WITHIN VINEYARD TEMPERATURE STRUCTURE AND VARIABILITY IN THE UMPQUA VALLEY OF OREGON

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Abstract
Climate influences viticulture and wine production at various scales with the majority of attention given to regional characteristics that define the general varieties that can be grown and the wine styles that can be produced. However, within vineyard scale effects of climate can be substantial due to landscape variations. To better understand the effect of local weather and climate on terroir, the goal of this research was to examine within vineyard temperature variations. Temperature data was collected from 23 sites in a commercial 33 ha vineyard in the Umpqua Valley of Oregon over a five-year period during 2011-2015. Dormant period temperatures (Nov-Mar) varied by roughly 1°C across the 23 sites with the extreme minimum temperatures varying by just over 3°C. Spring temperatures (Apr-May) varied by roughly 2°C for the vineyard locations with frost occurrence varying as much as nine days in most years. During the summer (Jun-Aug) maximum temperatures varied more than minimum temperatures across the sites, while extreme maximums ranged nearly 5°C. During the ripening period (Sept-Oct) diurnal temperatures ranges at the 23 sites averaged 20°C. Over all years and sites the growing season heat accumulation averaged 1467 GDD but ranged from 1181 in the coolest year (2011) to 1705 in the warmest year (2015). The average range of GDD during these vintages shows that within vineyard variability in heat accumulation is 375 GDD. These variations in temperatures and heat accumulation are weakly correlated with elevation differences between the sites, however the combined effects of slope/aspect have more significant correlations with temperatures at these sites, especially minimum temperatures. As a result of the within vineyard differences in temperatures and heat accumulation, this commercial vineyard adequately ripens a range of varieties from Albariño, , Viognier, Syrah, Tempranillo, Grenache, , Touriga Nacional, Tannat and others.

Keywords: terroir, temperature, mesoscale, viticulture, spatial variation

1 INTRODUCTION

Climate is clearly one of the most important factors in the success of all agricultural systems, influencing whether a crop is suitable to a given region, largely controlling crop productivity and quality, and ultimately driving economic sustainability (Jones et al. 2012). In the continuum of terroir influences on grapevine growth and wine production, weather and climate are the controlling factors that determine what can be grown where and how (Vaudour and Shaw, 2005; Vaudour et al., 2015). At the global scale, climates establish the broad cool to warm to hot climates for winegrape production (Jones et al. 2012). At the regional scale climate establishes between region differences in the suitability of different varieties and the potential wine style produced (Jones et al. 2010). At the vineyard scale within block aspects are often considered to be generally uniform, however landscape variations clearly drive differences in growth and ripening within vineyards (Battany, 2009). As such numerous studies have been carried out to better understand the local to microscale variations in temperatures in vineyards worldwide. Matese et al. (2014) have proposed a low-cost Wireless Sensor Network to automate data collect at a fine scale. de Rességuier et al. (2016) have implemented a sensor network across Saint-Emilion and Pomerol in France that has provided the framework for spatial mapping of temperatures over the region. The results have been used for local scale assessment of plant phenology and fruit ripening, and for studying regional atmospheric circulation on site temperature variations (Eveno et al., 2016). Examining spring frost hazards in Champagne, Madelin and Beltrando (2005) used a network of sensors to help map the spatial variation of frost risk in the region. The importance of finer scale temperature observations has also been noted by Irimia et al. (2013) for use in accurate vineyard climate suitability assessments. Given the importance of a better understanding of spatial variations in temperature and it role in producing terroir-scale influences in weather risk, vine growth, and fruit ripening, the goal of this research is to examine within vineyard temperature variations in a commercial vineyard in the Umpqua Valley of Oregon.

