FINAL REPORT

Washington State Grape and Wine Research Program

DUE 5:00 p.m. December 12th, 2016
by email to: ARCGrants@wsu.edu

Wine Research Advisory Committee Research Review – January 18-19, 2017

PROJECT TITLE: Predicting Key Phenological Stages for Grapevines. A Simple but Scientific Approach for Management and Site Selection

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Cooperator Name:		**Cooperator Name:**	
Organization	Boushey Vineyards	Organization	Hogue Ranches
Description of participation:	Advice, Access to the vineyards for data collection	Description of participation:	Advice, Historical data, Access to the vineyards for data collection

BUDGET AND OTHER FUNDING SOURCES

FINAL FINANCIAL REPORTING

BUDGET *(LIST COMPLETED BUDGET NUMBERS)*

	Year 1 FY	Year 2 FY	Year 3 FY
Item			
Salaries	$25,577	$26,600	$20,388
Benefits	$17,234	$18,313	$6,035
Wages			
Benefits			
Equipment			
Supplies	$500	$500	$500
Travel	$1500	$1500	$1500
Miscellaneous			
Total	$44,811	$46,913	$28,423
Footnotes:			

<u>Project Summary:</u>

Plant development is primarily controlled by temperature which plays a role in determining the appearance of phenological stages and the length of the phenophases (Johnson and Thornley 1985, Kwon et al. 2008). In this way, phenology can be modeled in function of temperature to characterizing differences among species (Parker et al. 2013) and predicting plant development under different environmental conditions (Caffarra and Eccel 2010). Using the degree-days model (DD) which is is calculated as the difference between daily mean air temperature and a threshold value known as base temperature (Tb) (Arnold 1959). Below the T_b the plant development ceases (Arnold 1959, Snyder et al. 1999).

Most of the thermal time models that have been implemented so far applied the same T_b for different phonological stages but an accurate prediction of the critical phenological events during a crop's cycle requires the determination of the an appropriate T_b (Hoover 1955, Parker et al. 2013). T_b can be estimated as Moncur (1989) exposing the plants under controlled environments, and finding differences between the occurrences of phenological stages. However, less uncertainty has been found in the methods that estimate T_b using phenology timing and temperature data collected under field conditions for several years or locations, and the selection of T_b is based on finding the temperature that provides the minimum variability in *DD* (Yang et al. 1995).

In grapevines, budbreak, flowering, veraison, and harvest are the most important stages, and the timing among these phenological stages varies between cultivars, climate and location (Jones and Davis, 2000). An accurate prediction of the occurrence of these stages can help with executing crop management practices and scheduling labor requirements and equipment. As example, knowing the occurrence of budbreak beforehand may assist in planning pruning that is needed to adjust crop load; after fruit set, leaf removal and cluster thinning is performed to improve vine balance and berry size; before and after veraison, irrigation is applied to control crop growth, enhance desired fruit traits and ensure vine health.

The goal of this study was to predict the appearance of budbreak, bloom, and veraison for 17 red and white grapevine cultivars through determining T_b and duration in thermal time required to reach each phenological stage and to implement these T_b and *DD* parameters for predicting the successive appearance of the three key stages as a function of grapevine cultivar.

Project Major Accomplishments:

Objective 1. *To develop an information and decision aid tool for the prediction of the key phenological stages for grapevine for application by growers, orchard managers, and enologists.*

Phenological data collected for 17 wine grape cultivars from 1990 to 2013 by the Viticulture Program at Washington State University, Prosser, Washington were used in this study. The red cultivars that were selected included Cabernet Franc, Cabernet Sauvignon, Lemberger, Malbec, Merlot, Pinot Meunier, Pinot Noir, Syrah and Zinfandel, while the white cultivars that were selected included Chardonnay, Chenin Blanc, Gewürztraminer, Muscat Blanc, Pinot Gris, Sauvignon Blanc, Sémillon and Riesling.

The phenological data that were collected corresponded to the day of year (DOY) when budbreak, bloom, and veraison occurred, these phases were chosen due to their importance, as they match with the periods where major changes in phenology occurred. Budbreak was defined as the stage when green leaf tissue is visible on 50% of the previously dormant buds. Bloom was considered when 50% of the flower caps have dropped, while veraison corresponded to the beginning of ripening (softening or color change on 50% of the berries).

