Unified Grant Management for Viticulture and Enology
CONTINUING PROPOSAL FOR THE 2022-2023 FUNDING CYCLE

OREGON WINE BOARD (OWB)

1. **Project Title**: Determining optimal irrigation initiation time

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3. **Cooperator(s)**: DANCIN Vineyards, Irvine & Roberts Vineyards, St. Laurent Land & Cattle Co., Pacific Crest Vineyard Services LLC

4. **Objective(s) of Proposed Research or Outreach Project**:

Determine optimal initiation time for irrigation using departures from non-stressed baseline stem water potential values

- *1.1. Pilot phase (end of 2020 growing season)*
  - *1.1.1. Identify grower-collaborator(s) and study site(s)*
  - *1.1.2. Identify data vines for field variability assessment*
  - *1.1.3. Measure vine water status at veraison and harvest*
  - *1.1.4. Determine appropriate experimental design from pilot data*
- *1.2. Experimental phase (2021 and 2022 seasons)*
  - *1.2.1. Layout plots based on predetermined experimental design (year 1)/maintain plots (year 2)*
  - *1.2.2. Measure vine water status regularly from late-May to harvest*
  - *1.2.3. Impose treatments*
  - *1.2.4. Collect agronomic data at harvest*
  - *1.2.5. Correlate agronomic data with initiation times and applied water amounts*

5. **Justification and Importance of Proposed Research or Outreach Project**:

When to initiate irrigation is a critical decision that can have a large impact on the current season's production. However, there is a remarkable lack of published work on *when* to start irrigating grapevines in the beginning of the season, especially considering the overwhelming body of literature that exists covering the topic of *how much* to irrigate. For example, a cursory keyword search of Thompson Reuters Web of Science database using "grape" and "irrigation," returned 888 publications. Adding "rate" reduced the number to 145, whereas adding "initiation" reduced the number to merely five. Clearly, a better understanding of the optimal initiation time for irrigation is required.

In addition to saving water and pumping costs, delaying irrigation initiation can have many positive direct and indirect effects on grapevine growth and development. Direct benefits include reducing overall vine vigor and organ growth by imposing a slight water deficit. It is well-documented that growth (cell expansion) is the physiological process most sensitive to water deficits (Hsiao 1973). Delaying irrigation would impose an early season water deficit that would reduce shoot elongation (Matthews et al. 1987) and berry growth (Matthews and Anderson 1989). Important indirect benefits would be an increase fruit quality by stimulating phenolic biosynthesis and reducing methoxypyrazines (Castellarin et al. 2007; Koch et al. 2012) and a decrease in disease pressure by creating a more favorable cluster microclimate (Iandolino et al. 2013; Stapleton et al. 1990). Thus, it is economically favorable to delay the initiation of irrigation just enough to create a slight water deficit.

Delaying irrigation for too long, however, has many negative effects, most of which are well-known to any agriculturist. Severe water deficits would result in weak plant growth (Hsiao 1973), inhibition of photosynthesis (Williams 2012), and reduced storage of reserve carbohydrates (Torres et al. 2021b). Moreover, fruit could be overexposed to solar radiation, causing sunburn and degradation of polyphenolics that would reduce wine quality (Torres et al. 2021a). Finally, small fruit would mean low yields in the current and subsequent seasons resulting in reduced profitability for the grower over several years (Levin et al. 2020). Thus, waiting too long to turn on the water can have devastating economic consequences and threaten long-term vineyard sustainability.

The three well-known methods for determining when to initiate irrigation are soil-based, ET-based, and plant-based – each with their own advantages and disadvantages. However, most are in agreement that for high quality wine grape production, plant-based methods are superior since they directly measure the level of water stress in the plant (Shackel 2011). In addition, there is a large body of literature describing various physiological responses to plant-based measures (as reviewed by Williams (2017).

The pressure chamber is considered the “gold standard” of plant-based measurement tools and though it is an old tool, it is still highly useful and relevant (Levin 2019). Measurement of midday stem water potential (SWP) has been shown in multiple woody perennial crop species to be a robust indicator of plant water status (Shackel 2011). However, it is still very sensitive to environmental conditions, which can often complicate data interpretation over time, thus making informed irrigation management decisions more difficult. By normalizing measured SWP values to environmental conditions at the time of measurement, the user can remove the environmental variables from the equation and simplify data interpretation over time and space. This can be done by expressing measured values to a theoretical non-stressed baseline value.

