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Franklin & Marshall College

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Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603

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Keck Geology Consortium: Projects 2007-2008
Short Contributions – Walla Walla

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Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
Keckgeology.org

INFLUENCE OF SOIL COMPOSITION AND SURFACE MATERIALS ON GRAPEVINE TEMPERATURE

KARL LANG: College of William and Mary
Research Advisor: Greg Hancock

INTRODUCTION

High quality grapes are a necessity for fine wine. To create ideal conditions for the production of quality fruit, a vineyard may employ a wide variety of techniques to control the variables in the environment in which grapes are grown. This study examines the role of vineyard temperature. According to Happ (1999), temperature is an important factor in controlling vine growth and grape ripening and flavor. Jones and Hellman (2003) cited heat summation as the single most important factor in choosing a vineyard site. Typically, viticulturalists use ambient air temperatures as indicators of the heat their vines receive. However, ambient air temperature does not accurately reflect the temperature variations experienced by different parts of the grapevine. This study seeks to determine more precisely how vine temperatures vary both above and below the ground as a function of vineyard soil and ground cover.

Vineyard soils are commonly believed to have a large control on the vineyard microclimate, particularly in the case of rocky soils (Gladstones, 1992). No study has yet examined this phenomenon in detail, or even the more general relationship between soil type and soil and grapevine temperature variations. The Walla Walla American Viticultural Area (AVA) is an excellent area to study theses variations because it contains a wide variety of soil types including soils that consist almost entirely of cobblestones (Figure 1). Also, management practices vary from vineyard to vineyard with some viticulturalists leaving bare soil between rows while others cultivate cover crops.

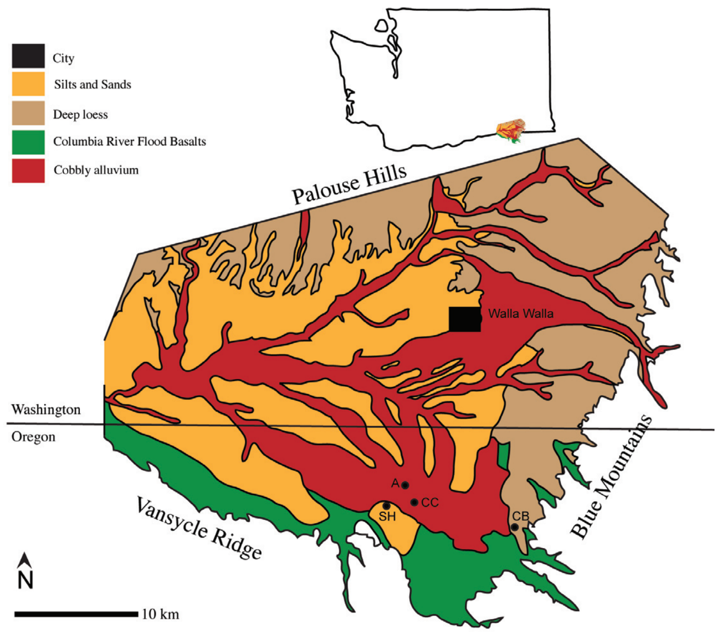


Fig 1. Surficial geology map of the Walla Walla American Viticultural Area with the four vineyard site locations (A, Armada; CC, Coccinelle; SH, Seven Hills; CB, Cockburn Hills). Topographic highs line bound the AVA, creating a triangular basin which traps cooler air in the center of the AVA before draining to the west. Adapted from Bussacca and Meinert 2000.

VINEYARDS

Four vineyard sites were used for this study (Figure 1). Sites were selected to be representative of different soils and surface materials; basalt cobbles at Armada Vineyard, cobbly loam at Coccinelle Vineyard, silt loam with a bare surface at Cockburn Hills Vineyard, and grass-covered silt loam at Seven Hills Vineyard. Soil profiles are illustrated in Figure 2.

