reduction in irrigation volume.

- **Perform rotational (nighttime) pumping:**
  - Pump during the night, when water demand on the river is at its lowest.
  - Recharge ponds at nighttime or irrigate at night, if direct feed.
  - Rotate with neighbor growers or within your own vineyard blocks.

- Electric pumps: Install time-of-use meter to significantly save PG&E costs.

July 9 Field Day Attendance

Registration for Water Conservation Field Day			
Thursday, July 09, 2009			
Hoot Owl Creek and Alexander Valley Vineyards			
8595 Hwy 128, Healdsburg			11:00 a.m.- 2:00 p.m.
Total attendance = 100			signed up = 79
attended	LAST NAME	FIRST NAME	VINEYARD / WINERY
1	Azevdeo	John	Kendall-Jackson
1	Azevdeo	Armon	Wilbur-Ellis
1	Bailey	Mark	Vineyard consultant
1	Bernier	Paul	Bernier Zinyards
1	Bialla	Paull	Bialla Vineyard
	Boller	Robert	Jackson Family Wines
1	Bowen	Chris	grower
1	Breyer	Laura	Breyer Vineyard IPM Services
1	Burney	Robert	Sunbreak Vineyard Services
1	Burns	Pat	Bevill Vineyard Management
1	Cantor	Sierra	Sotoyome RCD
1	Carvajal	Arturo	NRCS Water Mgmt Engineer
1	Cassidy	Ann	Advanced Viticulture
1	Collin	Dave	Stuhlmuller Vineyards
1	Crabb	Tony	Puma Springs Vineyard
1	Cuthbert	Cody	Clendened Vineyard Management
1	Darden	Anna	Darden Vineyards
1	Dennison	Karen	Constellation Wines
1	Duckett	John	Jordan Winery
1	Elliott	Deborah	Water Resources Specialist-Napa County
1	Epifanio	Charlotte	NRCS - Petaluma Field Office
1	Estines	Gilles	grower
1	Euphrat	Fred	Principal Consultant, Joint Comm. Fisheries/Aquaculture, Pat Wiggins, chair
1	Fisher	Greg	Sotoyome RCD
1	Flores	Ed	Fedco Construction - Ecology Compliance Manager
1	Folger	Clinton	Green Pastures Valley, LLC
1	Francis	Bill	Wilbur-Ellis
1	Frey	Nick	SCWC
1	Gabor	Jenny	NRCS - Petaluma Field Office
1	Gelly	Mark	VITEC
1	Giusso	Tony	Giusso Vineyards
1	Giusso	Gary	Giusso Vineyards

1	Grasseschi	Barbara	Puma Springs Vineyard
1	Greenspan	Mark	Advanced Viticulture
1	Gunsalus	Pamela	Gunsalus Vineyard
1	Gunsalus	Glen	Gunsalus Vineyard
1	Hagstrom	Steve	
1	Haran	Michael	Haran Vineyard
1	Hasebe	Kunio	SRJC Student
1	Hatten	Lyle	Hatten Vineyards
1	Hatten	Lyle	Hatten Vineyards
	Heck	Brittany	Gold Ridge RCD
	Heckert	Kara	Sotoyome RCD
1	Henson	Sandi	Jackson Family Wines
1	Herrick	Greg	Herrick Vines
1	Herrick	Lorri	Herrick Vines
1	Holler	Mark	Camalie Networks
1	Houser	Mark	HOC / AVV
1	Hussey	Chuck	Chalk's Bend Vineyard
1	Ivaldi	Dan	Wilbur-Ellis
1	Johnson	Noelle	Gold Ridge RCD
1	Jones	Chuck	Hawk's Roost Vineyard
	Keenan	Dick	grower
1	Kelly	Mark	Consultant
1	Kelly	Paul	SC Supervisor
1	Kenworthy	Diane	Sunbreak Vineyard Services
1	Kerschner	MaryAnn	MAJIK Vineyards
1	Kerschner	Jim	MAJIK Vineyards
1	Kiger	John	Kiger Vineyard
1	King	James	Clendened Vineyard Management
1	King	MaryAnn	Trout Unlimited
	?		Trout Unlimited
	?		Trout Unlimited
1	Koplen	Dennis	Koplen Vineyard
1	Koplen	Linda	Koplen Vineyard
1	Lamborn	Matt	Pacific Geodata
1	Lentz	Susan	Polesky-Lentz Vineyard
	Leras	Nick	Leras Vineyard
	Lingenfelder	Mark	Chalk Hill Vineyard
	London	Chris	Spring Hill Ranch & Vineyard
	London	Karen	Spring Hill Ranch & Vineyard
1	Maffei	Joanne	Maffei Vineyard
1	Marca	Dan	from Oregon
1	Marca	Danielle	from Oregon
1	McKenna	Pat	McKenna Vineyards
1	Meek	Gerald	Meek Vineyard
1	Miller	Stephen	
1	Monson	Dwight	Monson Vineyards

