Annual/Final Report Format 2023-2024 Funding Cycle

California Grape Rootstock Improvement Commission (CGRIC)

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1. **Summary**

Field evaluation and survey of grapevine rootstock drought susceptibility in northern California

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This study focuses on surveying and evaluating grapevine rootstock performance under drought conditions in variable mesoclimates of northern California. The initial phase of this project focused on identifying the most purchased and planted grape rootstock cultivars in wine grape producing regions of northern California. With help from collaborating vineyard owners, manager, and nurseries, we identified five rootstock cultivars which account for over 70% of the volume of grafted vines sold from 2019-2022. These were 101-14 Mgt, 1103 Paulson, 110 Richter, 3309C, and SO4. These cultivars were identified as the most in-demand in the Lake, Mendocino, and Sonoma counties within the previously stated timeframe. These cultivars were selected to compare drought responses in wine grapes among disparate climate regions of the north coast in the 2023 growing season (April – October). Additionally, these rootstocks represent a wide range of purported tolerance to water-limiting conditions and should provide stark contrasts in performance by viticultural region.

Following identification of rootstock cultivars, it has been the objective of this study to quantify the responses to drought conditions for each grape rootstock given unique mesoclimatic conditions. Nine collaborator vineyards were chosen to represent eight separate American Viticultural Areas, each with one or more of the selected rootstock cultivars grafted to Cabernet Sauvignon or Chardonnay. During the initial stages of site selection, the scion varieties Pinot noir and Sauvignon blanc were considered for inclusion in the study. However, after difficulties finding combinations with all rootstock cultivars across three counties, it was decided to limit the study only the two scion varieties, Cabernet Sauvignon and Chardonnay; these scions account for nearly 40% of the planted winegrape acreage in California and are readily found in most regions. Beginning in May 2023, data on vine water status, berry development, and seasonal environmental changes were recorded on a monthly basis at each collaborating vineyard. Vine performance data was collected and compared with environmental data including precipitation, temperatures, direct solar radiation, and soil physical and chemical properties. Observed trends and patterns were summarized to elucidate distinctions in rootstock performance under unique mesoclimates.

2. **Annual or Final Report:** Annual report 2023-2024

3. **Project title and UGMVE proposal number:**

   Project title: *Field evaluation and survey of grapevine rootstock drought susceptibility in northern California*

   Proposal number: 2022-2650

4. **Principal Investigator/Cooperator(s):**

Principle Investigator: Dr. Christopher Chen

Cooperator(s):

Dr. Andrew Walker
Novavine Nursery
Sunridge Nurseries
Redwood Empire Vineyard Management
Brassfield Estate Vineyards and Winery
Bonterra Organic Estates
Hopkins Vineyard
Roederer Estate
Redwood Empire Vineyard Management Company

5. Objective(s) and Experiments conducted to meet objective(s):

Objective 1: *Survey current grapevine rootstock preferences and availability*

The primary objective of the first six months of this study was to identify candidate rootstocks for drought-tolerance testing which are currently available to and in good-standing with wine-grape growers in the North Coast region of California. From the start of the project in October 2022 to December 2023, the PI gathered data to identify the top five grape rootstock cultivars which fit this criteria. Data was provided directly from project collaborators and has been identified as 'sensitive' by several organizations. In order to respect the position of project collaborators, this report has summarized the information on rootstock preferences in a pooled-summary of values provided to this study by both nurseries and growers.

Due to the long-term scope of this study, selection of rootstock cultivars was based on both the volume sold and planted as well as regional preferences for particular rootstocks.

Objective 2: *Evaluation of common grapevine rootstock drought tolerance*

During 2022, seven sites were identified as study locations. These study locations are located within a geographic range of approximately 3,000 mi^2 and represent seven different American Viticultural Areas across three counties of northern California. An additional four sites were added in early 2023 to increase the range of this study across the majority of vineyard growing regions in northern California.

Site selection was dependent upon rootstock cultivars present and grafted to scions matching Chardonnay and/or Cabernet Sauvignon. Due to the difficulty of matching clones across different properties, scion clone was not considered as a variable of concern. These scion varieties were chosen because together they represent approximately 40% of the planted acreage for wine grapes across California. Sites were also selected to each represent a unique mesoclimates in the North Coast region. Two of the eleven trial locations are located in a valley adjacent to coastline, two sites are situated in an alluvial flood plain, one site is located near an opening to San Pablo Bay, and the remaining sites represent inland-valley-floor or mountainous vineyards.

Water infiltration test –Anderson Valley

Of the sites selected each is unique for the region. Hopkins Vineyard was selected as a site which experiences regular flood events and often has completely submerged Chardonnay vines during winter rains. Brassfield Estates Winery was selected to represent Cabernet Sauvignon on multiple rootstocks in high-elevation, volcanic soils. Roederer Estates and three site managed by Redwood Empire Vineyard Management Company are located in coastal and inland valleys, where the former is at a higher latitude and reaches colder temperatures in winter. Site locations provided by Bonterra Organic Estates and Redwood Empire Vineyard Management Company are located in near-coastal, valley floor mesoclimates which reach higher temperatures than the other sites in this study.

Pruning weights (2022)

Site-specific data for soils were collected for each location. These data include soil nutrient and organic matter profiles, soil water holding capacity, soil infiltration rates, and soil bulk density. Temperature data loggers were also installed at each site to record differences in diurnal and seasonal temperature shifts among all study plots. Some of the vineyard trial locations also have weather stations, however these stations differ in construction, materials, or measurement devices and were not included in the study information for lack of uniformity.

Data the Normalized Difference Vegetation Index (NDVI) and actual evapotranspiration (ET_c) were collected for years 2018-2023 from the online database, OpenET for blocks corresponding to field studied areas. These data were analyzed and visualized using R studio software.

Beginning in May 2023, test plots were selected at each site, flagged, and monitored for indicators of water stress throughout the 2023 growing season. This was achieved with use of a N_2 gas pressure chamber and measured as bars of stem water potential which were converted to megapascals for subsequent figures and tables. Berry characteristics such as total soluble solids (TSS) were recorded on a monthly basis for each study location. Other primary metabolites such as pH, and titratable acidity (TA), will be analyzed from frozen samples in 2024. Yields were collected between September and October 2023 and recorded prior to harvest. Winter pruning weights will be collected in January and February 2024 prior to vineyard managed pruning.

Data related to weather and environmental conditions will be analyzed and correlated with grapevine physiological data following final data collection in 2024.