The weather data that were used in this study included the minimum (T_{min}) and maximum (T_{max}) daily air temperature and were recorded by two automated weather stations located at approximately 750-868 m from the vineyard (46.3°N; 119.7°W; 260–365 m. above sea level). The weather stations were located close each other and had similar conditions. The data were downloaded from the AgWeatherNet Portal (www.weather.wsu.edu).

The daily mean air temperature (Ti) for successive phenological stages and the DOY when a stage was observed for each cultivar. *DD* requirement for reaching the stages was calculated as the accumulation of daily *DD* throughout the duration among successive stages (n days) using the base temperature method (Arnold 1959) as showed below.

$$Ti = \frac{(Tmax + Tmin)}{2}$$

$$DD = \sum_{i=1}^{n} Ti - Tb$$

Base temperatures were estimated individually for the three phenological stages and for each individual cultivar and estimating the temperature that minimizes the standard deviation for *DD* between the different years (Table 1).

Using the variation between years a lapse of DD_{min} and DD_{max} where the occurrence of the stage is more likely was calculated. The values obtained for the T_b varied among cultivars and phenological stages. The lowest T_b value was found for budbreak, with an increase for both bloom and veraison. Also, the variation of the estimated T_b's for each stage increased from budbreak through veraison (Table 1).

Table 1. Base temperatures, and DD requirement for the three stages and seventeen cultivars.

Cultivar by color	*Budbreak*			*Bubbreak-Full bloom*			*Full bloom-Verison*		
	Tb	DD_{min}	DD_{max}	*Tb*	DD_{min}	DD_{max}	*Tb*	DD_{min}	DD_{max}
Red									
Cabernet Franc	*7.4*	*92*	*124*	*7.9*	*330*	*346*	*12.5*	*506*	*610*
Cabernet Sauvignon	*8.3*	*72*	*102*	*10.4*	*219*	*230*	*12.5*	*494*	*581*
Limberger	*7.3*	*92*	*129*	*8.9*	*289*	*301*	*10.7*	*595*	*742*
Malbec	*7.7*	*62*	*109*	*8.8*	*309*	*315*	*11*	*528*	*722*
Merlot	*7.6*	*107*	*144*	*9*	*281*	*296*	*10.5*	*653*	*741*
Meunier	*6.1*	*153*	*214*	*7.1*	*347*	*356*	*10.5*	*570*	*679*
Pinot Noir	*8.1*	*72*	*101*	*9.7*	*235*	*246*	*12.1*	*541*	*635*
Syrah	*7.3*	*61*	*156*	*8.7*	*349*	*354*	*10*	*635*	*790*
Zinfandel	*7.2*	*114*	*169*	*9.1*	*277*	*288*	*11.2*	*580*	*667*
White									
Chardonnay	*6.5*	*121*	*161*	*8.2*	*316*	*328*	*9.7*	*680*	*769*
Chenin Blanc	*6.9*	*107*	*140*	*7.7*	*340*	*353*	*9.2*	*733*	*844*
Gewurtztraminer	*7*	*111*	*153*	*8.4*	*302*	*317*	*10.5*	*623*	*724*
Muscat Blanc	*6.6*	*109*	*172*	*8.3*	*331*	*337*	*11.2*	*521*	*642*
Pinot Gris	*6.9*	*125*	*191*	*8.3*	*284*	*293*	*10.4*	*652*	*701*
Sauvignon Blanc	*7.4*	*89*	*128*	*8.8*	*304*	*315*	*11.1*	*558*	*657*
Semillon	*7*	*115*	*154*	*8.7*	*282*	*290*	*11.7*	*584*	*707*
White Riesling	*7.6*	*83*	*112*	*9.6*	*239*	*254*	*11.6*	*571*	*671*

Objective 2. To evaluate the model with expanded data from different environmental conditions and to implement the model as a decision support tool on the AgWeatherNet portal for use by local grapevine growers and orchard managers.

A tool was created to implement the model developed in the objective 1 in the AgWeatherNet portal to simulate the interval of days with a higher probability of reaching 50% of bud break, full bloom and veraison for each cultivar (http://weather.wsu.edu/?p=104050). This simulation is possible to perform using any of the stations of the AgWeatherNet to cover all the productive areas in the state.

The interface requires the input of cultivar, year, and closest station to simulate and predict the interval dates. Then, the view of the interface is as below (Diagram 1).