	Morison	Ames	Medlock-Ames Winery
1	Munselle	Brett	Wasson Vineyards
	Munselle	Bill	Wasson Vineyards
1	Neely	Mark	NCRWQCB
	Pasterick	Gerry	Vineyard of Pasterick
1	Polesky	Herb	Polesky-Lentz Vineyard
1	Porter	Mike	Mike Porter Vineyard Construction, Inc.
1	Potter	Maria	Sotoyome RCD
1	Pusich	Bob	Pusich Vineyards
1	Roth	Tom	Lynn Woosley Rep
1	Rowan	Mary Calla	Wine Creek Vineyards/Constellation Wines
1	Salisbury	Bob	R.F.S Vineyards
1	Salisbury	Mark	R.F.S Vineyards
	Salomone	Jim	PG & E
	Santiago	Augustin	Medlock-Ames Winery
1	Sherron	Valerie	Sotoyome RCD
1	Sherwood	Brad	SC Water Agency
1	Smith	Rhonda	UCCE
1	Speigal	Sherri	NRCS
1	Stadnik	Ruth	Green Pastures Valley, LLC
1	Tevendale	William	
1	Tollini	Joe	Bevill Vineyard Management
1	Tuhtan	Judy	SCWC
1	Vivas	Juan	Giusso Vineyards
1	Vogenson	Matt	Bevill Vineyard Management
1	Wagner	Wells	Sylvan Hills Vineyard
1	Wallace	Don	Photographer
	Wasson	Carolyn	
1	Weller	Nelson	Longview Vineyard
1	Yoa	John	UCCE
1	Young	Brent	Jordan Vineyards
1	Young	Chris	Vino Farms
1	Press Democrat	Photograper	
1	Another	Photographer	
4	Staff	HOC/AVV	

August 12 Field Day Attendance

Registration for Water Conservation Field Day			
August 12, 2009			
Hoot Owl Creek and Alexander Valley Vineyards			
8595 Hwy 128, Healdsburg			11:00 a.m.- 2:00 p.m.
Total attendance =	96		signed up = 94
attended	LAST NAME	FIRST NAME	VINEYARD / WINERY
	Anderson	Bob	United Winegrowers
	Arroyo	Noelle	Viluko Vineyards
	Arroyo	Karen	Viluko Vineyards
	Aston	Darcy	FishNet 4C Program Director
	Baker	Ginger	SCWC
	Bazzano	Phil	Bazzano Vineyard
	Browde	Joe	CSWA
	Butler	Bob	Butler & Slazinksy Vineyard
	Cadd	Larry	Cadd Ranch
	Caravajal	Arturo	NRCS
	Charles	Bea	Vineyard Owner
	Charles	Mike	Vineyard Owner
	Chavez	Stan	Mariposa Vineyard
	Cianfichi	Domenic	Garton Tractor
	Cole	Brooke	NRCS
	Cummings	Earle	
	Cuneo	Jim	Robert Young Vineyards
	Desmond	Larry	Mendocino Waterworks
	Edwards	Brent	Pacific Geodata
	Ellis	Sandy	Farm Bureau - Napa
	Estrella	Juanita	EDD
	Fanucchi	David	Fanucchi Ranch
	Foppiano	Allan	Foppiano
	Freese	Phil	Winegrow
	Frey	Nick	SCWC
	Gibson	Terry	Ross Station Vineyards
	Goepfrich	Raymond	Gopfrich Vineyard and Winery
	Greenspan	Mark	Advanced Viticulture
	Hagstrom	Steve	
	Handal	Dick	Handal Family Vineyards
	Hansen	Tony	Blu Skye Sustainability Consulting
	Hasebe	Kunio	SRJC Student
	Hinch	Steve	friend of Kuneo Hasebe
	Haydon	Susan	RCD
	Heintz	Deanna	Diageo
	Heton	Todd	Frias Family Vineyard
	Frias	Fernando	Frias Family Vineyard
	Holler	Mark	Camalie Networks