METHODS

Onset Computer Corporation HOBO© Pendant temperature data loggers were installed at five locations within each vineyard. Data loggers were

Basalt cobbles *Armada* | Basalt cobbles and silt *Coccinelle* | Thick loess *Cockburn Hills* | Vegetated silts/sands *Seven Hills*

Fig 2. Row images and generalized soil profiles to one meter depth. Including basalt cobble alluvium (Armada and Coccinelle), cohesive loess (Cockburn Hills), and semi stratified sands (Seven Hills). Shading indicates depth of topsoil. Adapted from Meinert and Busacca 2000.

inserted into grape clusters at various heights above the surface, buried under a thin layer of soil on the surface and at depths of 25 cm and 50 cm below the surface, and suspended within solar radiation shields 1.5 m above the ground at the end of vineyard rows (Figure 3). This configuration measured the temperature variations experienced by the vine in the root zone and in the grape clusters. These measurements were then compared to ground surface temperatures, and ambient air measurements recorded concurrently in the solar radiation-shielded boxes. The loggers were programmed to record the temperature every twenty minutes, except for the ambient air loggers which recorded every hour.

Due to limitations imposed by the number of available data loggers, it was not possible to concurrently monitor all positions in all vineyards. Data was collected using a time matrix than ensured consistent placement in each vineyard per time interval so that the results could be directly compared. Ambient air temperature and surface temperature monitors were continuously recording between 7/25/08 and 8/31/08. Cluster monitors were operating with the highest precision (a minimum 4 loggers) for the first 5 days, then subsurface monitors operated with high precision (4 loggers) for the next 5 days, and then data was recorded with 2 loggers in both clusters and buried for the rest of the time period.

Fig 3. **A** freestanding HOBO ambient temperature monitor at Seven Hills vineyard. **B** Digging pits to bury subsurface HOBOs in Armada vineyard (special thanks to Dr. Pogue). **C** In situ cluster HOBO (top arrow) and surface HOBO (bottom arrow) at Cockburn Hills vineyard.

The collected data was analyzed from three perspectives. First, the raw data was compared to determine real temperature differences per vineyard site. Relative temperature differences at each site (e.g. between cluster temperature and ambient air temperature) were compared with other sites to determine possible soil type and ground cover effects. Lastly, total heat summation for the four-day intervals was summed and compared as average daily growing degree-days (GDD). GDD are calculated by averaging daily ambient air temperatures temperatures and subtracting a base value of 10° C, see equation below.

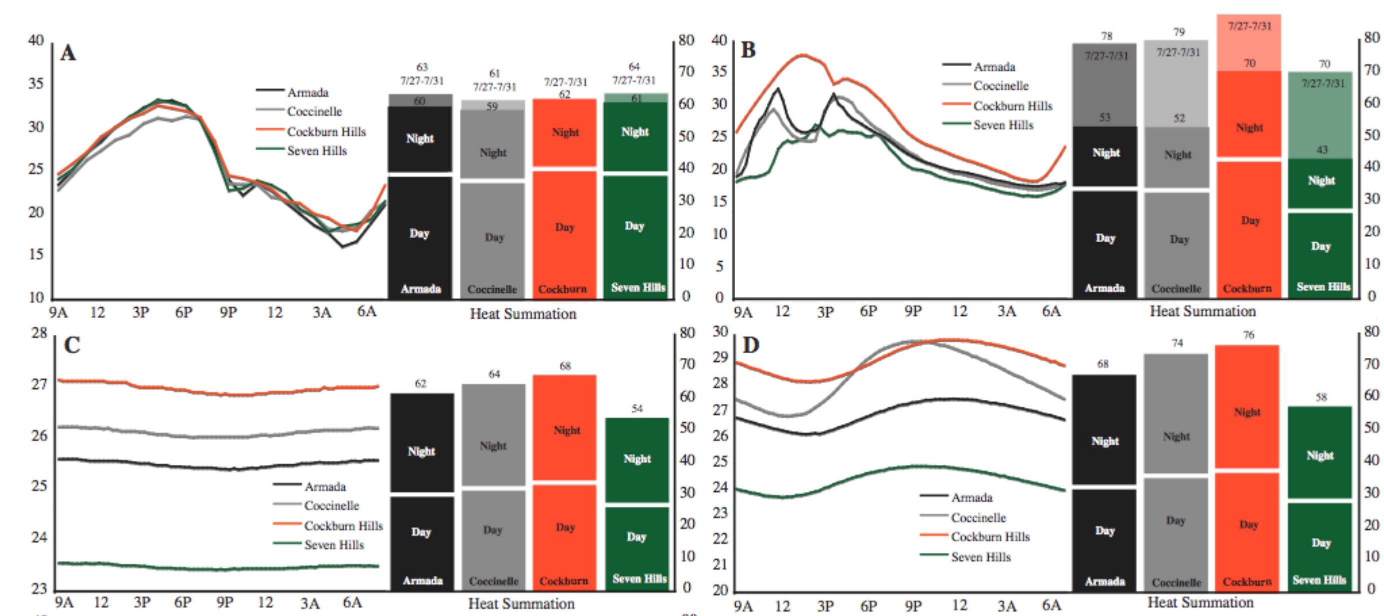
$$GDD = Sum\ (Tmax-Tmin/2)\ -10$$

This base temperature of 10° C is commonly used because grapevines exhibit very little growth below this temperature. This calculation is designed to quantify the amount of heat the vine can use to grow and mature (Hellman and Jones, 2003).