Objective 3: *Trial establishment and environmental control*

Establishment of a statewide trial to test rootstock drought tolerance is dependent upon further funding of this project. Project number 2023-2756 was submitted to funding agencies in January 2023 to support further testing and trial establishment. Funding was not granted for that proposal 2023-2756 and may be resubmitted in the following cycle. Rootstocks selected for this study directly match those in the preliminary work of project number 2022-2650 with the exception of the cultivar 'Freedom', which was included to increase relevance to San Joaquin Valley grape growers. The submitted proposal (# 2023-2756) recommends the establishment of three sister-study sites located at University of California Hopland Research and Extension Center, Kearney Research and Extension Center, and Langtwins Vineyard in Lodi, CA. These locations represent three unique climatic regions where winegrapes are grown. This proposal is backed by the University of California RECs and the private grower at Langtwins currently and will include four additional Co-PIs on the project.

Objective 4: *Drought tolerance and rootstock performance*

Summary of rootstock drought tolerance and performance under drought conditions are addressed in this report for project number 2022-2650. Conditions in 2023 saw colder spring temperatures and higher winter precipitation than historic averages. This led to a lack of drought stress at experimental sites previously described. Data on vine water status, berry development, and final yields were still collected. Temperatures at each site were also recorded with an in-field temperature data logger. These data show unique differences in vine performance in the given growing season by site and rootstock within each scion cultivar.

6. Summary of Major Research Accomplishments and Results by Objective:

Objective 1: *Survey current grapevine rootstock preferences and availability*

Based on data collected from growers and nursery collaborators, the top five most-demanded rootstock cultivars represent approximately 80% of grape rootstocks grafted and planted since 2020. These rootstocks are as follows in descending order: 1103 Paulson, Freedom, Salt Creek/Ramsey, 3309C, and SO4. However, these rootstocks do not directly represent the demand in the North Coast region of California where Freedom and Ramsey have little to no demand by growers. Specifically for the North Coast the most-demanded rootstocks are as follows in descending order: 1103 Paulson, SO4, 3309C, and 110 Richter. There is significant overlap in rootstock preferences between the North Coast region and the state of California as a whole, with notable exceptions such as Freedom and Ramsey.

Region	Rootstock	Approx. %	Years
Statewide	1103 Paulson	36	2020-2022
Statewide	Freedom	25	2020-2022
Statewide	Salt Creek/Ramsey	7	2020-2022
Statewide	3309 C	7	2020-2022
Statewide	SO4	5	2020-2022
North Coast	1103 Paulson	40	2020-2022
North Coast	SO4	12	2020-2022
North Coast	3309 C	12	2020-2022
North Coast	110 Richter	11	2020-2022

This information suggests a strong preference for 1103 Paulson, SO4, and 3309C both within the study region of northern California and across the state in its entirety. These values are approximations of the recent demand of each rootstock listed and only represent what was provided to the project by collaborators. Likewise, availability of rootstocks were limited to trial collaborators. Limitations were only noted with respect to 1103 Paulson rootstocks, suggesting high demand and insufficient supplies.

Objective 2: *Evaluation of common grapevine rootstock drought tolerance*

To evaluate grapevine rootstock drought tolerance, this study requires collaboration by private grape-growers in the North Coast region of California. Study sites were scouted and selected to overlap with a given list for both scions and rootstocks. Scions were selected by most-planted acreage in California Districts 1, 2, and 3. Rootstocks were selected based on data provided by industry collaborators. Sites for this study were selected if they met the requirements for the study. These requirements included the following:

1. Willing to collaborate with this project
2. Has one or more of the following scions:
    - Cabernet Sauvignon
    - Chardonnay
3. Has two or more of the following rootstocks grafted to scions listed above:
    - 101-14 mgt
    - 110 Richter
    - 1103 Paulson
    - 3309C
    - SO4
4. Is located in a different mesoclimatic region and/or American Viticultural Area than other collaborators

Scion cultivars included in this survey represent >50% of planted wine-grape acreage in Districts 1, 2, and 3. Scion clone was not included in the requirements due to the difficulty with matching clone-scion-rootstock combinations across vineyards and among distinct regions. Rootstock cultivars represent approximately 70% of the rootstocks sold or planted for wine-grape production in the North Coast region of California since 2019. Currently the rootstocks and scions at existing study sites are presented in the table below. There are eight American Viticultural Areas represented across the three counties included in this study. They are as follows:

County	AVA #1	AVA #2	AVA #3
Mendocino	Anderson Valley	McDowell Valley	Sanel Valley
Lake	High Valley	Red Hills	
Sonoma	Petaluma Gap	Russian River Valley	Chalk Hill

Each collaborating vineyard has been given the designation of either coastal valley, inland valley, or inland mountainous mesoclimate based on average annual growing degree days and distance from the nearest coastline. Classifications may change based on climate-related data by the conclusion of this survey. Currently the delineation of coastal or inland is as follows:

Coastal - Valley	Inland - Valley	Inland – Mountainous
Hopkins Vineyard	Fetzer/Bonterra Org.	Beckstoffer Vineyards
Santo Giordano	LaFranchi Vineyard	Battle Vineyards
Roederer Estates	Blue Heron	Brassfield Estates
Navarro Vineyards	Anthony’s Hill Vineyard	

Results – Vine Performance (2023)

Data was collected on vine water stress and berry development regularly through the 2023 growing season. At harvest, data was also collected for individual cluster weights and counts per vine. These data showed significant differences when compared between rootstocks, scions, and geographic locations in almost all cases.

a) Vine Water Stress

While grapevines were not water stressed in the north coast regions of California in 2023. Stem water potentials (SWPs) were measured at each site once per month to elucidate any differences in performance among rootstocks or geographic locations. Pre-harvest irrigation occurred during the first week of September at most sites which decreased water stress on vines but showed the rate of recovery from drought-stress relative to each scion (Fig. 1).

Every input variable included in this study (i.e., Date of Measurement, Rootstock, Scion, and Geographic Location) significantly impacted stem water potential measurements (Table 1). Interactive effects were also found between Rootstock, Scion, County, and Date in 2023 suggesting that vine water stress at a given timepoint is affected by the grower’s choice of rootstock and scion combination, as well as the site conditions of the vineyard.

These results suggest that vine water status throughout a growing season will be impacted by the location of the vineyard which had a significant effect on the levels of water stress the vines will experience. This has implications for how vine-water relations data should be reported to the public as conditions on site will impact how vines respond to water stress regardless of rootstock x scion combination.

Data collected during this study corroborates the impact rootstock selection has on vine water stress (Figure 1). Vines grafted to SO4 became more water stressed more rapidly the remaining rootstocks included in this study. Vines grafted to 110 Richter recovered from water stress more rapidly than other rootstocks and to a greater degree.