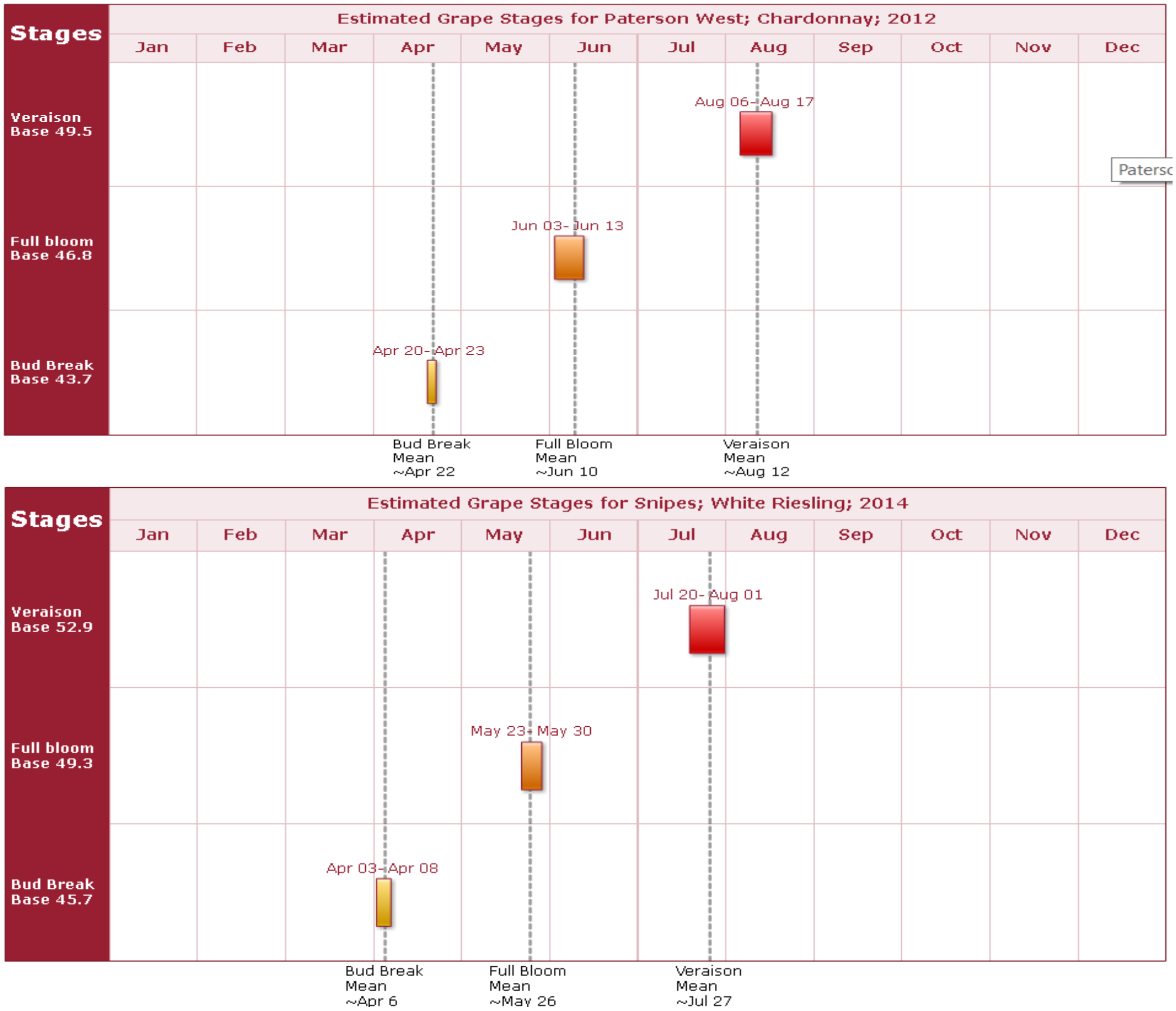

Diagram 1. View of the interface for simulation of grape stages in two different scenarios.

A database supplied by Hogue Ranches and Viticulture Department of WSU was used to evaluate the model; it included 600 observed dates of occurrence of the different stages (200 for each stage) and different cultivars from the stations of Roza, Paterson West, Sunnyside and WSU Prosser.

The results showed an appropriate adjustment of the model with a proportion of observed dates inside of the simulated interval of 0.67, 0.89 and 0.70 for bud break, full bloom, and veraison respectively, the total proportion was 0.77. In total 89 observed data were higher than the interval, while only 37 were below. To decrease the uncertainty of the prediction requires less uncertainty at the definition of the starting point for the heat accumulation at each stage. However, this version of the model offers a suitable decision support tool for growers. To evaluate the model with expanded data from different environmental conditions and to implement the model as a decision support tool on the AgWeatherNet portal for use by local grapevine growers and orchard managers.