2 MATERIALS AND METHODS

This research collected data from 23 sites in a commercial 33 ha vineyard in the Umpqua Valley AVA of Oregon (Figure 1). The Umpqua Valley AVA was established in 1984 and is Oregon's oldest defined wine region (Jones, 2003). The winegrowing history in the region dates back to the late 1840s when Jesse Applegate and others planted the first winegrape vineyards in the valley. After prohibition the state's first winery was established in the Umpqua Valley in 1934. The Umpqua Valley has a complex topography that is a result of the collision of three mountain ranges of varying age and structure: the Klamath Mountains, the Coast Range and the Cascades (Jones et al., 2004). As a result, the region is often called "The Hundred Valleys of the Umpqua" because it is made up of a series of interconnecting small mountain ranges and valleys. The Umpqua Valley grows over 40 different varieties across a range of relatively cool climates in the northern portion of the region, intermediate climates in the central valley, and warmer climate in the southern valley extensions. Today there are approximately 1200 ha planted to nearly 100 vineyards that produce roughly 7000 tons of fruit, which is made into wine at numerous wineries within the region.

To examine the within vineyard structure and variability in temperature, 23 sensors (Hobo Data Loggers®, Onset Computer) were installed at approximately 1.5 m height in solar radiation housings across 18 blocks that best represented the range of slopes, aspects and elevations found in the vineyard (Figure 1). Data were continuously collected at 15 minute intervals over a five-year period during 2011-2015 and summarized during important periods of the year (i.e., dormant, spring, summer, ripening and the entire growing season). For the growing season of April 1 through October 31 average and absolute maximum and minimum temperatures along with the number of days above 35°C and below 0°C were tallied for all sites. In addition, growing season average temperatures (Jones et al. 2012) and standard growing degree-days using a 10°C base temperature we calculated for each location (Jones et al. 2010). Temperature variations were compared to site characteristics such as elevation, slope and aspect using correlation and regression.

3 RESULTS AND DISCUSSION

The 23 vineyard locations ranged from 166 to 227 m in elevation with surrounding slopes that ranged from 1 to 20.5° and over a full range of aspects (NNE to NNW). Dormant period temperatures (Nov-Mar) varied by roughly 1°C across the 23 sites with the extreme minimum temperatures varying by just over 3°C (not shown). Spring temperatures (Apr-May) varied by roughly 2°C for the vineyard locations with frost occurrence varying as much as nine days in most years (not shown). During the summer (Jun-Aug) maximum temperatures varied more than minimum temperatures across the sites, while extreme maximums ranged nearly 5°C (not shown). During the ripening period (Sept-Oct) diurnal temperatures ranges at the 23 sites averaged 20°C (not shown).

Examining just the growing season from April 1 through October 31, on average the sites ranged nearly two degrees in average temperatures (15.8-17.6°C) and 375 growing degree-days (GDD 1289-1664) (Table 1). Over all years and sites the growing season heat accumulation averaged 1467 GDD but ranged from 1181 in the coolest year (2011) to 1705 in the warmest year (2015). Average minimum temperatures during the growing season vary more across the sites (2.6°C) than do average maximum temperatures (1.7°C). However, the absolute maximum temperature (40.5°C averaged over all sites and years) varies more than the absolute minimum temperature (-1.3°C averaged over all sites and years) (3.8°C vs. 2.6°C; Table 1). The number of days over 35°C during the growing season averages 25 over all sites and years, but ranges from a high of 39 days to a low of 14 days. Frost risk at this vineyard is normally concentrated in the month of April and was the highest during 2011 and lowest during 2014, averaging four events below 0°C over all sites and years (Table 1). However, the sites range seven events below 0°C on average from a low of two to a high of nine.

Overall the warmest sites in terms of GDD are prominent south-facing locations (AAngle, AGH2, ASS2, etc.), these locations also tend to have the highest average and absolute maximum temperatures while experiencing the lowest frost risk (Table 1). The cooler sites tend to be located in the western most vineyard block area (Figure 1) and at lower elevations and more northerly aspects. These sites (ACH3, ACH6, ACH5, etc.) tend to have lower maximum temperatures, few days above 35°C and have higher frost risk.

