WA 46°N WINE

Washington State Grape and Wine Research Program
Washington State Wine Commission Research Grant Program

FINAL REPORT and SUMMARY
2024-25 Funding Cycle

Project Title: Advancing Sensor-based Irrigation Scheduling

Principal Investigator: Dr. Pete Jacoby, Washington State University, Pullman

Project Duration: Three years, FY 2022-2025 funding cycle

Summary: Project funding for this project provided a partial match to a Northwest Center for Small Fruit Research (NCSFR) grant. This combined funding supported data collection from two sites instrumented with soil water content sensors (Syntek Drill & Drop probes) and soil water tensiometers (METER Group Teros Gen. II). The sites each contain four replicates of paired sensors under surface drip and subsurface drip. Research plots were sited within commercial vineyard blocks of red wine varieties (*Cabernet Sauvignon* at Kiona Winery near Benton City, WA and *Syrah* at Ducleaux Cellars near Milton-Freewater, OR). Soil moisture data was recorded for three growing seasons and grape samples collected from treatments were weighed for yield estimates and analyzed for quality attributes.

The Kiona site was irrigated at a 60% deficit rate applied under a grower determined irrigation schedule and the Ducleaux site was irrigated by a sensor driven automated system from a sentinel sensor at 20-in. below soil surface. Data is being analyzed to correlate soil water depletion rates with soil water tension after repeated irrigations under each method of irrigation scheduling. These analyses will determine the impact of irrigation scheduling techniques to maintain yields while extending periods of soil water tension and related periods of moderate vine stress for enhancing grape quality factors.

While this research will progress under a currently supported grant from NCSFR, the results to date can be summarized as follows: (1) soil water content sensors that are contained within a probe and are capable of measuring to a depth of 2-3 feet can be used to drive automated irrigation. The depth of the sentinel sensor should be selected at a depth at which soil water depletion rate begins to stabilize after the irrigation event has concluded; (2) use of a soil water tensiometer can provide additional verification of soil water status by indicating when vines cannot extract soil water and additional vine stress will occur; (3) both soil water content and water tension status will vary according to soil type and can be predictive of the on-set and duration of vine water status.

The vine itself is considered the best indicator of impacts from various edaphic (soil) and atmospheric factors on physiological status of the vine, and stem water potential has been found to be a good indicator of vine water stress. However, the process of measuring stem water potential is time consuming, and when done during the highest temperatures of the day when vine water stress is typically at a zenith, researchers are exposed to potential heat stress levels that could expose them to heat stroke. In July of 2025, a pair of FloraPulse stem water potential sensors were installed on 18-year old vines at the Kiona research site to provide an indication of stem water potential differences between vines irrigated by surface drip and

subsurface drip irrigation. These sensors are producing a continuous record of stem water potential in real-time and reveal an amazing level of diurnal change in stem water stress.

Washington State Grape and Wine Research Program

FINAL REPORT

WRAC Project 2023-3.CP.JP1
DURATION: FY 23 - FY 25 July 2022-June 2025

ADVANCING SENSOR-BASED IRRIGATION SCHEDULING

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Cooperators

Kiona Winery and Vineyards, Benton City, WA

Ducleaux Cellars and Vineyards, Milton-Freewater, OR

Tuctronics Partnership, Inc., Walla Walla, WA

Overview: This project received $40,445 from WA Wine over a 3-year period to partially match federal funding provided via competitive grants from the Northwest Center for Small Fruits Research. Project objectives described below were addressed in experiments conducted within cooperating commercial vineyards listed above. Collaboration with a locally owned small business, Tuctronics Partnership, provided a critical source of expertise on soil water sensors and irrigation automation, as well as support services in programming and instrument maintenance.

Project Objective(s) and Experiments Conducted to Implement Each: The over-arching objective of this proposed study was to evaluate the combined use of two types of soil water sensors for enhancing irrigation efficiency. Irrigation amount and frequency of application was monitored through recorded measurements of soil water content and soil water tension. The primary hypothesis being tested was to determine the potential to achieve and maintain a consistent level of water stress on the grapevine under deficit irrigation. If accepted, findings would confirm the ability for using sensors to control irrigation scheduling to achieve water savings while maintaining goals for both grape yield and quality.

The study site at Kiona Vineyards involved a grower determined, manually activated irrigation schedule while the vineyard block at Ducleaux Cellars and Vineyards near Milton-Freewater, OR used sensor-controlled water management involving automatic irrigation scheduling using a program called AutoWATER which was developed by Tuctronics Partnership. At each location four replicated sets of soil water content and soil water tension sensors were installed in plots receiving either surface drip or subsurface drip application treatments. Experimental design was a randomized complete block with four replications.