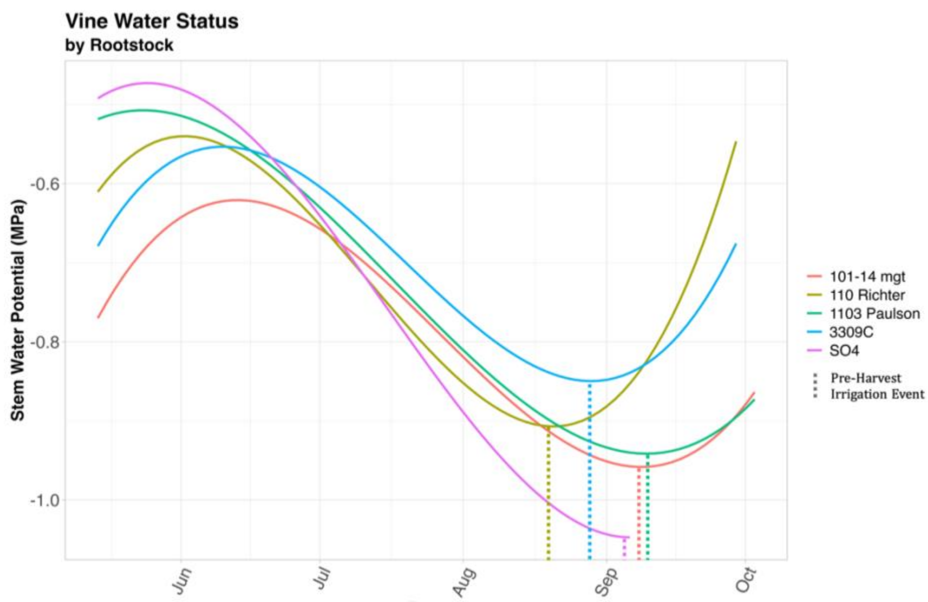

Figure 1: Vine stem water potential by rootstock from May to October 2023.

Table 1: Significance table of input variables on vine stem water potentials.

SWP	***Factor***	**p-value**	**significance**
	Date	<0.001	*
	Rootstock	<0.001	*
	Scion	<0.001	*
	County	<0.001	*
	Date·Rootstock·Scion	0.000208	*
	Date·Rootstock·County	<0.001	*
	Date·County·Scion	0.00056	*

b) Berry Development

Total Soluble Solids (TSS)

Berry development in 2023 was less affected by rootstock or scion choice than SWPs. Sugar accumulation as ºBrix (TSS) were not significantly different by cultivar selections but did vary significantly by county (Table 2). There were no interactive effects present in the data for sugar accumulation

Berry weight

Berry size was also significantly different by geographic location. However, there was also a significant difference by scion. This is an expected result, and it is widely reported that different wine grape cultivars produce differently sized berries.

Berry pH and Titratable Acidity

Throughout the growing season, berry samples were taken and frozen to later analyze berry pH and titratable acidity. These samples are currently being processed using hand titration techniques in laboratory.

Table 2: Significant interactions of input variables with berry sugar accumulation.

TSS	***Factor***	**p-value**	**significance**
	Date	<0.001	*
	Rootstock	0.12	
	Scion	0.913	
	County	<0.001	*
	Date·Rootstock·Scion	0.482	
	Date·Rootstock·County	0.779	
	Date·County·Scion	0.626	

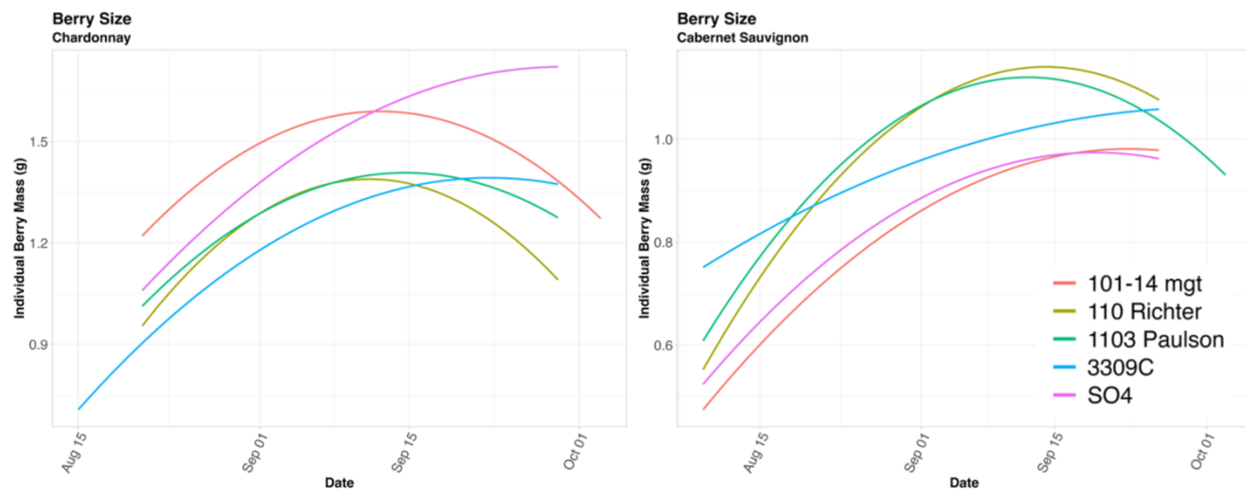

Figure 2: Berry mass, Aug. - Oct. 2024 (left = Chardonnay; right = Cabernet Sauvignon)

c) Harvest Parameters

Vines in each experimental block were harvested by hand and weighed in field, immediately after excision. Harvest weight per vine and cluster count per vine were recorded for each location and block and later analyzed for effects of rootstock, scion, and location on these harvest parameters. Date of harvest was also noted and varied significantly by geographic region (i.e., County) and scion variety. Rootstock had little, to no impact on time of harvest.

Harvest Timing by County, Rootstock, and Scion

Timing of harvest was largely dependent on the geographic location of each test vineyard. The majority of wine grapes in this region were harvested later than average in 2023 compared with previous years. Vineyards located in Lake County had the highest spring temperatures of the three counties where experimental sites were located. The first harvests occurred in Mendocino and Lake counties on Sep. 5 and 6, respectively. The remaining sites in Mendocino County were not ripe until the last week of September; these were the vineyards located in Anderson Valley, a coastal valley where many cold-adapted vineyards exist. Likewise, vineyards located in Sonoma County were not harvested at all until the last week of September 2023. Each harvest was between 2-4 weeks later than historic averages by calendar date.

Cluster Count per Vine and Individual Cluster Weights

The number of clusters per vine varied significantly by all three input variables (Rootstock, Scion, and County) and showed significant interaction effects between rootstock and scion as well as rootstock and geographic region (Table 3). These effects held true for the individual cluster weights but also saw an interactive effect between scion and region.
Differences in cluster count and weight by scion may be somewhat intuitive. However, the significant effect of rootstock, geographic location, and the interaction of these two

variables were somewhat of a surprise. The impacts of geographic location may have been associated with a difference in winter precipitation, bud development the year prior, or some other factor. Weather records are being collected to determine if precipitation or spring temperatures played a major role in the observed differences in harvest parameters by site.

