FINAL REPORT
29 June 2018

Washington State Grape and Wine Research Program

PROJECT TITLE: ***Assessing and Ameliorating Salinity and Sodicity in Eastern Washington Wine Grape Vineyards***

Project Duration: ***July 2016 – June 2018***
WRAC Project No.: 13C-3319-6620

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Cooperator Name:	**TOO MANY TO LIST**
Organization	
Description of participation:	VINEYARD BLOCKS AND WATER SOURCES FOR SAMPLING

BUDGET AND OTHER FUNDING SOURCES

FINAL FINANCIAL REPORTING

BUDGET *(LIST COMPLETED BUDGET NUMBERS)*

	Year 1 FY	**Year 2 FY**	**Year 3 FY**
	Jul 16 – Jun 17	Jul 17 – Jun 18	Jul XX-Jun XX
Item			
Salaries		25,860	
Benefits		9,703	
Wages		2,000	
Benefits		207	
Equipment			
Supplies		2,000	
Travel		1,600	
Miscellaneous		500	
Total	32,000	41,870	
Footnotes:			

Total Project Funding: **73,870**

Project Budget Status:

A portion of the budget still remains at the time of developing this report. All samples have been collected and analyzed but the bill has not yet been received. The cost of the spring 2018 should result in utilizing the funds remaining in this project.

OTHER FUNDING SOURCES/SUPPORT

Agency Name: **Sirius Minerals, LTD**
Amount requested: **$37,840**
Amount awarded: **$28,160**

Project Summary:

Grapes are classified as moderately sensitive to salt (Maas, 1986). Saline and sodic soils can occur naturally in the irrigated wine grape production areas of Washington State; however, vineyards typically are not established in low-lying sites that are risk for additional salt accumulation. Many vineyards are either partially or entirely irrigated from groundwater sources. Most deep wells in central Washington growing regions contain high concentrations of carbonates and bicarbonates and may also be high in sodium, depending on the chemistry of the groundwater.

Long term use of low-quality water leads to soil degradation, as soils become either saline (a nonsodic soil containing sufficient soluble salts to adversely affect the growth of most crop plants), sodic (a nonsaline soil containing sufficient exchangeable sodium to adversely affect crop production and soil structure under most conditions of soil and plant type), or both saline/sodic. Growers have increasingly brought in soil sample results or requested help with struggling vineyards, where the test results clearly indicate that the soils are saline and/or sodic (>1.5 dS/m or > 13 % ESP [Exchangeable Sodium Percent]) (US Salinity Laboratory Staff, 1953).

While soil salinity and/or sodicity is not limited to wine grapes, use of deficit irrigation in vineyards can accelerate the development of the problem. Additionally, growers may increase deep well groundwater use in drought conditions when irrigation district water sources are limited (e.g., 2001 drought).

Grapevine response to soil salinity and sodicity have been studied (Bramley et al, 2011; Suarez, unpublished data). Remediation strategies have been identified, but may be limited in their adoption in Washington due to the specificity of location from which they were developed. The goals of this proposed research are to first gain an understanding of the degree of affected eastern Washington vineyards and then to evaluate potential techniques that effectively remediate/ameliorate soil salinity and/or sodicity.

Project Major Accomplishments:

Objective 1: Survey vineyards and water sources for degree of salinity and/or sodicity in south central Washington (including but not limited to the following AVAs: Yakima Valley, Horse Heaven Hills, Red Mountain, Columbia Valley, and any AVAs contained within these).

Procedures:

Objective 1 takes a survey approach to determine the range of effects from using impaired water sources on vineyards in south central Washington. Vineyard sites were identified based on knowledge of growers who have expressed concerns in the past through sharing results of soil and or water tests. Bulk soil and irrigation water samples were collected from vineyards in fall 2016 and 2017 as well as spring 2017 and 2018 to see seasonal fluctuations as well as to look for consistency or changes with time

Sites chosen represent a combination of management practices. The first choice made was by grape color and the second as to whether the grapes are intended for regular or high tier wines. These factors were chosen to see if degraded soil characteristics show as a differentiation between grape color or intended market (e.g., regular pricing or "higher tier"). However, since the initial selection of sites, there have been changes in the fruit market targets for several vineyard blocks. Thus, we have collected data from each site on type of water source (ground vs surface), grape color, and AVA, but will not report on target market.