Specific objectives addressed during this study included the following:

1. Install and initiate continuous data recording sensors with cloud data storage capacity. Sensors included METER Group TEROS 21 Gen.II tensiometers to determine soil water matric potential (soil water that is available to the vine) paired with Syntek (Drill and Drop) water content sensors that measure the total soil water content (available and soil bound) within the top 24-36 inches of the soil profile. The Kiona site also contained eight SENTEK (EnviroSCAN) electronic water capacitance probes, each capable of tracking total soil water content across a 72-84 inch-deep soil profile. These probes allow a comparison of water content measured in real-time under four rates of irrigation applied as surface drip versus subsurface drip. An advantage of Syntek probes is gained by the manner in which they are installed which reduces the amount of soil disturbance compared to installation of other types of sensors commercially available. Data storage for all studies is being maintained on a cloud server provided by Tuctronics Partnership.

2. Evaluate the combined data from these two sensor types (total water content and available water) for potential use in automated irrigation scheduling systems. At the Kiona site, soil water sensors are recording both content and availability of water to vines currently being irrigated at 60% of water replacement equivalent, applied by either surface drip or subsurface drip released at two (2) feet below soil surface. The METER sensors were installed by hand at depths of 10, 18, and 26 inches below soil surface to determine the best placement depth for determination of soil water availability under both surface drip and sub-surface drip.

3. Obtain simultaneous measurements of vine water stress in the treatment plots with a water status console and an auto-porometer with internal infrared gas analyzer to determine rates of transpiration and photosynthesis on four (4) dates during the growing season to correlate vine water stress with both soil water content and availability for scheduling irrigation events.

4. Analyze data and present to growers through popular media (commodity press articles, radio, and recorded podcasts) **as well as peer reviewed scientific journals with high impact ratings**.

Summary of Major Research Accomplishments and Results by Objective:

Objective 1. Eight Syntek drill and drop probes were installed in four pairs to monitor soil water content at 4-inch intervals with the top 2-3 feet of the soil profiles at each research site (Kiona and Ducleaux) and data was obtained in real-time during the entire growing season during each year of the study. These sites are continuing to produce data under funding provided by a grant from the Northwest Center for Small Fruit Research. Likewise, soil water tension data is being generated by the METER Group Teros Gen.II soil water tensiometers at both sites.

Objective 2. No determination has been made regarding the necessity for using more than one type of sensor to drive automated irrigation. Hopefully, a future research proposal will provide some resolution to this issue by producing an algorithm built from multiple types of sensors. Based on research to date, it is recommended that sensor placement should be near the base of the vine and the sentinel sensor for water content be at a depth of 15-20 inches below the soil surface and the sentinel sensor for soil water tension should be placed at a similar depth and proximity to the vine for either surface drip or subsurface drip. Sentinal sensors are defined as those used to regulate automated irrigation scheduling.

Objective 3. This objective was impacted by a slow start of the growing season owing to cooler temperatures which delayed the implementation of deficit irrigation in both 2022 and 2023 growing seasons. The latter season (2023) was cooler and wetter than normal and did not produce stress levels in vines that were needed to evaluate this objective. The El Nino conditions experienced in the dormant season of 2023-24 also impacted assessment of stress impacts made during summer of 2024. Additionally, extremely cold events in 2024 greatly reduced fruit production in most blocks at the Ducleaux vineyards. Fortunately, our research was located within a block of the winegrape cultivar Syrah JP which demonstrated more cold resistance than the other varieties and cultivars planted within the vineyard and both yield and quality of grapes was achieved.

In addition to the weather conditions impacting data retrieval, the workforce required to obtain simultaneous data collection during extremely hot daily temperatures to document overall vine activity level, a different method for estimating stem water stress in future research being investigated via the use of FloraPulse stem water potential sensors. Two of these sensors were successfully installed in 2025 and appear to be functioning well. If results prove positive, this sensor could replace the need for using other methods to measuring relative levels of vine water stress in future studies. An additional advantage would be a continuous record of vine water stress rather than data obtained during the period of a few hours on a single day.

Objective 4.

Outreach and Education Efforts - Presentations of Research: It is critically important to communicate research results to end-users and stakeholders. A variety of media methods are available to execute this communication or research outreach. Successful collaboration with professionals employed with commodity trade journals and media outlets has been experienced

in our program. This source usually reaches intended audiences quickly and efficiently. Our program has also conducted field-based research/outreach events conducted in grower-owned vineyards and at local commodity events. For creating a durable record of research results, publishing research findings in peer reviewed journals with high impact ratings to reach the global scientific community may prove the best method to represent Washington State University on a global basis. These journals also provide peer reviews of science and methodology with lower potential for rejection of papers on bias from peer rivalry than publications published by commodity-based organizations and professional societies.

An emphasis on outreach efforts during 2023 produced numerous publications, podcasts, and popular media products during the year. A number of these publications were published in the UK and distributed across a large international audience. Localized outreach included presentations and publications through WAVE and VEEN, as well as local radio and popular press within WA. A list of outreach articles published during this project life is included below.