Impacts by rootstock are more notable where rootstock selection had a significant influence on the number of cluster per vine and the weight of each cluster. These data may be influenced by a number of factors including the root architecture, the rate of water uptake at different depths, or the scion interaction of the different grapevine rootstocks. The data on individual cluster weights showed that the scion measured also interacted with the county in which vineyard was located. This effect likely has to do with spring temperatures and water availability in the vineyard.

Table 3: Statistically significant variables in harvest measurements comparing all sites.

# Clusters per Vine		
Factor	p-value	sig
Rootstock	0.006	*
Scion	0.002	*
County	<0.001	*
Rootstock · Scion	<0.001	*
Rootstock · County	<0.001	*
Scion · County	0.916	
Individual Cluster Weight (g)		
Rootstock	0.036	*
Scion	<0.001	*
County	<0.001	*
Rootstock · Scion	<0.001	*
Rootstock · County	<0.001	*
Scion · County	<0.001	*

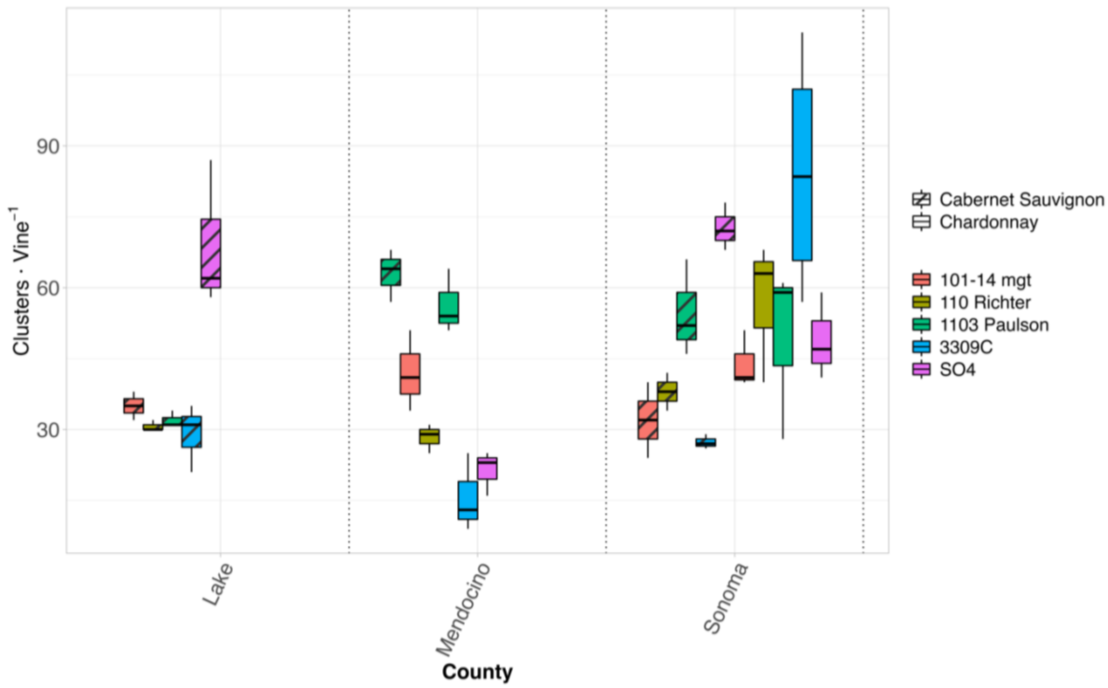

Figure 3: Average cluster count per vine by rootstock (colors) and scion (pattern), 2023.

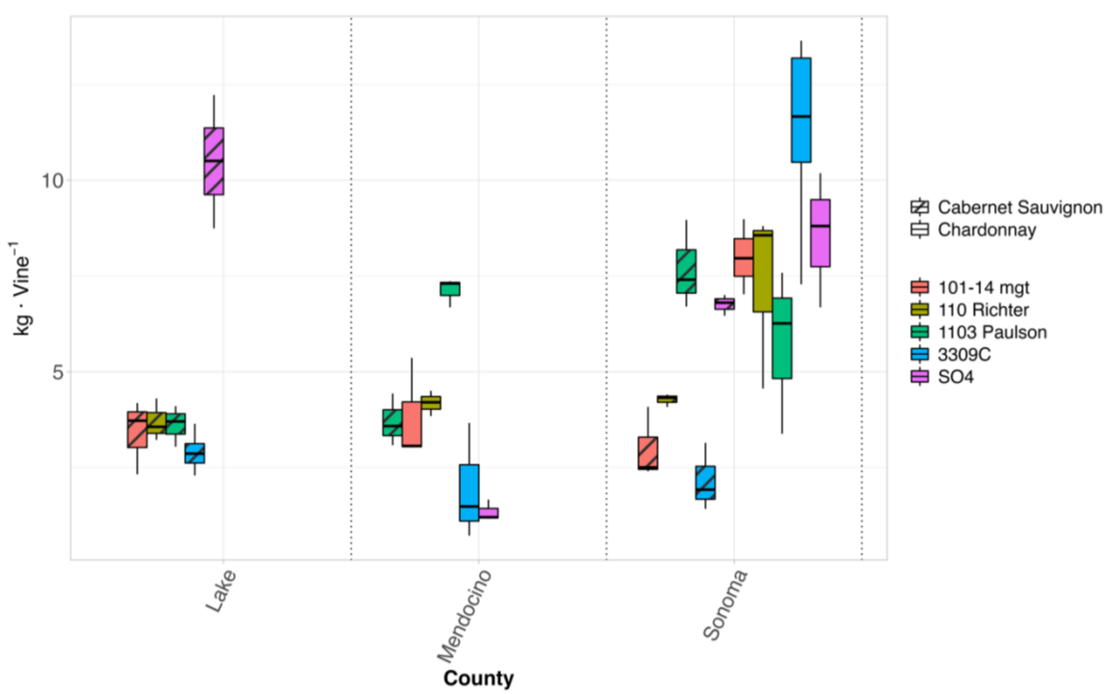

Figure 4: Average yield per vine by rootstock (colors) and scion (pattern), 2023.

Objective 3: *Trial establishment and environmental control*

Site Descriptions

Sites included in this study were classified and grouped by weather and climate, site capacity/potential, and geographic features. Data for these parameters were collected from various sources including open source databases, grower-collected data, and through on-site sample collection and processing. Sites were classified by either county of residence or dominant geographic descriptor, dependent upon the type of data being analyzed. Due to the large number of individual vineyards included in this study, classification by vineyard was not practical.