TEMPERATURE ANALYSIS

Data collected over the total 37 days was assembled and cataloged in a spreadsheet for analysis. The lower precision data collected after 8/05/08 gave averaged temperatures very similar to the higher precision sets collected in the first 10 days thus, results presented here are a direct comparative analysis focusing on the higher precision data sets of the first 10 days. Excluding the first transition day of each set, the total set was subdivided into four days, averaged and further divided into day and night periods. Days correspond to data sampled from 9:00 to 20:40, and nights, from 21:00 to 8:40.

Average subsurface temperatures at both 25 and 50 cm depths for the four days is presented in the line graph component of Figure 4. Comparing the subsurface graphs C and D to the surface temperature graph B, there is a noticeably large degree of temperature variance. Results show that at about



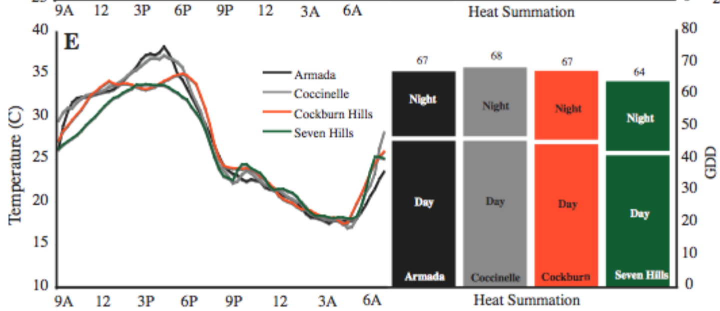


Fig 4. Line graphs depict average daily fluctuation as measured in the following locations. **A** average ambient temperatures. **B** average surface temperatures. **C** 50 cm subsurface temperatures. **D** 25cm subsurface temperatures. **E** cluster temperatures. Bar graphs correspond to four day GDD accumulation, subdivided to show average day and nighttime contributions. Measured days were 7/27/08-7/31/08 for **E**, 8/01/08-8/05/08 for **C** and **D**; both periods for **A** and **B**.

50 cm, subsurface temperatures approach a dirunal equilibrium value. Temperatures at 25 cm depth to vary inversely with surface temperatures. This phenomenon is observed in all vineyards, and in Coccinelle to the highest degree. In fact, as daytime surface temperatures peak around 2 PM, subsurface temperatures just begin to rise. Nightly, subsurface temperatures maintain a temperature at least 6° C warmer than the surface at all locations, Both 25 cm and 50 cm data show an average rate of temperature decrease with depth of about 0.12° C/cm. Peak subsurface temperatures occur between 22:00 and 0:00; latest at Cockburn Hills and earliest at Coccinelle. Interestingly, the amount of time during which the temperature at 25 cm depth exceeded surface temperatures ranged from 14 to 16.3 hours at Cockburn Hills and Coccinelle, respectively. This subsurface temperature dominance begins between 18:00 and 20:00, earliest at Coccinelle and latest at Cockburn Hills.

The grape cluster temperature data set was compared to ambient air temperatures and analyzed for consistent trends in the data (Figure 4, E). Diurnal cluster temperatures tended to follow ambient air temperatures closely. Maximum absolute temperatures reached in both Armada and Coccinelle were only a few degrees C higher than Cockburn Hills. The highest average temperature difference, roughly 5° C below ambient air temperatures, occurred at Cockburn Hills; spending only 6 hours a day with cluster temperatures above ambient air temperature. The lowest average difference occurred at Coccinelle, which was less than 1° C below the ambient air temperature, with the same amount of time above ambient. All vineyards but Coccinelle experienced particularly low differences in cluster temperatures, ranging from 7° C below ambient at Seven Hills to 14° C below at Cockburn Hills. Coccinelle experienced a maximum 2° C below ambient temperature difference. Cluster temperatures exceeded ambient air temperatures in all vineyards for about 6 hours each day in the mid to late afternoon.