Comparing the site temperatures with location topographical characteristics finds a positive, but weak correlation between growing season average temperatures or GDD and elevation ($r = 0.38$), slope ($r = 0.36$), and aspect ($r = 0.33$). Converting aspect into a range class and multiplying by the slope to derive a slope-aspect value produces the highest correlation with GDD ($r = 0.51$). Growing season mean maximum temperatures, absolute maximum temperatures, and the number of days over 35°C do not exhibit significant correlations with elevation, slope or aspect alone, although absolute maximum temperatures do have a significant positive correlation with combined slope-aspect ($r = 0.34$). Growing season minimum temperatures exhibit the strongest correlation with topographical variations in elevation or combined slope-aspect (Figure 2) with average and absolute minimum temperatures having positive relationships ($r = 0.56$ and $r = 0.60$, respectively) and the number of days below 0°C showing a negative relationship ($r = -0.55$).

4 CONCLUSION

This study documents the combined effect slope and aspect have on the temperature and GDD range within a single 33 hectare vineyard in the Umpqua Valley of Oregon. Overall, prominent south-facing locations are the warmest with the highest average and absolute maximum temperatures, the most days over 35°C and highest GDD accumulation. Sites at lower elevations with more northerly aspects experienced lower maximum temperatures, fewer days above 35°C and higher frost risk.

The rather steep slopes and various aspects, not unsurprisingly influenced growing season frost risk but their impact on GDD accumulations was surprisingly large and similar to what might be expected in comparing different regions.

Is this site unique because of its wide diurnal temperature swings or do vineyards in all climate zones that have similar elevation, slope-aspect changes experience similar intra-vineyard GDD differences from block to block?

In this vineyard the observed intra-vineyard GDD accumulation differences enable variety-site matching to a range of varieties from Albariño, Viognier, Syrah, Tempranillo, Grenache, Touriga Nacional, Tannat and others not typically grown in the same vineyard to where each ripens at its climatic edge.

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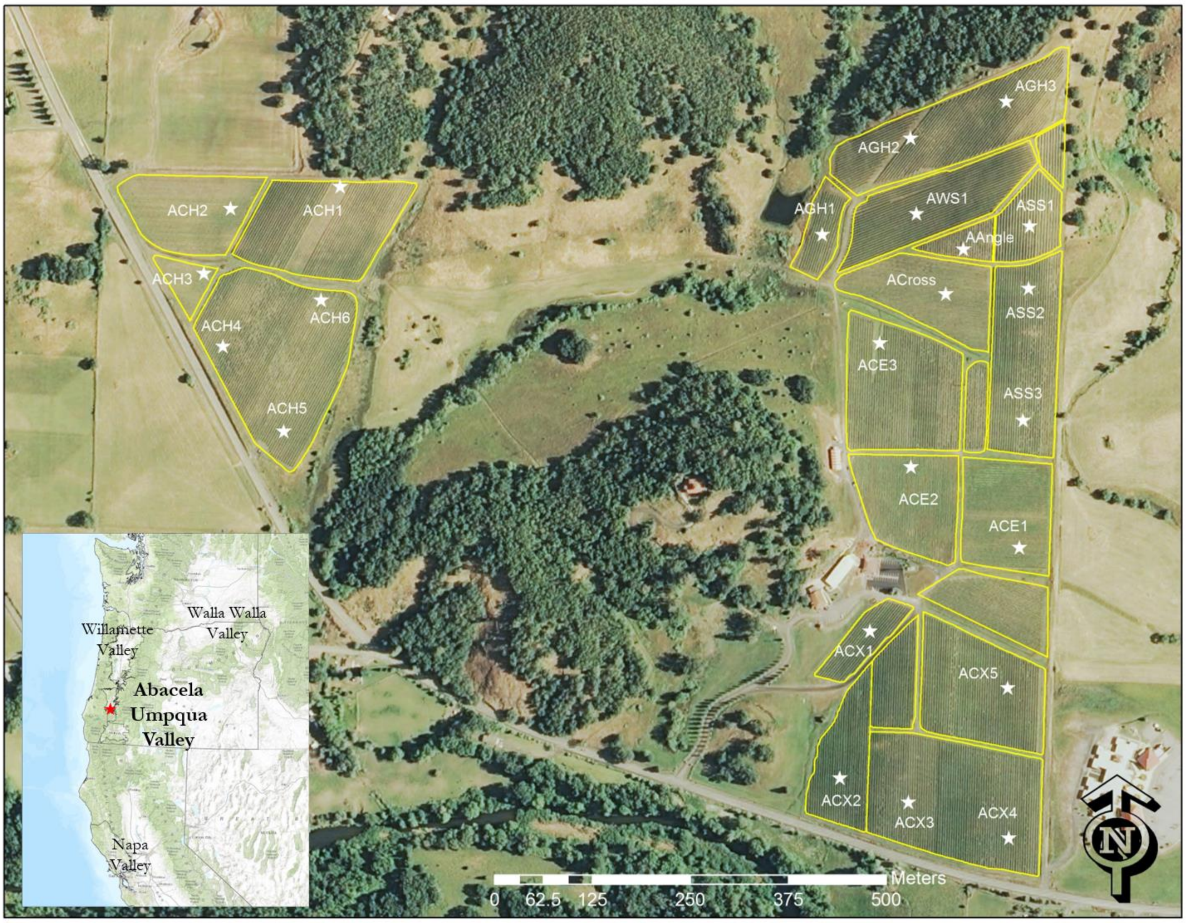