To look at spatial variability within the vineyard, in fall 2017, three vineyards were chosen for intensive sampling across the vineyard block. Based on the results from the spring 2017 soil samples, a Cabernet Sauvignon block from the Horse Heaven Hills was chosen for having high EC (2.63 dS/m) and moderate sodium (ESP 11.2), a Viognier block from Red Mountain with low EC (0.81 dS/m) and high sodium (ESP 16.5), and a Riesling block in the Yakima Valley that had low EC (0.70 dS/m) and low sodium (ESP 0.7) in spring 2017. Soils were sampled from below the vine/dripline every 50 cm across the inter row to the next vine (Fig.1) in four different locations (replications) in each block.

Results:

Survey Results:

The survey of soil and water sources resulted in 29 – 39 vineyard blocks and 20 - 25 water source samples collected at each interval. The changes in numbers were due to increasing sample size intentionally but also blocks being removed so no longer accessible.

There were 8 vineyard blocks sampled in the Columbia Valley (CV), Horse Heaven Hills (HHH) and Yakima Valley (YV), and 15 in the Red Mountain (RM) AVA. The percentages of blocks irrigated by ground water were 13, 75, 0, and 73, respectively. Soil and water analytical data were analyzed to see if there were statistically significant differences in chemical properties by AVA, season (spring vs fall collection), and water source. There were only a few factors that differed with season. Soil EC was higher in the spring than fall (0.94 vs 0.30 dS/m). The seasonal fluctuation in EC is consistent with findings in other studies where soils in the drier periods of the year have routinely been found to have lower EC than in the wetter times (Nejimi, 2012). Water pH and EC were also higher in the spring (8.46 and 343 dS/m) than the fall (8.34, 308 dS/m).

Several soil and water chemical properties varied with water source and AVA. In general, the soils were low in EC (Table 1), the parameter which measures the soil salinity, but soils from HHH have EC values that are in the medium risk category (Horneck et al., 2007). The average value for soils irrigated with ground water is just below the level considered medium risk (0.75), so monitoring the soils irrigated with ground water sources will be important.

The trend towards sodicity is more concerning (Table 1). The average ESP for CV and YV soils is <5, thus unlikely to be risky, but the averages for HHH and RM soils were considerably higher and in the medium risk classification of 5 – 15 ESP (Horneck et al., 2007). This is also true of soils irrigated with ground rather than surface water sources. In addition, while soil Ca did not differ by AVA, it was lower in ground than surface water irrigated soils, showing a trend of reduction in plant available Ca with increasing soil Na.

Table 1: Average values of soil chemical properties differing by AVA or water source. Values followed by different letters are statistically different. ESP = exchangeable sodium percentage.

Parameter	pH	EC	Ca	Na	ESP
		dS/m	meq/100 g soil		
Columbia Valley	8.14 B	0.48 C	12.76	0.338 B	2.65 C
Horse Heaven Hills	7.98 B	0.85 A	12.23	0.927 A	7.16 B
Red Mountain	8.51 A	0.69 AB	11.33	1.009 A	10.34 A
Yakima Valley	7.46 C	0.54 BC	11.82	0.357 B	2.80 C
Level of Significance	*0.001*	*0.001*	*0.391*	*0.001*	*0.001*
Ground water	8.33 A	0.74 A	11.07 B	1.07 A	9.81 A
Surface Water	7.84 B	0.56 B	12.61 A	0.38 B	3.35 B
Level of Significance	*0.018*	*0.016*	*0.022*	*0.001*	*0.001*

Water chemistry was similar to soil chemistry in terms of variability with AVA and water source (Table 2).

Table 2: Average values of water chemical properties differing by AVA or water source. Values followed by different letters are statistically different. SAR = sodium absorption ratio.

Parameter	pH	EC	Ca	Na	SAR
		dS/m	meq/100 g soil		
Columbia Valley	8.39 AB	320 B	21.28 A	19.79 B	4.78 B
Horse Heaven Hills	8.41 AB	320 B	15.12 B	39.63 A	49.02 A
Red Mountain	8.50 A	382 A	14.42 B	48.65 A	36.19 A
Yakima Valley	8.28 B	257 C	20.05 AB	11.70 B	2.94 B
Level of Significance	*0.013*	*0.001*	*0.030*	*0.001*	*0.001*
Ground water	8.55 A	382 A	13.12 B	50.76 A	47.01 A
Surface Water	8.28 B	280 B	20.89 A	16.03 B	4.77 B
Level of Significance	*0.018*	*0.002*	*0.022*	*0.001*	*0.001*

To better evaluate the impacts these results, the data were classified by qualitative characteristics. Horneck et al. (2007) describe the following ranges for EC and ESP as low, medium and high risk, respectively: <0.75 dS/m, <5%; 0.75 – 4 dS/m, 5 – 15 %; > 4 dS/m, >15%. For water quality, the USDA Soil Salinity Lab (1953) established a classification system for risks associated with irrigation water. These risk categories are based on both EC (C) and SAR (S) of the irrigation water. They are classified as low (1), medium (2), high (3) or very high (4) for each factor. Thus, a C1-S1 water sample (EC < 250, SAR < 10) pose little to no risk for prolonged irrigation use on most crops.