GDD calculations of heat summation were summed using subsurface and cluster temperature data sets for the four day interval. This data is presented in the bar graph components of Figure 4, with figure parts representing area specific GDD totals. The white line cutting the bars represents the relative proportion of GDD accumulated during the day and night (and pertain only to the solid bar data sets). A and B display total GDD calculated from both four-day averaged data sets. Differences in these data sets are only observed to a significant degree in B, resulting from higher average temperatures observed on the surface during this time period. However, while total GDD vary, general data trends are maintained.

The consistently highest GDD total was observed for Cockburn Hills, followed closely by the two cobbly vineyards Armada and Coccinelle. Seven Hills maintaind a relatively lower heat summation, particularly when GDD are calculated using subsurface temperatures. For all locations, more GDD accumulate at night using subsurface temperatures, and during the day using ambient air temperatures. Temperatures measured at a depth of 25 cm yield a higher GDD in all locations except for Seven Hills. Even 50 cm depth calculations produce higher total GDD than ambient air calculations; again excepting Seven Hills.

CONCLUSIONS

Interestingly, relative to surface temperatures, subsurface temperatures only vary modestly. The largest 25 cm depth variance was 17° C warmer, observed at Coccinelle. This, however, may be inadvertently biased. While absolute temperatures were much higher at Cockburn Hills, subsurface temperature variance was similar to the cobbly vineyards. This finding suggests that perhaps the influence of a cobbly substrate is easily masked by higher overall temperatures (in this case dependent on elevation). Upon closer inspection of the data, cobbly vineyards Coccinelle and Armada do still have an impact.

They are able to maintain subsurface temperatures higher than surface temperatures much longer than Cockburn Hills or Seven Hills. Thus, the summation over this time period is comparable despite the cobbly vineyards' lower overall temperatures. This would indicate that a cobble substrate is most effective at maintaining higher than expected subsurface and shallow surface temperatures for a longer period of time (up to 2.3 hours more per day). Taking this into account, it would be logical to assume that if the Armada and Coccinelle had the same average ambient air temperature as Cockburn Hills they would have higher GDD due to their ability to sustain higher subsurface temperatures longer.

The results also illustrate how vineyard temperature, as measured by the ambient air temperature, differs from the temperature experienced by the roots and clusters of the vines. If heat summation is calculated as GDD using ambient air temperatures, large variations in the heat actually experienced by the vine will not be observed. Results show that these GDD totals can vary by more than 20 percent depending on the temperature data set is used. This is particularly important for cobbly vineyards. Separate measurements allow a viticulturalist to make careful modifictaions a vine to control site specific heat exposure. Close mointoring of exposure in clusters during fruit set might, for example, help a viticulturalist better predict the arrival of véraison. The most accurate data for calculating GDD would account for this observed variation at the vine scale. Even a simple approximation for the difference between ambient air temperatures and shallow subsurface temperatures would greatly increase GDD accuracy.

COMPLICATIONS

Several complications arose which require the results to be interpreted with some caution. Notice the notches in surface temperature data in Figure 4, B that indicate depressed temperatures due to shading of the data loggers by the vine canopy. Daily, as the sun reached its zenith and surface temperatures increased, the surface data loggers were completely shaded. This phenomenon occurred at nearly every site, but to a lesser degree at Seven Hills, due to an E-W row orientation.

Additionally, there is a noticeably lower average ambient air temperature at Coccinelle than at Armada. Both vineyards are located at the same elevation, and in similar soils. This may be due to the presence of an irrigation canal near the ambient temperature data logger. The cool water may have decreased the ambient air temperatures resulting in an apparent increase in relative temperature differences in this vineyard. At most this could have increased the relative temperature difference in the cluster data set by a few degrees, marginally inflating GDD totals.

Finally, a wide variety of factors affect the temperatures experienced at a given vineyard. These include but are not limited to, elevation, row orientation, aspect, proximity to water or developed areas, annual precipitation, irrigation methods and viticultural practices. It was possible to control these factors to some degree by only directly comparing relative temperature differences from ambient air or surface temperatures. However, the Cockburn Hills data was obviously affected by the higher elevation of that site. The elevation of the Cockburn Hills vineyard places it above the nocturnal cold air pool that reduces nighttime temperatures on the valley floor where the other sites were located.

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