Elevation

Elevation on-site differs drastically both within and among vineyards included in this study with a minimum elevation of 2 meters above sea level and a maximum of 679 meters above sea level. The largest elevation gain within a single vineyard is 75 meters between blocks. Elevation was expected to influence the amount of incoming solar radiation that the vines are exposed to with more $\mu mol \cdot m^{-2}$ of direct solar radiation being directly related with elevation; this is particularly true of light in the UV spectrum which can be absorbed by air molecules, ozone, particles, and clouds (Blumthaler et al., 1997). However, direct measurements with a handheld spectroradiometer disproved this expectation (Figure 9). Ambient, atmospheric CO_2 concentrations also differ by elevation. Thus, height of a vineyard above sea level may play a role in net carbon assimilation rates of the vines during period of vegetative growth (Blumthaler et al., 1997; Fyllas et al., 2017). NDVI did differ by geographic classification, however coastal vineyards at low elevation had the highest vigor of the three classifications. Likewise, inland mountain vineyards had the lowest NDVI values; this is the opposite response to what was expected based on atmospheric CO_2 levels. Vine vigor may be affected more strongly by variables other than CO_2 concentrations in coastal valleys with ample water availability and high elevation mountainsides with harsh winds and poor soils.

Soils

During the period this trial has been active, soil conditions at separate locations were tested for bulk density, infiltration rate, nutrient content, organic matter content, and water holding capacity. These soil measurements and samples were taken from blocks where vines will be selected for water-stress monitoring beginning in June 2023. However, they are meant to represent the site and the mesoclimatic region in its entirety. Vine water availability will differ by site due in part to soil characteristics which were recorded between October 2022 and March 2023.

Some soil factors were consistent among sites. Bulk density of soils was not significantly different in the middle of vine rows when compared with locations directly underneath vines. However, water infiltration rates were on average threefold faster and significantly higher in the middle of rows when compared to under vines. Infiltration rate was significantly impacted by both the vineyard and location of sampling (i.e., under vine or middle row). It is too early to explain the lack of correlation observed between bulk density and infiltration rate, however all sites tested cultivate cover crops in middle rows and actively remove vegetation underneath vines. Cover crops have been shown to influence water infiltration rates in agricultural settings (Folorunso et al., 1992a; Folorunso et al., 1992b) and could be a contributing factor to the large difference between water infiltration rates underneath vines and in the middle of vineyard rows. The decrease in infiltration rates underneath vines may play a role in excess water runoff and water percolation in the soils during the growing season. This difference may influence vine drought susceptibility as well as water is redirected from the point of initial contact with the soil to a region with higher water infiltration rates.

Soil pH was not significantly different between blocks of the same vineyard but differed significantly among vineyards tested. Soil organic matter and cation exchange capacity were similar among all sites tested as well. Soil electroconductivity differed significantly by both vineyard and sampling location. Of the nutrients included in soil sampling tests the following were found to have no significant differences in total concentration among vineyard locations: P, NO_3-N, Mn, and K. Nutrients which were found in significantly different concentrations among vineyards were: Zn, Ca, Cu, Fe, Mg and Na. The differences observed in salt-like cations such as Mg, Ca, and Na also altered the Ca:Mg ratio and percent CEC accounted for by these three nutrients among most vineyards. Sodium (Na) was particularly high in one of the vineyards closest to San Pablo Bay and had the largest shift in percent CEC accounted for by Na. Nutrients which showed significantly different concentrations by sampling location (undervine or middle row) were: Na and Zn; both are micronutrients and may be influenced by proximity to brackish water sources or cultural practices like foliar micronutrient fertilizers.

Soil testing showed that these locations have relatively similar soil physical properties such as bulk density, infiltration rates, and presence of cover crops. Vineyards tested also showed similar concentrations of most vine-essential macronutrients in Autumn 2022 with the exception of some salt-like cations (i.e., Ca, Mg, Na) and iron. There were few observable differences in soil chemistry when comparing samples taken underneath vines with those from the middle of vineyard rows.

Precipitation

Data for precipitation was collected from the OpenET database and includes information from 2018 to 2023. These data were grouped by geographic type for each vineyard and plotted in Figure 5. Total precipitation within this time frame did not vary by geographic type (e.g., Coastal, Inland, Mountainous), but did vary significantly among experimental vineyards. Total rainfall between November 2022 and June 2023 was also greater than the period between 2019 and 2022. This data shows that the 2023 growing season was not dought-afflicted when compared to the previous three season.

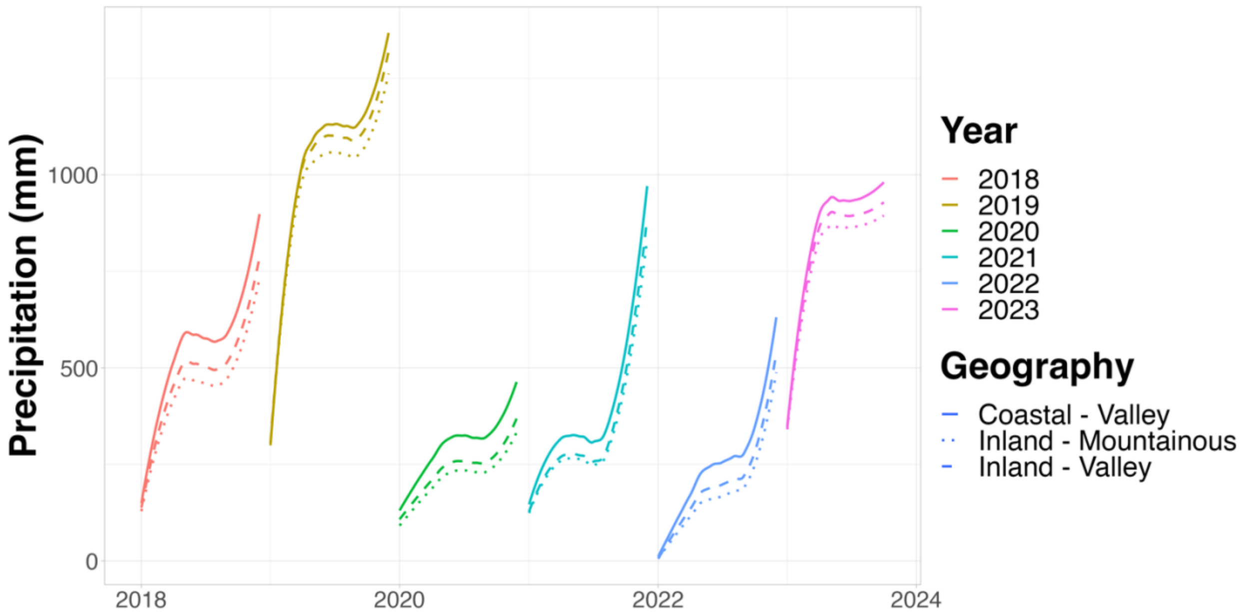

Figure 5: Precipitation by geographic description based on calendar year (2018-2023).