The results from the qualitative characterization of the samples (Tables 3 and 4) support the findings described above. The only time a water samples showed high salinity (C3) was in fall 2016 and no subsequent sampling from that water source showed the same high value. Looking at the qualitative soils data (Table 3) supports that regardless of water source, soil EC is low to medium.

Sodium build up is of concern. Surface water irrigated blocks in this study are showing some slight increases in ESP, and in spring 2018, 30% of the samples had S3 rankings. The trend is even more concerning in groundwater irrigated vineyard blocks, where in spring 2018, up to 50% of the blocks had irrigation water categorized in S4, which is considered unsuitable for irrigation, and 17% in S3, which is considered suitable only if C categories are 1 or 2 (which they are) and routine calcium amendments are made to the soils.

Table 3: Qualitative interpretation of soils data by sampling period, as a percentage of each classification from ground or from surface water irrigated vineyard blocks.

Irrigation Water Source	Season Sampled	EC Rankings (%)			ESP Rankings (%)		
		Low	Medium	High	Low	Medium	High
Ground	Fall 2016	100	-	-	60	20	20
	Spring 2017	35	65	-	45	40	15
	Fall 2017	100	-	-	16	58	26
	Spring 2018	60	40	-	55	30	15
Surface	Fall 2016	100	-	-	93	7	-
	Spring 2017	47	53	-	79	16	5
	Fall 2017	100	-	-	76	12	12
	Spring 2018	56	44	-	75	19	6

Table 4: Qualitative interpretation of water data by sampling period, as a percentage of each classification from ground or from surface water irrigated vineyard blocks.

Irrigation Water Source	Season Sampled	C-S Rankings as % of Samples					
		1-1	1-4	2-1	2-3	2-4	3-1
Ground	Fall 2016	-	-	60	20	30	10
	Spring 2017	8	-	38	8	6	-
	Fall 2017	-	-	46	16	38	-
	Spring 2018	-	-	33	17	50	-
Surface	Fall 2016	60	-	40	-	-	-
	Spring 2017	36	9	35	-	-	-
	Fall 2017	9	-	82	-	9	-
	Spring 2018	20	-	50	50	-	-

Spatial Distribution Results:

The spatial soil sampling showed several different patterns that are of interest in terms of the soil chemical properties. The Yakima Valley (YV) vineyard was in the low range for soil EC and ESP, whereas the Horse Heaven Hills (HHH) vineyard had medium EC and medium ESP, and the Red Mountain (RM) vineyard had high ESP but low EC.