Objective 3. To determine the dormancy release in grapevine buds for better prediction of bud break.

Photoperiod shortening is the main factor leading the onset of bud dormancy, the critical day length is the photoperiod when dormancy induction occurs (Fennell and Hoover, 1991). Then, the temperature is the main factor that impacts the phenology during dormancy and bud break occurrence and intensity; an exposure of chilling is required at the beginning of the dormancy period called endodormancy. Then, DD requirement controls the dormancy release; this phase is called ecodormancy (Andreini, et al., 2009). So far no biophysical method has been developed to infer the beginning of endodormancy to determine the start the chilling accumulation for modeling, nor the transition from endodormancy to ecodormancy to establish the beginning of heat accumulation (Alonso, et al., 2005).

In that way, the dates of the endodormancy and ecodormancy onset were estimated (Table 2) evaluating the duration from sampling to budbreak of single node cuttings placed in a growth chamber at a constant temperature of 25±1°C with 15 hours of light (forcing conditions for budbreak) during 2013, 2014, 2015 and 2016 (in progress). The cuttings were sampled from an experimental vineyard located at the Irrigated Agriculture Research Extension Center (46.3°N; 119.7°W; 355 m above sea level), Washington State University, Prosser, WA.

Endodormancy period, in general, is longer for Cabernet Sauvignon, its critical day length is higher meaning that dormancy induction is earlier. Besides, the chilling requirement of 'Chardonnay' is lower. Unlike the ecodormancy period which is shorter for Cabernet that has a lower DD requirement (Table 2).

Table 2. Observed dates for endodormancy induction, release and bud break

Year	*Cultivar*	*Induction*	*Release*	*Bud Break*
2013	*Cabernet Sauvignon*	*4-Sep*	*6-Nov*	*22-Apr*
2014	*Cabernet Sauvignon*	*1-Sep*	*16-Nov*	*8-Apr*
2015	*Cabernet Sauvignon*	*5-Sep*	*8-Nov*	*11-Apr*
2013	*Chardonnay*	*7-Sep*	*29-Oct*	*22-Apr*
2014	*Chardonnay*	*9-Sep*	*26-Oct*	*29-Mar*
2015	*Chardonnay*	*7-Sep*	*25-Oct*	*8-Apr*

With the occurrence dates for each stage the critical day length, the chilling requirement, and DD requirement were calculated (Table 3). The base temperature for both cultivars was 5.2 ºC which was calculated with the same method mentioned in the objective 1. Further, with that method the temperature thresholds for chilling units (CU) were also calculated; one chilling unit is one hour of exposure of the grapevine to temperatures between a minimum threshold (5 ºC and 7.9 ºC) and a maximum threshold (14.5 ºC and 15.5 ºC) for Cabernet Sauvignon and Chardonnay respectively.

Table 3. Intervals of day length, chilling requirement, and DD where most likely dormancy induction, endodormancy release and BB occur respectively

	Cabernet Sauvignon	*Chardonnay*

	min	*max*	*min*	*max*
Critical day length for dormancy induction (Hours)	*12.8*	*13.4*	*12.7*	*13.0*
Chilling requirement to overcome endodormancy (CU)	*590.0*	*600.0*	*320.8*	*326.5*
DD for ecodormancy release and BB	*276.2*	*290.8*	*284.4*	*336.1*

This model can be used as decision support to predict the BB occurrence. An accurate prediction of BB has severeal advantages, including a better efficiency for pest and disease control activities, treatments to make uniform or to increase the percentage of BB (hydrogen cyanamide) or improved pruning (Swanepoel, et al., 1990).

Information Dissemination, Extension, and Outreach Activities:

Zapata D.M., Salazar M., Chaves B., Keller M., and Hoogenboom G. 2014. Determination of cultivar-specific threshold temperatures and heat requirements for prediction of budbreak, full bloom, and veraison in wine grape. Poster presentation at the 2014 Annual Conference of the American Society for Horticultural Science (ASHS) that was held on July 28th – August 1st in Orlando (FL).

Zapata D.M., Salazar M., Chaves B., Keller M., and Hoogenboom G. 2014. Dormancy Stage and Budbreak in Wine Grapes. Poster presentation at the Washington State University Academic Showcase, March 28th, Pullman (WA).