	Houser	Mark	HOCV
	Howe	David	Ranch Systems
	Howell	Rich	Quality Shoots
	Huebel	David	Saracina Vineyards
	Johnson	Steve	Jain Irrigation
	Joseph Jr.	Edmond	Chateau Joseph
	Joseph Sr	Edmond	Chateau Joseph
	Kowalski	Karl	Egret Farms
	Lahborn	Matt	Pacific Geodata
	Larrick	Rod	Larrick Vineyards
	Lyon	Jeff	Gallo Family Winery
	Manning	David	Sonoma County Water Agency
	McKamey	Matt	Premier Pacific Vineyards
	McLaughlin	Art	Ray Carlson & Associates
	Meisler	Trisha	Sotoyome RCD
	Miller	Richard	
	Monson	Dwight	Monson Vineyards
	Monson	Alex	
	Morriello	Debbie	SRJC Student
	Nagle	John	Gallo Family Winery
	Noren	Ken	Vintage Nurseries
	Purdom	Jody	Wine Business Monthly Magazine
	Raggio	Nora	Bluxome Vineyard
	Reuling	Jackie	Reuling Vineyards
	Reuling	Tim	Reuling Vineyards
	Reynolds	Ann	Advanced Viticulture
	Roberts	Rose	Farm Stewards
	Robinson	Zac	Husch Vineyards
	Robledo	Sal	Redwood Ranch
	Rotlisberger	Dan	Redwood Empire Vineyard Management
	Russell	Bette	
	Salomone	Jim	P G & E
	Sherron	Valerie	Sotoyome RCD
	Sherwood	Brad	SCWA
	Silvas	Anthony	Diageo
	Simpson	Julie	Two Moon Vineyard
	Spilseth	Sarah	NOAA National Marine Fisheries Sevice
	Staff		HOCV
	Staff		help for Rich Thomas
	Sullivan	Lindsay	Rudd Winery
	Thomas	Rich	
	Thomas	Steve	Wildwood Vineyards
	Tolbert	Louise	Ray Carlson & Associates
	Valentin	Gilberto	Two Moon Vineyard
	Vincent	Donna	D.V. Vineyards
	Widlow	Jerry	Widlow Vineyards
	Widlow	Judy	Widlow Vineyards

	Yates	Jerry	Golden Vineyards

Soil Moisture Monitoring Photos

Crossbow eKo nodes (above) and soil moisture sensors (below) used to measure the two dimensional wetting pattern below an emitter (right side of lower photo).

Six Ranch Systems telemetry nodes (above), as connected to the six AquaSpy soil moisture probes and six in-line flow gauges (below).

Photos from the Demonstration Field Days:


Mark Houser, Vineyard Manager of Hoot Owl Creek / Alexander Valley Vineyards

Nick Frey, Executive Director of the Sonoma Winegrape Commission


Supervisor Paul Kelley


Attendees

Arturo Carvajal, NRCS Water Management Engineer


Atendees

Atendees

Atendees

Mark Greenspan, Project Coordinator

Atendees

Atendees

Atendees

Phil Freese, Viticulture Consultant, being interviewed by KRCB

Bob Anderson, Executive Director of United Winegrowers of Sonoma County being interviewed by KRCB

Wilbur-Ellis Cooking Crew


Richard Thomas Cooking Crew

Acknowledgements and Contributors

The success of this project was made possible through significant efforts from the following people and organizations.

Mark Houser, Vineyard Manager for **Alexander Valley Vineyards / Hoot Owl Creek Vineyards**: The vineyard was the site for the demonstration. Mark, his staff, and the winery staff were outstanding partners for the project. From idea exchange, execution of plans, event preparation to hosting of the two demonstration field days, the project's success was largely due to their efforts.

Sonoma County Winegrape Commission, with Executive Director, Nick Frey, and his staff, were instrumental in promoting knowledge about the project to the grower community and in coordinating the invitations and RSVP's for the two field days. Nick also served as master of ceremonies for the Field Days and continues to support the project in many different ways.

While much of the equipment was rented or purchased, the following companies donated equipment and/or time to the project:

AquaSpy: Donated six soil moisture sensor probes to the irrigation project.
Jain Irrigation: Donated micro-sprayer equipment to the cooling demonstration.
Camalie Networks: Mark Holler donated a tremendous amount of time getting the ēKo system up and running, as well as constructing a web site access portal for the ēKo system data.
Crossbow Technologies: Loaned some of the components of the ēKo Pro system.
Ranch Systems: Loaned some of the components of their system as well as providing field time.

The entire list of contributors appears on the next page:

STUDY CONTRIBUTORS:

Alexander Valley Vineyards
www.avvwine.com

AquaSpy
www.aquaspy.com

California Sustainable Winegrowing Alliance
www.sustainablewinegrowing.org

Camalie Networks
www.camalienetworks.com

Jain Irrigation, Inc.
www.aquariusbrands.com

Hoot Owl Creek - Alexander Valley Vineyards
www.avvwine.com

Crossbow Technology, Inc.
www.xbow.com

Natural Resources Conservation Service
www.nrcs.usda.gov

Ranch Systems, LLC
www.ranchsystems.com

Sonoma County Farm Bureau
www.sonomacountyfarmbureau.com

Sonoma County Water Agency
www.scwa.ca.gov

Sonoma County Winegrape Commission
www.sonomawinegrape.org

Sotoyome Resource Conservation District
www.sotoyomercd.org

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PROJECT CONTRIBUTORS