Figure 1: Abacela Winery and Fault Line Vineyard temperature sensor network (acronyms are based on the block name and are the same as in Table 1). Inset show the location of the vineyard relative to other west coast regions and the Umpqua Valley AVA.

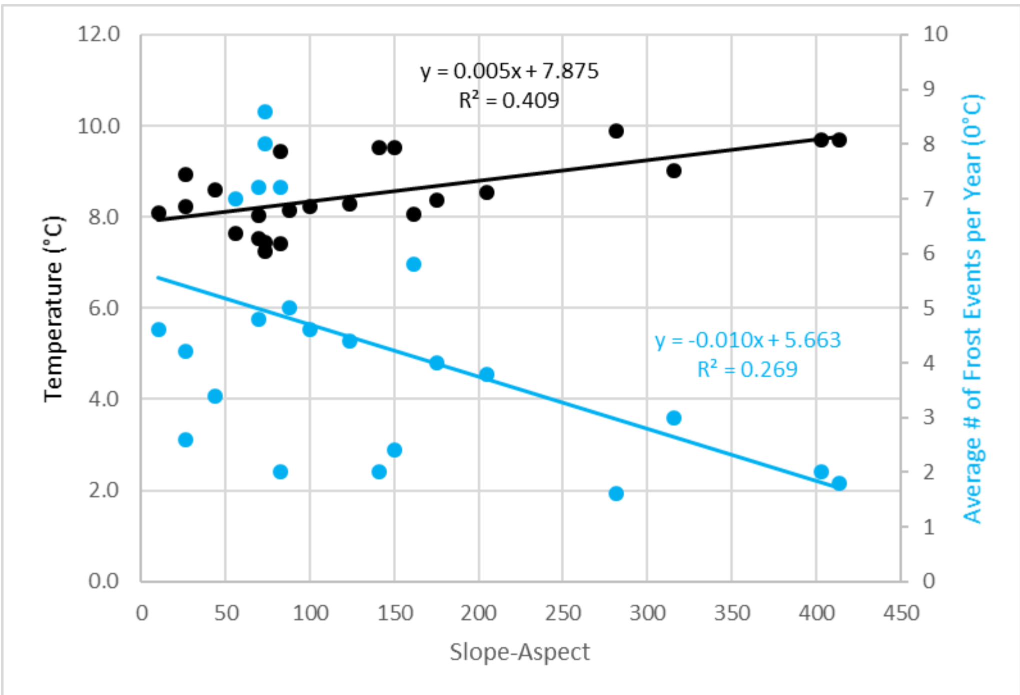

Figure 2: Comparison between average growing season minimum temperatures (left axis, black) and the average number of frost events per year (right axis, blue) and combined slope-aspect characteristics for the 23 sites in Figure 1.