Zapata, D.M., Salazar M., Keller M., Mills L., and Hoogenboom G. 2013. A model for predicting budbreak, blooming, and veraison on wine grape cultivars. Oral presentation at 40th SACNAS National Conference - Society for Advancement of Chicanos and Native Americans in Science; 2013 October 3–6; San Antonio, Texas.

Salazar, M., B. Chaves, M. Keller, L. Mills, D. Zapata, and G. Hoogenboom. 2013. Changes in wine grape phenology and the relationship with local climate in Washington. Poster presented at the 2013 Washington Association of Wine Grape Growers, Kennewick, Washington.

Zapata, D., M. Salazar, M. Keller, L. Mills, and G. Hoogenboom. 2013. How it works: starting date and base temperature for the prediction of the developmental stages of grape. Poster presented at the 2013 Washington Association of Wine Grape Growers, Kennewick, Washington.

Zapata, D., M. Salazar, M. Keller, L. Mills, and G. Hoogenboom. 2012. Prediction of key phenological stages for grapevine. Poster presented at the 2012 Washington Association of Wine Grape Growers, Kennewick, Washington

Camargo, H., M. Salazar, B. Chaves, and G. Hoogenboom., (2016, February). Predicting Key Phenological Stages for Grapevines. A Simple but Scientific Approach for Management and Site Selection. Poster session and short presentation at WAWGG Annual Meeting, Convention. Tri Cities (WA).

Camargo, H., M. Salazar, and G. Hoogenboom. (2016, September). Predicting the dormancy and bud break dates for grapevines. Oral presentation at Hortimodel 2016 conference of the International Society for Horticultural Science, Avignon, France.

Camargo, H., M. Salazar, and G. Hoogenboom. 2016. Predicting the dormancy and bud break dates for grapevines. Hortimodel 2016 submitted paper. Acta Horticulturae.

Literature Cited:

1. Alonso, J., Anson, J., Espiau, M. and Socias, R. 2005. Determination of endodormancy break in almond flower buds by a correlation model using the average temperature of different day intervals and its application to the estimation of chill and heat requirements and blooming date. J Amer Soc Hort Sci, 130 (3):308-318.
2. Andreini, L., Viti, R. and Scalabrelli, G. 2009. Study on the morphological evolution of bud break in Vitis vinifera L. Vitis 48 (4):153-158.
3. Arnold, C. 1959. The determination and significance of the base temperature in a linear heat unit system. Proc. Am. Soc. Hortic. Sci 74:430-445.
4. Caffarra, A., and E. Eccel. 2010. Increasing the robustness of phenological models for Vitis vinifera cv.
5. Chardonnay. Int. J. Biometeorol. 54:255-267.
6. Fennell, A. and Hoover, E. 1991. Photoperiod influences growth, bud dormancy, and cold acclimatation in Vitis labruscana and Vitis riparia. Journal of American Society of Horticultural Science 116 (2):270-273.
7. Hoover, M. 1955. Some effects of temperature on the growth of southern peas. Proc. Am. Soc. Hortic.
8. Sci. 66:308-314.
9. Johnson, I., and J. Thornley. 1985. Temperature dependence of plant and crop process. Ann. Bot-London. 55:1-24.
10. Jones, G.V., and R. Davis. 2000. Climate influences on grapevine phenology, grape composition, and wine production and quality for Bordeaux, France. Am. J. Enol. Vitic. 51:249-261.
11. Kwon, E., J. Jung, U. Chung, and J. Yun. 2008. Using Thermal Time to Simulate Dormancy Depth and
12. Bud-Burst of Vineyards in Korea for the Twentieth Century. J. Appl. Meteorol. Climatol. 47:1792-1801.
13. Moncur, M. 1989. Base temperatures for budbreak and leaf appearance of grapevines. Am. J. Enol. Vitic. 40:21-26.
14. Parker, A.K., I.G. De Cortázar-Atauri, C. Van Leeuwen, and I. Chuine. 2011. General phenological model to characterise the timing of flowering and veraison of Vitis vinifera L. Aust. J. Grape Wine
15. Res. 17:206-216.
16. Snyder, R.L., D. Spano, P. Duce, and C. Cesaraccio. 2001. Temperature data for phenological models. Int. J. Biometeorol. 45:178-83.
17. Swanepoel, J. Villiers, F. and Pouget, R. 1990. Predicting the date of budburst in Grapevines. S Afr. J. Enol. Vitic. 11 (1):46-49.
18. Yang, S., J. Logan, and D. Coffey. 1995. Mathematical formulae for calculating the base temperature for growing degree days. Agric. For. Meteorol. 74:61-74.