Crop Evapotranspiration and NDVI

Data for crop evapotranspiration (ET_c) were collected via satellite imagery using the Landsat 7-8 satellites and accessed through OpenET software. Data was available from 2018-2023 and represents ET crop for individual blocks included in this study.

ET_c did not differed significantly between home county, rootstock selection, scion choice, nor by geographic classification (Figure 6). However, the recorded volume of precipitation at each site, the estimated NDVI values, and the interaction between NDVI and precipitation did significantly impact crop evapotranspiration.

This result suggests that the level of evapotranspiration from a given vineyard is more impacted by the water available to the vine and the vigor of those vines than by the genetic or geographic influences at the site. Water loss in vineyards appears to be a function of these factors and may not be decreased easily by rootstock or scion selection. The impacts of geography on ET_c may be limited in scope for this study as data was collected from a relatively small area; comparing results from the included experimental sites with others in a more distant region may alter the conclusions drawn on geographic impact on crop evapotranspiration.

When comparing average ET_c and NDVI between 2022 and 2023 (the active years of this study), ET_c was relatively uniform among all sites with the exception of inland valley vineyards (Table 4). These sites geographically unique among the geographic classifications in this study and receive higher temperatures in spring and summer than sites near coastal influence or at high elevation.

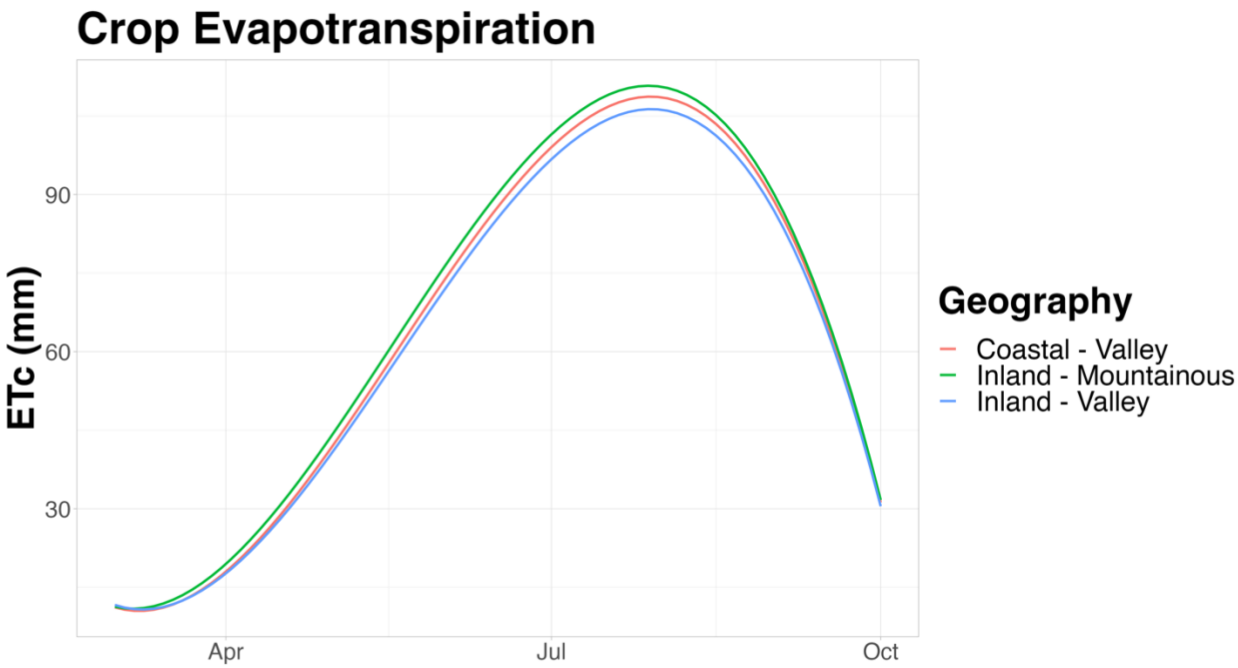

Figure 6: Crop evapotranspiration (ETc) comparing blocks at each experimental site. Colors denote separate blocks within the same vineyard location. Data from OpenET using Landsat 7-8 satellite information with resolution of 30m x 30m

Table 4: Comparisons of crop evapotranspiration and NDVI by geographic classification across years of the study.

Crop Evapotranspiration (ET_c)			
Year	*Geography*	*ETc (mm)*	*Post-hoc*
2022	Inland - Valley	53.31	a
2022	Coastal – Valley	44.28	b
2022	Inland - Mountainous	45.79	b
2023	Inland - Valley	42.66	b
2023	Coastal – Valley	43.50	b
2023	Inland - Mountainous	44.71	b
Normalized Difference Vegetation Index (NDVI)			
Year	*Vineyard*	*NDVI*	*Post-hoc*
2022	Inland - Valley	0.51	a
2022	Coastal – Valley	0.50	ab
2022	Inland - Mountainous	0.49	ab
2023	Inland - Valley	0.44	b
2023	Coastal – Valley	0.53	a
2023	Inland - Mountainous	0.44	b

NDVI differences

While ET_c was consistent and had no significant variability by geographic classification in 2023, the NDVI values of coastal vineyards were higher on average than inland vineyards. In a season of deficit precipitation, this discrepancy may be attributed to cover crop or weed species growth in cooler, foggy coastal vineyards. However, the excess precipitation prior to the start of the 2023 growing season eliminates this as a factor differentially impacting geographic locations. Indeed, cover crops were abundant in 2023 across all vineyard sites.

Growth and vigor of inland sites preceded substantial growth in coastal vineyards in this study and may account for differences between coastal and inland NDVI values based on satellite data (Figure 7). The time of the week/month the satellite image was taken may have an effect on the reported NDVI scores of those sites, particularly if the images were taken before coastal vineyards grew significantly. This is speculation, unfortunately there is no information on temporal aspects of the satellite imagery used for this study.