Table 1: Sensor site topography and temperature observations from the locations shown in Figure 1. Elevation, slope and aspect are derived from averages of a 10 x 10 m area surrounding the sensor. All temperature variables are averaged over the April 1 through October 31 period.

Location	**Elev (m)**	**Slope (°)**	**Aspect (°)**	**Tavg (°C)**	**GDD (C° units)**	**Tmax (°C)**	**AbsTmax (°C)**	**Days >35°C**	**Tmin (°C)**	**AbsTmin (°C)**	**Days <0°C**
ACH3	174	2.8	252	15.8	1289	25.8	38.4	14	7.4	-2.3	7
ACH6	177	2.9	207	16.0	1324	25.9	38.7	15	7.2	-2.4	8
ACH5	173	2.9	207	16.1	1350	25.9	39.6	16	7.4	-2.3	9
ACH4	174	2.8	225	16.1	1357	26.4	39.3	22	7.5	-2.2	7
ACX5	186	1.0	86	16.2	1369	25.7	39.5	17	8.1	-1.4	5
ACH2	177	2.9	243	16.3	1389	26.5	39.6	22	8.1	-1.6	5
AGH1	182	3.5	180	16.4	1407	26.8	40.8	26	8.0	-1.7	5
ACE3	192	11.2	19	16.4	1418	27.0	40.5	29	7.6	-1.7	7
ACX2	166	6.5	200	16.5	1433	26.8	41.0	27	8.1	-1.7	6
ACX1	192	8.8	171	16.5	1436	25.8	39.7	17	8.4	-1.4	4
ACX4	170	4.0	225	16.5	1439	26.6	41.4	27	8.2	-1.5	5
ACE2	218	20.5	70	16.5	1440	26.4	40.7	23	8.5	-1.2	4
ASS3	195	2.6	90	16.6	1453	26.4	41.0	25	8.2	-1.3	4
ACE1	190	2.9	117	16.6	1455	26.3	40.3	22	8.6	-1.3	3
ACX3	166	4.9	225	16.7	1474	27.0	41.1	31	8.3	-1.5	4
AGH3	227	13.8	234	17.0	1538	26.6	41.1	26	9.7	-0.3	2
AWS1	186	5.0	236	17.0	1542	26.4	40.1	22	9.5	-0.6	2
ASS1	207	16.1	211	17.1	1552	26.4	40.8	25	9.7	-0.2	2
ACross	183	5.3	351	17.2	1571	27.0	41.5	30	8.9	-0.9	3
ACH1	185	10.5	242	17.2	1588	27.3	41.8	37	9.0	-0.9	3
ASS2	192	2.8	252	17.4	1609	27.2	41.4	36	9.4	-0.2	2
AGH2	187	4.7	236	17.5	1641	27.5	42.2	39	9.5	-0.4	2
AAngle	192	11.3	225	17.6	1664	27.2	41.0	34	9.9	-0.1	2

Statistic	**Elev (m)**	**Slope (°)**	**Aspect (°)**	**Tavg (°C)**	**GDD (C° units)**	**Tmax (°C)**	**AbsTmax (°C)**	**Days >35°C**	**Tmin (°C)**	**AbsTmin (°C)**	**Days <0°C**
Median	186	4.7	225	16.5	1440	26.5	40.8	25.4	8.3	-1.4	4.2
Mean	186	6.5	196	16.7	1467	26.5	40.5	25.2	8.5	-1.3	4.3
Stdev	15	5.1	74	0.5	104	0.5	1.0	7.1	0.8	0.7	2.1
Max	227	20.5	351	17.6	1664	27.5	42.2	39	9.9	-0.1	9
Min	166	1.0	19	15.8	1289	25.7	38.4	14	7.2	-2.4	2
Range	61	19.5	331	1.8	375	1.7	3.8	25	2.6	2.3	7.0