The non-stressed baseline water potential is the theoretical maximum water status that plants achieve under non-limiting soil moisture conditions (Williams and Baeza 2007). In other words, it is the plant water status in field capacity soils. Importantly, plant water status cannot be improved through more irrigation. When the soil is at field capacity, water is easily extracted by plants – and thus transpiration is driven solely by the water potential gradient between the leaf and the atmosphere, known as the vapor pressure deficit (VPD). As the soil dries out, the plant’s water status will depart from the non-stressed baseline value as it experiences increasing water stress and responds less to VPD. This departure can be used as a relative marker of water stress over time, across sites, and across cultivars to determine when to initiate irrigation.

This project directly addresses three key strategic pillars of the Oregon Wine Board: **Wine Quality, Sustainable Production,** and **Changing Climate**. This proposal is focused on the Oregon Wine Board specific area of interest centered around "*Developing or improving environmentally and economically sustainable methods of viticulture and their effects on grape composition, ripening, and vine health, and their amelioration of the effects of climate change."* In particular we focus on *"identifying and improving irrigation monitoring and management practices, methodologies, and precision technologies."*

In addition, the benefits of this research will enhance the sustainability of Oregon's agriculture through improved understanding and management of water resources – a core pillar outlined in the Oregon Water Resources Department Strategic Plan for 2019-2024 (https://bit.ly/39ESZ1s). This project has defined and industry-driven outcomes related to wine grape and wine production by directly improving management practices of wine grape growers across the state. The outcomes of this project will be valuable in improving competitiveness and sustainability of wine grape growers and winemakers, therefore allowing the whole industry to better manage irrigation and remain profitable.

6. **Procedures to Accomplish Objective(s)**:

Determine optimal initiation time for irrigation using departures from non-stressed baseline stem water potential values

Experimental treatments. Irrigation treatments will be characterized by varying the initiation timing based on normalized vine water status thresholds (ΔSWP). ΔSWP is defined as departure of measured midday stem water potential (SWP_{abs}) from the calculated non-stressed baseline (SWP_{ns}):

$$\Delta SWP = SWP_{ns} - SWP_{abs}$$

SWP_{abs} will be measured using a pressure chamber (model 615, PMS Instrument Company, Albany, OR) as described in Levin (2019), and SWP_{ns} will be calculated from air temperature and relative humidity measurements from previously published relationships (Williams and Baeza 2007). Five treatments will be applied at each site once plot-averaged ΔSWP are within the described treatment ranges:

Treatment	ΔSWP threshold for irrigation initiation
T1 (control)	0.2 MPa (2 bar)
T2	0.4 MPa (4 bars)
T3	0.6 MPa (6 bars)
T4	0.8 MPa (8 bars)
T5	1.0 MPa (10 bars)

Irrigation scheduling. Upon initiation of irrigation in each treatment, vines will be irrigated at 70% ET_c using two 2 L/hr. emitters per vine. Vineyard ET_c will be estimated using the following equation: $ET_c = ET_o * K_c$, where ET_o is grass reference ET and K_c is the crop coefficient. Weekly totals of daily ET_o will be obtained from the weather station (MDFO, AgriMet, United States Bureau of Reclamation) located at the Southern Oregon Research and Extension Center (SOREC). The crop coefficient will be calculated weekly from accumulated growing degree-days (GDD) from 1 April (base 10° C) using a VSP-specific equation developed by A.D. Levin (developed in projects previously funded by Oregon Wine Board and Agricultural Research Foundation at OSU). Applied water will be measured using inline water meters with telemetry for remote data transfer.