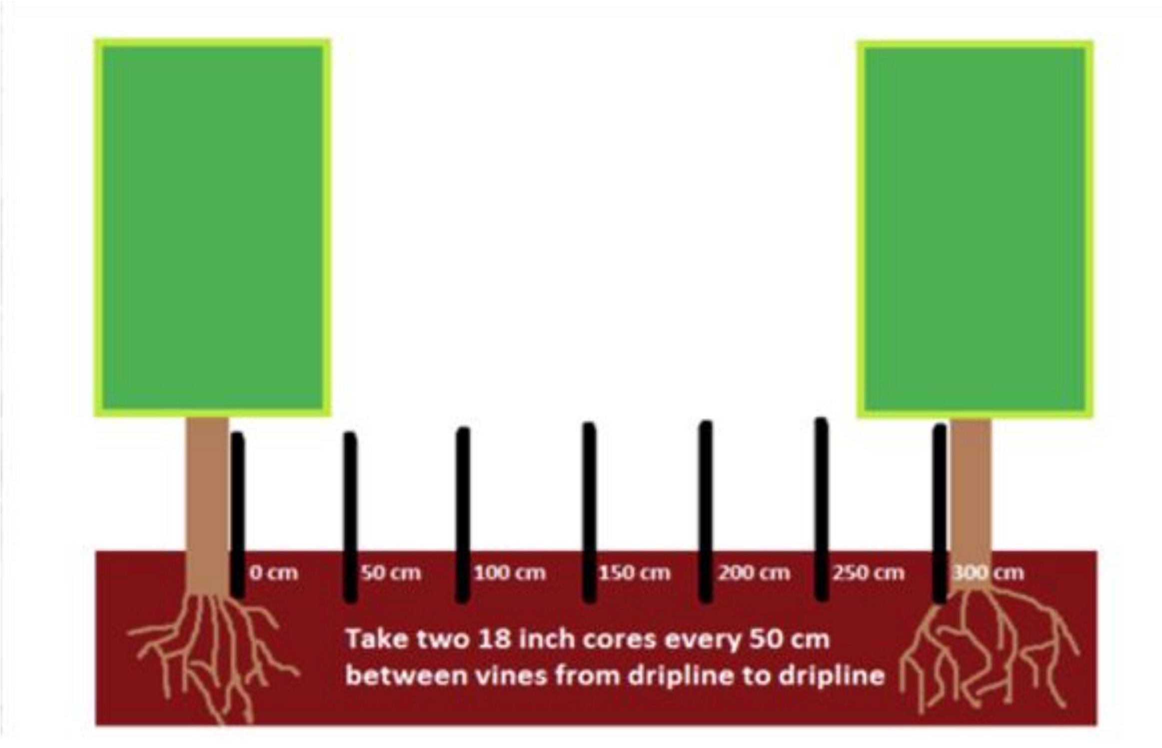

Figure 1: Soil sampling design to evaluate salinity and sodium concentration across vineyard rows, looking at influence of area of irrigation.

Soil pH was in a narrow range from row to row in the vineyard at the HHH site, whereas soil pH was high near the rows and low in between at the RM site and low near the rows and higher between at the YV site (Fig. 2). The high pH across the HHH site can be explained by the difficulty with water penetration at that site, resulting in water essentially flooding across the rows, which is supported later with soil Na and ESP data. With the YV site, the lower pH in the rows is likely a result of past N fertilizer applications reducing soil pH within the rows, and the inter-row pH is more consistent with the soil pH of non-managed soil. This is supported by the pattern in the RM vineyard, where the pH between the rows is the same as that in the YV soils, but the higher pH in the rows is reflective of increased sodium in the soil where the irrigation water is applied.

Soil Ca differed slightly between vineyards, but within a vineyard site was consistent with space (data not shown). Soil Na and ESP followed the same general patterns across each vineyard site, so only the EPS data is presented Fig. 3). This clearly shows that the YV vineyard is unaffected, the RM vineyard has a build up of sodium within the rows but not between the rows, and that the HHH vineyard has high Na across the rows. The ESP is in the high range within the row and out to about 2 feet in the RM site, but is at the high end of the medium range across the HHH site.