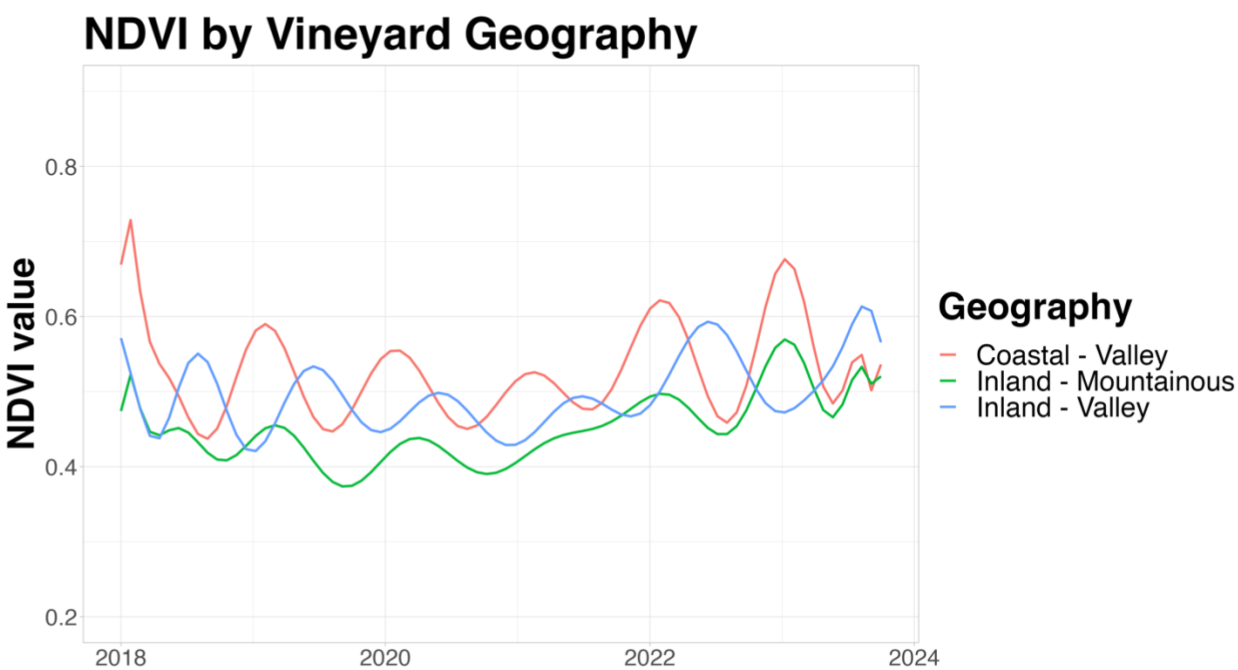

Figure 7: Normalized Difference Vegetation Index (NDVI) comparing blocks. Colors denote unique geographic classifications. Data provided by OpenET software.

Satellite measured NDVI of individual vineyard locations showed that coastal valley vineyards tended to have larger maxima and minima NDVI values in years with insufficient water and may have water availability impacted by coastal morning fog (Figure 5 & Figure 7). In contrast, inland mountainous vineyards had lower NDVI values in all years when comparing maxima and minima for each season, suggesting less vigorous growth regardless of soil properties, rootstock selection, or scion choice (Figure 7). Mountainous regions tend to have higher incidence of solar radiation in wavelengths that are metabolically important to grapevines (Figure 8 & Figure 9) and lower vine vigor. The decrease in vine vigor relative to inland valleys and coastal vineyards may be associated with highly weathered soils, increased UV exposure, higher wind speeds, or some other factor not described here.

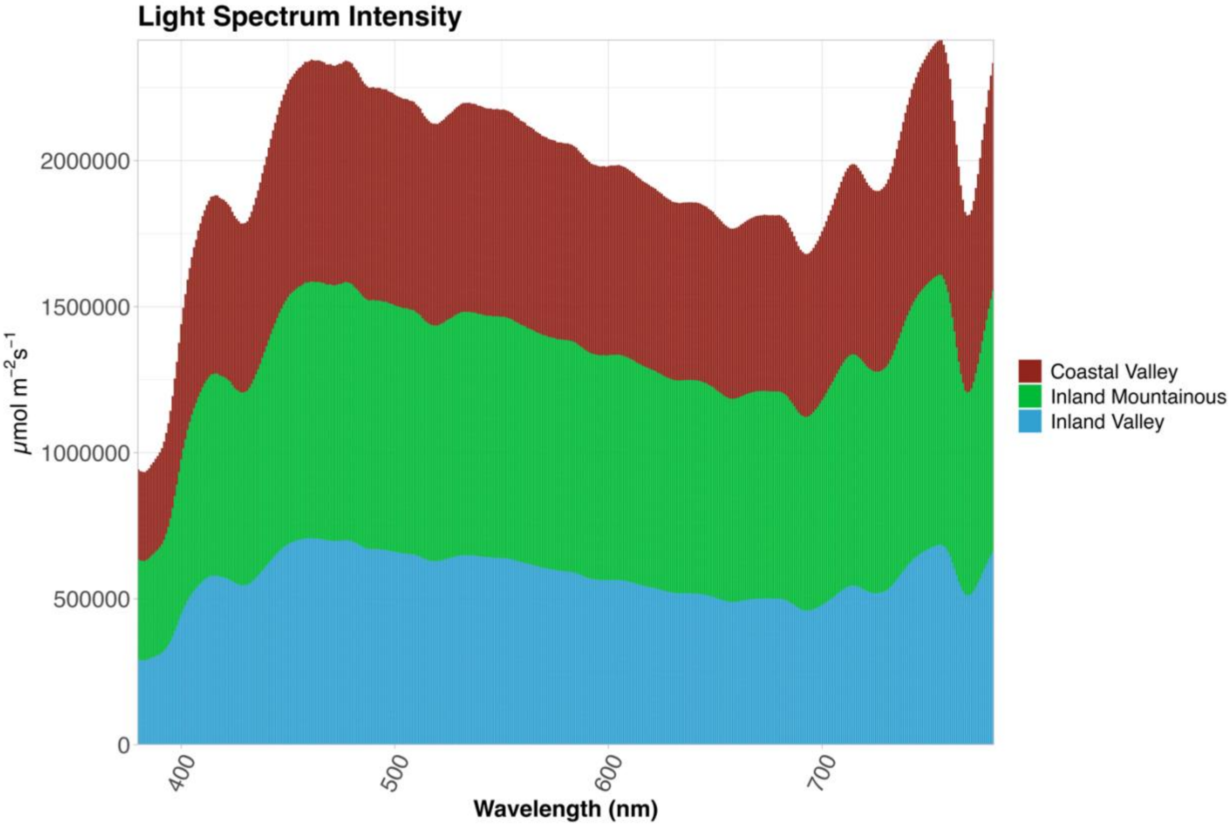

Figure 8: Incoming solar radiation by geographic location (values are ***stacked*** *and not a sum value).*

Solar Radiation

Incoming solar radiation was measured using a portable spectroradiometer and grouped by geographic classification. Solar radiation intensity was comparable for all classifications, with wavelength specific differences observed. In most visible wavelengths, coastal vineyards had the lowest light intensity of the three categories. However, coastal sites had higher red and near infrared radiation than either inland category (Figure 9). Infrared light is responsible for the majority of heat accumulation on the Earth's surface and would account for higher temperatures in the canopy during hours with direct sun exposure when compared with a site with less incoming red and near infrared light.