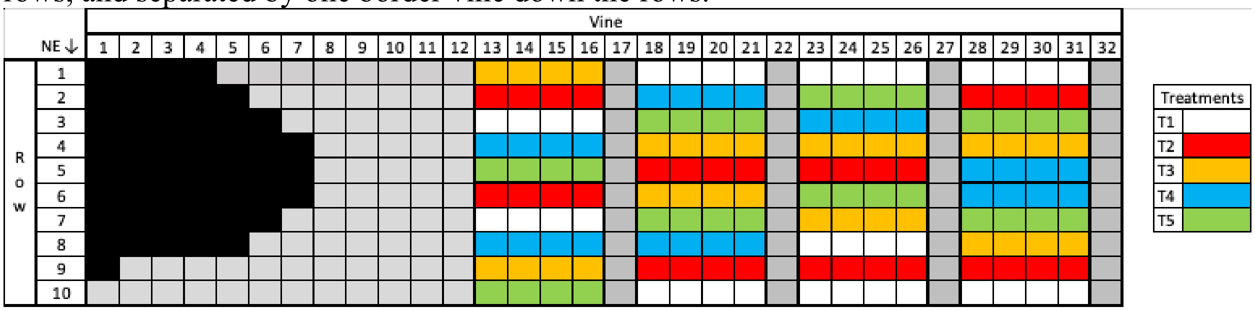
Sites and plot layout

Three commercial vineyards have been selected as field sites for the experimental portion of this project. While all are planted to the same rootstock-scion combination, have the same planting density, and trellis/irrigation infrastructure, they are located in distinct areas of the Rogue Valley. These sub-regions represent a broad transect of different soil types and climates, thus inferences can be generalized to range of conditions. Full details about sites including vineyard design and soil characteristics, and all results from pilot phase are given in the attached annual progress report.

Layout plots based on predetermined experimental design

At each of the three sites, the five irrigation treatments are laid out in a randomized complete block design (RCBD) with eight replications (Fig. 1).

Figure 1. Plot layout at Irvine site that is representative for all sites. Layout shows the five treatments (T1-T5) arranged in an RCBD with eight replications. Treatments are blocked across rows, and separated by one border vine down the rows.



Measure vine water status regularly from late-May to harvest

SWP_{abs} will be measured weekly as described above beginning approximately one month after budbreak (mid- to late-May, depending on site) through to harvest. Efforts will be made to ensure measurements are taken just prior to an irrigation set to characterize maximum water deficit during that period. Non-stressed baseline SWP values will be calculated at each measurement date/site as described above. One leaf per plot will be measured for SWP and used for data analyses. Just prior to SWP_{abs} measurements, stomatal conductance and fluorescence measurements will be taken using a porometer/fluorometer (LI-600, LI-COR Biosciences, Lincoln, NE). Sampled leaves will be similar to those as for SWP. Four leaves will be measured per plot and used for data analyses.

Impose treatments

Treatments will be imposed once treatment-averaged ΔSWP are within the described treatment ranges by opening valves for plots assigned to those treatments. In other words, the average ΔSWP of all plots within a given treatment must be within the range to impose treatment. Once valves are open and irrigation has been initiated, irrigation will be applied as described above.

Collect agronomic data at harvest and quantify applied water amounts

Agronomic data will be collected at harvest to characterize crop yield and quality in response to treatments. Just prior to commercial harvest, 50-berry fruit samples will be collected from each plot and brought back to the laboratory for further analyses described below. At harvest, individual vines will be harvested, clusters counted, and fruit weighed using a field scale. Berry samples will be brought back to the lab and weighed with an analytical balance. A subsample of 20 berries/plot will be saved and stored at -80ºC for HPLC-DAD analyses of flavonoids as in Torres et al. (2021a). The remaining fruit will be crushed, juice decanted, centrifuged, and analyzed for primary chemistry as follows: total soluble solids (TSS; ºBrix) will be measured using a handheld digital refractometer (AR200, Reichert Technologies, Buffalo, NY), while juice pH and titratable acidity will be measured using an auto-titrator (T50, Mettler-Toledo, Columbus, OH).

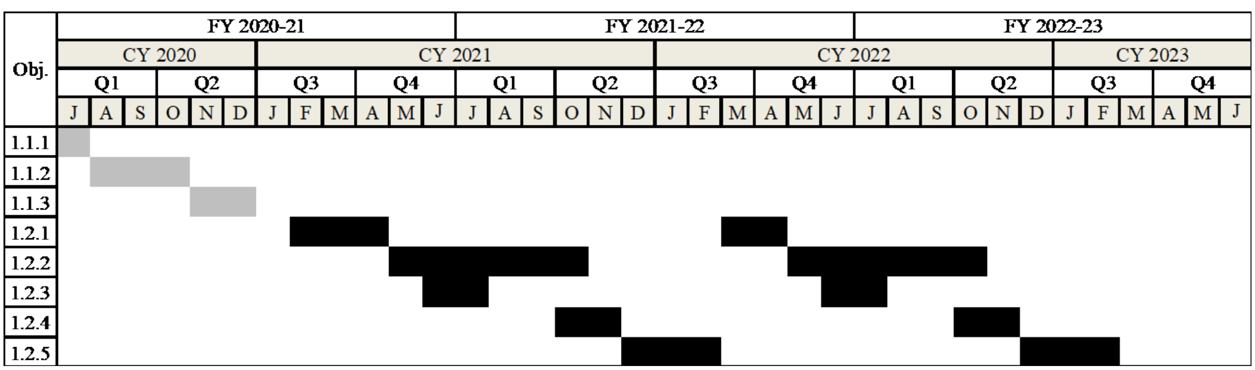
Analyze agronomic data and correlate with initiation onset timing and applied water amounts