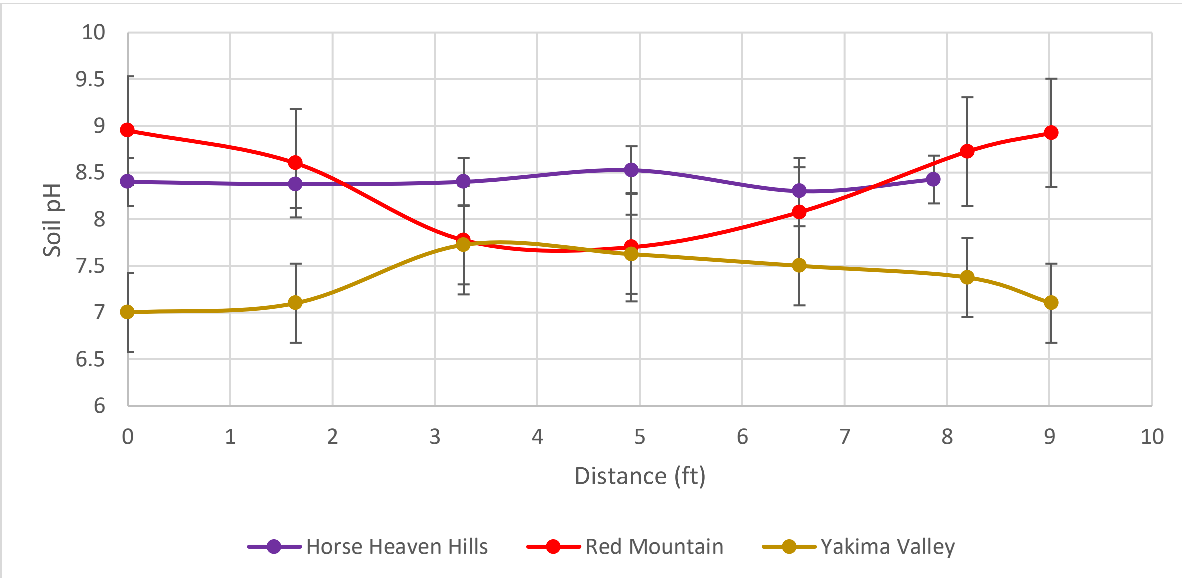

Figure 2: Average soil pH from vine row to vine row (vine 1 at 0 ft and vine 2 at either 8 or 9 ft). Error bars are plus or minus 1 standard deviation from the mean.

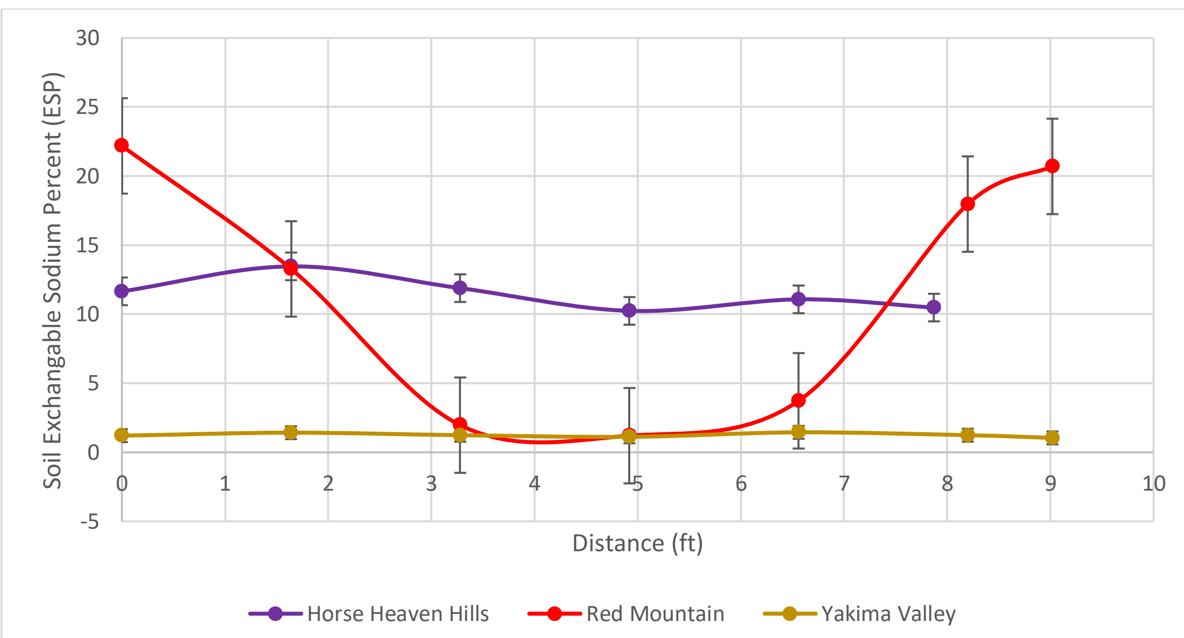

Figure 3: Average soil exchangeable sodium percent (ESP) from vine row to vine row (vine 1 at 0 ft and vine 2 at either 8 or 9 ft). Error bars are plus or minus 1 standard deviation from the mean.

In general, EC values were low risk across the vineyard blocks, with only a few places where it was close to 0.75, the low end of the medium risk range (Horneck et al., 2007). However, the distribution of the EC tells a very interesting story (Fig. 4). The spatial distribution of EC at the RM site was not very variable. However, at the HHH and YV sites, EC was highest at the sampling point closest to, but not under, the row (i.e., about 1.5 ft from the drip line). This elevation in EC shows the extent of the water movement from the drip irrigation line. Essentially, as the irrigation water and, when fertilized, the nutrients carried in it move out to a certain point the soil then dries and "strands" the nutrients into a zone where there is no longer enough soil moisture to move the, thus building up the salts. This is supported by previous work looking at water and nutrient movement in drip irrigated vineyards in central Washington that informs the recommendations for where to collect soil samples for nutrient analysis (Davenport et al., 2008; Davenport et al., 2011; Singer et al., 2018).