Another notable feature is the increase in low wavelength light at inland valley vineyards. Shorter wavelengths, closer to ultraviolet, have a direct impact on upregulation of anthocyanin biosynthesis and could result in a notable difference between inland valley and coastal anthocyanin content and anthocyanin hydroxylation patterns. Anthocyanins and other phenolic compounds were not included for testing in this study. However, phenolic testing by geographic classification may yield interesting results.

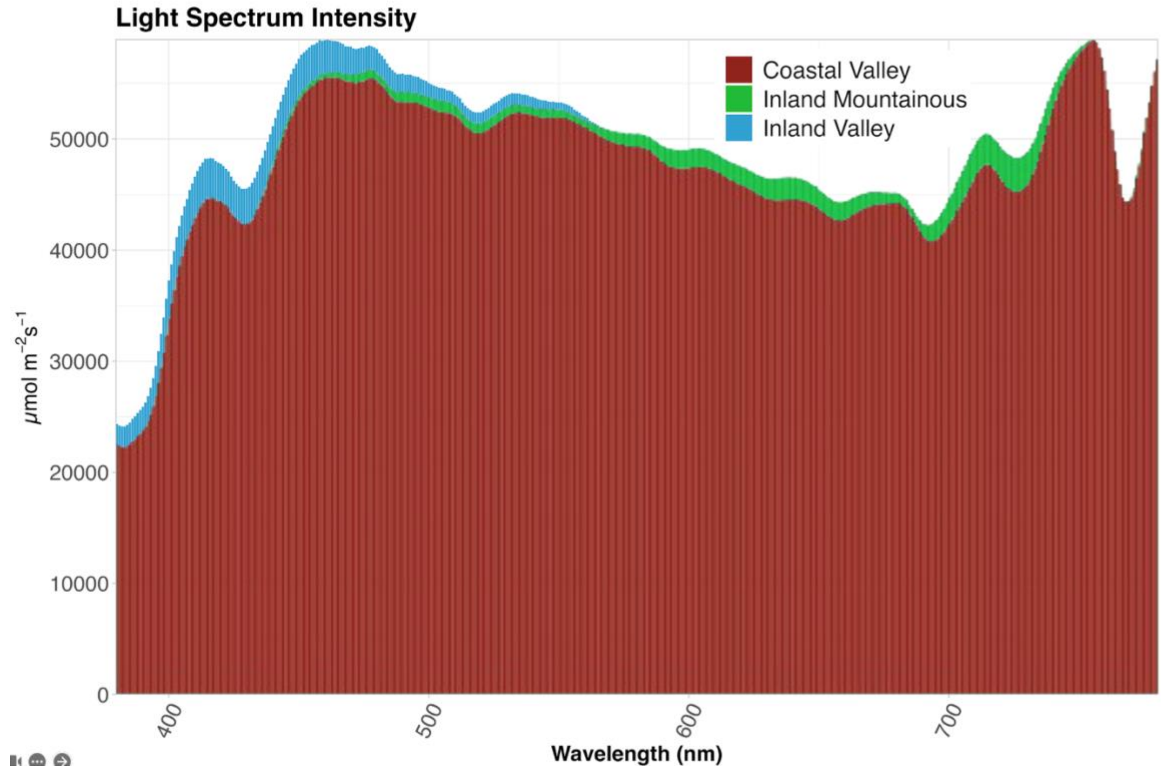

*Figure 9: Incoming solar radiation by geographic classification (values are **overlapped** and representative of sum values for each category).*

Temperatures

On-site temperatures were recorded with HOBO temperature loggers fastened in the canopy for 10 months starting in December 2022. Some loggers were destroyed by grower-collaborator operations during this time. Data on surviving temperature loggers is still being processed.

Objective 4: *Drought tolerance and rootstock performance*

The performance of rootstocks under drought conditions was dependent upon drought conditions in 2023. The 2023 grape-growing season was notably not water-limited and drought stress was absent from all vines tested during the 2023 growing season. Regardless, data collected displayed a significant impact of rootstock selection on numerous variables and an even greater impact of geographic classification and location on the factors recorded.

7. Outside Presentations of Research:

Data for this study is still being collected and analyzed and will conclude in 2024. Following the conclusion of this part of the study, information gained from this research will be disseminated through University of California Cooperative Extension workshops, meetings, and events. It will also be conveyed through conferences and seminars hosted by other organization. At least one publication should result from this study and would be made available to the public without cost to the reader.

8. Research Success Statements:

This work has been successful thanks to the many grower-collaborators who offered vineyard locations for data collection. Nine different organizations provided grapevines and researcher access for this study. The data collected is robust and helps draw conclusions of the impact of rootstock selection and geographic influence on vine performance in the north coast of California.

Rootstocks alone were shown to impact yields, individual cluster weights, cluster counts per vine, and vine water status. They were also not a barrier to grapevine berry development in any way. Geographic classification also interacted with effects observed from rootstock selection to influence vine water status, yields, cluster counts, and individual cluster weights; geographic classification by itself also influenced berry development through modulation of berry size and sugar accumulation throughout the 2023 growing season.

9. Funds Status:

Initial funding requirements for this project are fully realized. Funding was extended to 2024 to allow for sufficient time to complete data collection and analysis. Any further investigation into this topic will require additional funding from CGRIC. Applications for the 2024 funding cycle are under consideration. Thank you for your patience and support.

Sources:

Blumthaler M., Ambach W., Ellinger R. (1997) Increase in solar UV radiation with altitude. Journal of Photochemistry and Photobiology B: Biology 39:130-134. DOI: https://doi.org/10.1016/S1011-1344(96)00018-8.

Folorunso O.A., Rolston D.E., Prichard P.T., Louie D.T. (1992a) Cover crops lower soil surface strength, may improve soil permeability. California Agriculture 46:26-27.

Folorunso O.A., Rolston D.E., Prichard T., Loui D.T. (1992b) Soil surface strength and infiltration rate as affected by winter cover crops. Soil Technology 5:189-197. DOI: https://doi.org/10.1016/0933-3630(92)90021-R.

Fyllas N.M., Bentley L.P., Shenkin A., Asner G.P., Atkin O.K., Díaz S., Enquist B.J., Farfan-Rios W., Gloor E., Guerrieri R., Huasco W.H., Ishida Y., Martin R.E., Meir P., Phillips O., Salinas N., Silman M., Weerasinghe L.K., Zaragoza-Castells J., Malhi Y. (2017) Solar radiation and functional traits explain the decline of forest primary productivity along a tropical elevation gradient. Ecology Letters 20:730-740. DOI: https://doi.org/10.1111/ele.12771.