Time-series plots of applied water, ΔSWP, and SWP_{abs} will be constructed to verify that vines received different amounts of water, and treatments were successfully imposed based on described methods. Agronomic data collected at harvest will be analyzed for each site separately by one-way ANOVA with statistical significance considered at $p < 0.05$. A unified analysis of all sites together will also be conducted to determine any significant effects of treatments across sites. Simultaneous pairwise comparisons among treatment means will be made for each response variable tested, and *p*-values adjusted for multiplicity using Dunnett's method. In addition, planned orthogonal contrasts will be used to conduct trend analyses to optimize initiation time based on fruit quality responses.

7. **Timetable for Project**:

The proposed timetable for this project is shown in Figure 2. Both the pilot and first year experimental phases of the project have been completed (Subobjectives 1.1 and 1.2). Details are given in the accompanying report document. The second year of the experimental phase will conclude in the 2022 growing season and data analyzed in early 2023.

Figure 2. Month-by-month of project activities by objective over the course of three fiscal years (FY). Also shown are corresponding calendar years (CY), fiscal quarters (Q1-Q4), and calendar months. Gray shading indicates pilot phase, while black shading indicates full experimental phase.



8. **Present Outlook and Estimated Success in Accomplishing Objective(s)**:

The present outlook for accomplishing proposed objectives is extremely positive. The pilot phase and first year experimental phase of the project have been completed. Sites have been identified, and collaborative agreements have been made with participating project partners. Plots have been laid out and marked at each site, and irrigation systems have been installed. At present, nearly all field data from 2021 growing season have been collected, and work is ongoing to process remaining samples and analyze data. All field instrumentation has been calibrated prior to deployment for the upcoming growing season. Laboratory instruments are similarly well-maintained and all SOPs are developed. We are fully prepared to continue this work in 2022 growing seasons.

9. **Outreach and Education**:

Approximately one-third of the PI's appointment at OSU specifically requires outreach and engagement with the wine grape industry. Thus, information obtained in this study will be disseminated by participating in wine grape industry meetings throughout Oregon at those sponsored by the OSU Extension Service. This research has already been showcased during the Southern Oregon Wine Grape field day in July 2021. Preliminary research results will be presented to industry meetings at the Oregon Wine Symposium in February 2022 and the Southern Oregon Grape Symposium in March 2022. Preliminary research results will also be presented to a national academic audience at the American Society of Enology and Viticulture (ASEV) national conference in June 2022, and to an international academic audience at the TerClim 2022 conference in Bordeaux, France in July 2022. It is anticipated that the results will also be published in trade journals/press (e.g., *Wine Business Monthly, Good Fruit Grower*) and peer-reviewed scientific journals such as the *American Journal of Enology and Viticulture* or *The Journal of the American Society for Horticultural Science.*

10. **Budget Support Summary by Objective(s)**:

Personnel: $36,790

Funds are requested for part-time salary and benefits for a Biological Sciences Research Technician II ("Technician") in each year of the study. Technician will be employed at 0.5 FTE. Responsibilities of the Technician will include execution of all field measurements (e.g., stomatal conductance and SWP), irrigation scheduling, coordinating harvest, and performing laboratory analyses. In addition, Technician will perform basic maintenance of treatment plots. Finally, Technician will collect and manage data, perform basic statistical analyses, and generate reports. Base salary for Technician is $40,020/year. Accordingly, other payroll expenses (OPE) for Technician are calculated at 83.86% of base salary.

Supplies and Expenses: $2,500

Funds are requested to cover expenses related to all field and laboratory consumable supplies, as well as yearly instrument and plot maintenance. Field and laboratory consumable supplies include compressed gas, sample bags, lab reagents, tubes, and vials ($1,000). Instrument maintenance costs include yearly cleaning and calibration of pressure chamber, light sensors, and HPLC ($1,500). Any plot maintenance costs associated with plot irrigation system components such as tubing, emitters, emitter plugs, meters and data loggers are factored in as well.