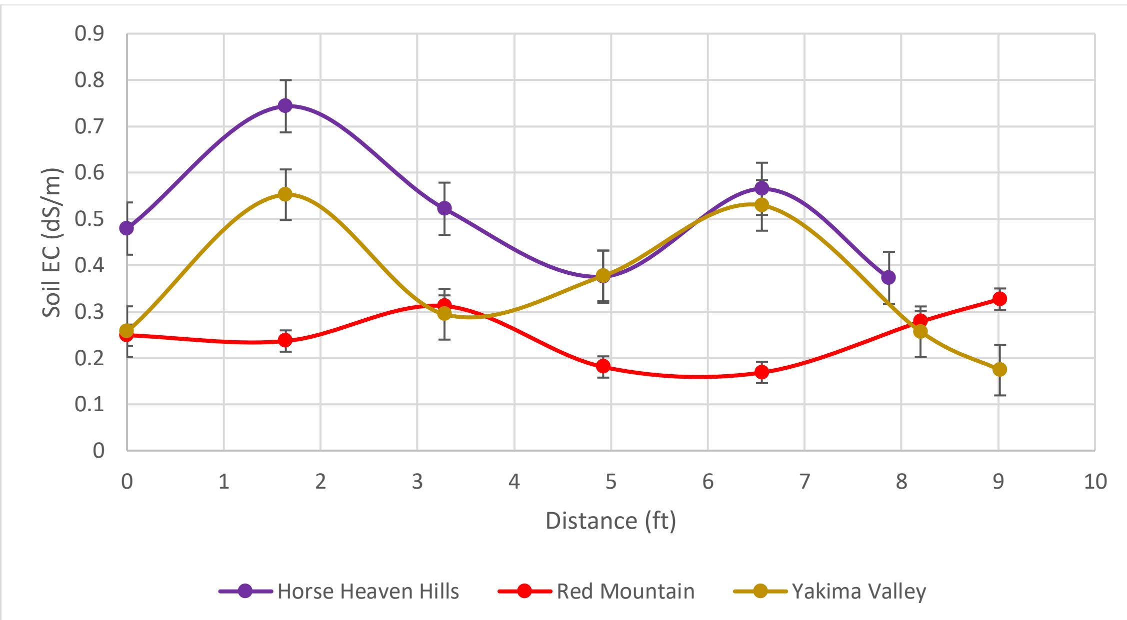

Figure 4: Average soil electrical conductivity (EC) from vine row to vine row (vine 1 at 0 ft and vine 2 at either 8 or 9 ft). Error bars are plus or minus 1 standard deviation from the mean.

Objective 2: Evaluate alternative management strategies to address vineyard soils that are salt or sodium affected.

Typical recommended strategies to manage saline and sodic soils involve leaching with excess water and applying certain soil amendments, such as sulfur or calcium sulfate. Using these techniques, or a combination thereof, depends upon the origin and extent of a saline/ sodic soil problem.

In the 2016 and 2017 growing season, a research trial funded by a fertilizer company was initiated on a Chardonnay Block in the Horse Heaven Hills with sodic soil conditions. Replicated trials comparing the use of gypsum and an alternative material, Polyhalite (K-Mg-Ca sulfate), at three different rates were established.

Treatment effects on soil are being evaluated through soil chemical testing and plant response is being evaluated through yield and fruit quality parameters (Brix, pH, and TA,). The impact of the treatments on plant chemistry is being monitored through collection of leaf tissue samples from each plot at veraison which will be analyzed for standard nutrients.

This project was funded by another agency and the result have been reported to them accordingly.

Conclusions:

For the most part, surface water sources (irrigation district water, river water) are low in salt and sodium and do not pose a threat to long term use in vineyards. However, untreated ground water irrigation sources (deep wells) are high in sodium and are resulting in the build up of sodium in vineyard soils. This build up has the potential to adversely affect productivity by reducing the ability of water to penetrate the soil (which has already occurred in some sodium affected vineyard blocks) and could result in a sodium induced calcium deficiency in vines.

In vineyards that rely on deep wells for irrigation, alternatives are to treat the water to reduce the sodium or to treat the soils with gypsum or another source of calcium to amend the soil.

Information Dissemination, Extension, and Outreach Activities:

Salinity and Sodicity: Emerging Issue in Washington Vineyards. WAVE, Prosser, WA, 5 Apr 2018

Literature Cited:

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