Peer Reviewed, High Impact, International Journals

Veloo, K., C.Z. Espinoza, A.E. Salgado, P.W. Jacoby, and S. Sankaran. 2025. Multispectral, thermal, and hyperspectral sensing data depict stomatal conductance in grapevine. *Remote Sens.* 2025, *17*(1), 137; https://doi.org/10.3390/rs17010137

Sadeghi, S.H., H.W. Loescher, P.W. Jacoby, and P.L. Sullivan. 2024. A simple, accurate, and explicit form of the Green-Ampt model to estimate infiltration, sorptivity and hydraulic conductivity. *Vadose Zone Journal*. John Wiley & Sons, Inc. https://doi.org/10.1002/vzj2.20341

Jacoby, P.W. 2023. Use of Deficit Irrigation to Enhance Winegrape Production Efficiency. ***In***: Zhang, Q. (eds) *Encyclopedia of Smart Agriculture Technologies*. Springer, Cham. https://doi.org/10.1007/978-3-030-89123-7_179-1

Ma, X.C., J. Wu, F. Han, Y. Ma, P.W. Jacoby. 2023. Optimizing crop water productivity and altering root distribution of Chardonnay grapevine (*Vitis vinifera* L.) in a silt loam soil through direct root-zone deficit irrigation. *Agricultural Water Management* https://doi.org/10.1016/j.agwat.2022.108072

Extension Outreach, Popular Press, Symposium Proceedings and Conference Abstracts

Jacoby, P.W. 2025. *Achieving Sustainable Water Use in Vineyards.* Poster presentation for the Annual Ravenholt Lecture and WAVE (WA Advancements in Viticulture & Enology) event. WSU-TC campus, Richland, Apr. 23.

Jacoby, P.W. 2025. *Subsurface Irrigation for Greater Vineyard Water Productivity.* Invited oral presentation delivered to an international webinar attended by scientists and vineyard owners from Portugal, Spain, France, and Italy. Lisbon, Portugal. Apr. 17.

Jacoby, P.W. 2025. *Optimizing vineyard irrigation.* Invited paper published in *Irrigation Today* a national publication of the Irrigation Association. Jan 29.

Jacoby, P.W. 2024. *Enhancing vineyard drought resilience and soil regeneration through sensor-driven scheduling of deep subsurface drip irrigation.* NCSFR Ann. Conf. proc., p. 30, Boise, ID. Nov. 17-19.

Jacoby, P.W. 2024. *Optimizing Water Use in Vineyards with Sensor-controlled Subsurface Irrigation*. Interactive flash talk presented at WSARE CAP conference. Salt Lake City, Utah. Oct. 1-2.

Jacoby, P.W. 2024. Enhancing Crop Water Productivity in Vineyards with Soil Water Sensors to Schedule Sub-surface Drip Irrigation. Published abstract and presentation at ASABE Ann. Meeting, Anaheim, CA. July 28-31.

Jacoby, P.W. 2024. Combating drought to increase soil water retention in vineyards. Adjacent Digital Politics Ltd., Crewe, Cheshire, UK https://doi.org/10.56367/OAG-043-10909

Courtney, Ross. 2024. Underground watering spreads across vineyards. Good Fruit Grower Magazine, April 15 Issue. https://www.goodfruit.com/underground-watering-spreads-across-vineyards/

Jacoby, P.W. 2024. Advancing sensor-based irrigation scheduling. PowerPoint oral presentation to WA State Wine Commission Research Advisory Committee annual research review, February 21-22. WSU Prosser – IAREC.

Jacoby, P.W. 2024. Use of DRZ Subsurface Irrigation for Greater Vineyard Water Productivity. Recorded oral PowerPoint presentation at Sustainable Washington – Central WA Soil Health in Irrigated Perennial Crop Production meeting, February 13. WSU Prosser – IAREC.

Jacoby, P.W. 2024. Optimizing water use in vineyards with sensor-controlled subsurface irrigation. Abstract and Poster presentation at WineVit – The WA Winegrowers Association annual meeting, February 5-7. Kennewick, WA

Jacoby, P.W. 2024. Improving vineyard irrigation efficiency with soil water sensors. Adjacent Digital Politics Ltd., Crewe, Cheshire, UK https://doi.org/10.56367/OAG-041-10909

Jacoby, P.W. 2023. Use of DRZ subsurface irrigation and sensor-based irrigation scheduling for greater vineyard water productivity. Invited Key-Note 50-minute address: Texas Wine Grape Growers Assn. Grape Camp, Nov. 14-16, Lubbock, TX.