Travel: $2,000

Funds are requested to support travel to research sites and for outreach activities. Round trip travel to all three experimental sites from SOREC will be 86 miles total. We estimate 20 trips per year per site at OSU mileage rate of $0.58/mile ($987). Remaining funds will be used to partially support PI and/or laboratory staff registration and travel to regional program meetings/conferences (e.g., registration fees, airfare, lodging, per diem, incidentals; $1,013).

11. **Total Budget Request**:

Item/Category	% Time on project	Requested 2022-2023
Personnel		
Bio Sci Research Tech II	50%	20,010
OPE (83.86%)		16,780
	Personnel Subtotal	**36,790**
Supplies and Expenses		
Field and laboratory supplies		1,000
Instrument maintenance		1,500
	Supplies and Expenses Subtotal	**2,500**
Travel		
Mileage to experimental sites		987
Conference/meetings/outreach		1,013
	Travel Subtotal	**2,000**
	TOTAL REQUEST	**41,290**

12. **Literature Cited**:

Castellarin, S.D., M.A. Matthews, G. Di Gaspero, and G.A. Gambetta. 2007. Water deficits accelerate ripening and induce changes in gene expression regulating flavonoid biosynthesis in grape berries. Planta 227:101-12.

Hsiao, T.C. 1973. Plant responses to water stress. Annual Review of Plant Physiology 24:519-570.

Iandolino, A.B., R.W. Pearcy, and L.E. Williams. 2013. Simulating three-dimensional grapevine canopies and modelling their light interception characteristics. Australian Journal of Grape and Wine Research:n/a-n/a.

Koch, A., S.E. Ebeler, L.E. Williams, and M.A. Matthews. 2012. Fruit ripening in Vitis vinifera: light intensity before and not during ripening determines the concentration of 2-methoxy-3-isobutylpyrazine in Cabernet Sauvignon berries. Physiol Plant 145:275-85.

Levin, A.D. 2019. Re-evaluating pressure chamber methods of water status determination in field-grown grapevine (Vitis spp.). Agricultural Water Management 221:422-429.

Levin, A.D., M.A. Matthews, and L.E. Williams. 2020. Effect of Preveraison Water Deficits on the Yield Components of 15 Winegrape Cultivars. American Journal of Enology and Viticulture 71:208-221.

Matthews, M.A., and M.M. Anderson. 1989. Reproductive Development in Grape (*Vitis vinifera* L.): Responses to Seasonal Water Deficits. American Journal of Enology and Viticulture 40:52-60.

Matthews, M.A., M.M. Anderson, and H.R. Schultz. 1987. Phenologic and growth responses to early and late season water deficits in Cabernet franc. Vitis 26:147-160.

Shackel, K. 2011. A Plant-based Approach to Deficit Irrigation in Trees and Vines. Hortscience 46:173-177.

Stapleton, J.J., W.W. Barnett, J.J. Marois, and W.D. Gubler. 1990. Leaf removal for pest management in wine grapes. California Agriculture 44:3.

Torres, N., J. Martinez-Luscher, E. Porte, R. Yu, and S. Kaan Kurtural. 2021a. Impacts of leaf removal and shoot thinning on cumulative daily light intensity and thermal time and their cascading effects of grapevine (Vitis vinifera L.) berry and wine chemistry in warm climates. Food Chem 343:128447.

Torres, N., R. Yu, J. Martinez-Luscher, E. Kostaki, and S. Kurtural. 2021b. Application of Fractions of Crop Evapotranspiration Affects Carbon Partitioning of Grapevine Differentially in a Hot Climate. Frontiers in Plant Science 22.

Williams, L.E. 2012. Effects of applied water amounts at various fractions of evapotranspiration (ETc) on leaf gas exchange of Thompson Seedless grapevines. Australian Journal of Grape and Wine Research 18:100-108.

———. 2017. Physiological tools to assess vine water status for use in vineyard irrigation management: review and update. Acta Horticulturae:151-166.

Williams, L.E., and P. Baeza. 2007. Relationships among Ambient Temperature and Vapor Pressure Deficit and Leaf and Stem Water Potentials of Fully Irrigated, Field-Grown Grapevines. American Journal of Enology and Viticulture 58:173-181.