Jacoby, P.W. 2023. Optimizing Water Use for Winegrapes with Sensor-controlled Subsurface Irrigation. Abstract in conference proceedings and Poster Presentation: Northwest Center for Small Fruit Research – Annual Conference, Nov. 13, Corvallis, OR

Jacoby, P.W. 2023. Optimizing Crop Water Productivity in Wine Vineyards. Audio Podcast describing research for saving water with DRZ subsurface irrigation. https://app.acaudio.com/playlist/from-farm-to-table-exploring-the-agricultural-sector

Jacoby, P.W. 2023. Enhancing irrigation effectiveness in vineyards with innovative technologies. Adjacent Digital Politics Ltd., Crewe, Cheshire, UK September 19, 2023. https://doi.org/10.56367/OAG-040-10909

Jacoby, P.W. 2023. Soil Water Sensors: Monitoring Water Use and Irrigation Scheduling. WSU-Vit/Enology News, Fall 2023 Issue, pp. 6,7 & 9. https://wine.wsu.edu/extension/viticulture-enology-news-veen/

Jacoby, P.W. 2023. Direct rootzone irrigation for enhancing drought resilience of winegrape vineyards. Abstract, 3rd Global Conference on Agriculture and Horticulture, Valencia, Spain. Sept. 11-13, 2023. https://agri-conferences.com/uploads/past-events/3rd-edition-of-global-conference-on-agriculture-and-horticulture-2023-book.pdf

Allen, Lee. 2023. Subsurface irrigation boon to vines. Western Farm Press, July Issue, p.18. Article based on phone interview with Pete W Jacoby. Western Farm Press : July 2023 (mydigitalpublication.com)

Allen, Lee. 2023. Scientist: Irrigation at roots is best. Farm Progress, June 8. Article based on phone interview with Pete W Jacoby. https://www.farmprogress.com/grapes/scientist-irrigation-at-roots-is-best

Jacoby, P.W. 2023. Direct Root-Zone: A novel form of subsurface irrigation delivery in vineyards. E-Book published by Adjacent Digital Politics Lt., Crewe, Cheshire, UK . https://edition.pagesuite professional.co.uk/html5/reader/production/default.aspx?pubname=&edid=a02fecd3-f5d1-4f24-87d3-6c929626eb6b

Jacoby, P.W. 2023. Optimising subsurface drip irrigation for effective drought defence. Adjacent Digital Politics Lt., Crewe, Cheshire, UK https://www.openaccessgovernment.org/optimising-subsurface-drip-irrigation-for-effective-drought-defence/162119/ https://doi.org/10:56367/OAG-039-10884

Jacoby, P.W. 2023. The importance of irrigation systems in enhancing winegrape vineyards resilience. Adjacent Digital Politics Ltd., Crewe, Cheshire, UK https://www.openaccessgovernment.org/irrigation-systems-enhancing-winegrape-vineyards-reslience/157257

Jacoby, P.W. 2023. Deep Root-zone Irrigation. WA Wine WAVEx webinar. 50 minutes. https://www.washingtonwine.org/wave/

Research Success Statements: This research has provided vintners/growers with the essential tools to utilize irrigation water to achieve highest irrigation efficiency and crop water productivity while ensuring irrigation sustainability during periods of drought and excessive summer heat events. Additionally, current research focused on automated irrigation scheduling with soil water sensors holds promise for labor saving and better use of irrigation delivery methods to reduce power and waste of water resources. Publications in preparation address strategies to improve soil nutrient retention through use of DRZ^{TM} subsurface drip irrigation. Other publications are being prepared for assessment of pulse irrigation on reducing number of irrigation applications and soil related water depletion rates for scheduling temporal irrigation events.

International and national recognition of the research being conducted by this project has been assessed by numbers of graduate student inquiries from foreign countries, literature citations in high impact international journals, and invited presentations. In 2025, the program leader received an invitation to present this research before an international conference on subsurface drip irrigation held in Portugal and another invited paper for *Irrigation Today*, the monthly publication for the Irrigation Association that includes members from industry across the U.S. Recognition from this paper focused in integrated sensor application and use of AI algorithms in automated irrigation systems has initiated several potential collaborations with industry leaders.

The unique nature of the system labeled "DRZ" (Direct Root Zone) allowed WSU to obtain a federal trademark for the process of using this single point subsurface delivery method of drip irrigation. This trademark (DRZ^{TM}) may soon be followed by a licensing agreement with a commercial firm which could mass produce and distribute the delivery devices and key operational methods for sale to the public.

Funds Status: All funds from this grant have been expended during FY25.

Project funds allocated in FY25 have been spent in the following categories.

Salaries and benefits:	-0-	
Wages and benefits:	-0-	
Equipment:	-0-	
Goods and services:	62%	(funds spent on diesel fuel for project vehicles, irrigation supplies and hand tools, equipment and instrument repairs)
Travel:	38%	(local in-state travel to collect data and obtain samples)
Other:	-0-	
TOTAL	**$ 8,000**	