CWIDB FY 2023 Budget (Rev 7/6/2022)--APPROVED 7/7/2022

Updated numbers for Central Billing (Ext. Admin.) Line items

Spending Authority and Predicted Income

		One-third calculation
Spending Authority (set in 2022 FY20 Long Bill), for Fund 2260 for BCEAAJ025	$574,246.00	$191,396.19
FY 2021 Wine Development Fee Revenues	$821,745.00	$273,887.61
FY 2021 Revenues incl. Misc + Defer	$844,987.00	$281,634.17

Approp Code	Appropriation Desc	Activity Code	Activity	Object Code	Req'd Expense	Object	Approp FY2020 Budget	Expenditures FY 2021 Budget	Approved FY 2022 Budget	FY2023 proposals	Activity Totals	% total Budget/Notes			With 1/3 DC salary
											Central Billing revised 7/6/22 by Jen Hughes				
BCAFAB046	IT Asset Maintenance	7701	CWIDB Admin	3140	*	Non-Cap IT-software pool	$778.00	**$0.00**		**see pymts to OIT**		**$1,000.00**			
BCAOPCOP1	Office Consolidation COP	7701	CWIDB Admin	6710	*	paid out of Ag Mgmt in 2020	$0.00	**$10,048.31**	**$10,182.00**	**$8,441.00**		**$12,500.00**			
BCC10B014	Ins Other Than Emp Benefits	7701	CWIDB Admin	2660	*		$632.00	**$1,013.00**	**$1,013.00**	**$2,344.00**		**$632.00**			
BCC15B003	CORE Operations	7701	CWIDB Admin	2655	*	software (CORE)	$2,041.00	**$1,466.00**	**$1,500.00**	**$1,640.00**		**$2,100.00**			
BCC20B013	Workers' Comp CF	7701	CWIDB Admin	1533	*		$1,094.00	**$946.00**	**$1,000.00**	**$982.00**		**$1,500.00**			
BCC30B010	Leased Vehicle	7701	CWIDB Admin	2251	*	Rental/Leased motor pool	$120.00	**$96.00**	**$120.00**	**$0.00**		**$120.00**			
BCCAPJ020	Indirect Cost Assessed	7701	CWIDB Admin	7200	*	Transfers out for Indirect	$20,000.00	**$22,918.00**	**$20,000.00**	**$25,064.00**		**$20,000.00**			
BCD15B020	PERA Direct Distribution	7701	CWIDB Admin	1526	*	paid out of Ag Mgmt in 2020	$0.00	**$4,446.00**	**$5,000.00**	**$4,283.00**		**$4,916.00**			
						FY21 83528									
						FY20 35,046									
						FY19 22,547									
						FY18 21,434									
BCL10B010	Legal	7701	CWIDB Admin	2690	*	FY17 6657	$11,525.00	**$23,712.00**	**$35,000.00**	**$64,543.00**		**$17,000.00**			
BCT10B004	Payments to OIT	7701	CWIDB Admin	2650	*	Cash fund cost share of OIT	$5,901.00	**$7,325.00**	**$8,500.00**	**$15,145.00**		**$6,000.00**			
						External Appropriations	**$42,091.00**	**$71,970.31**	**$82,315.00**	**$122,442.00**	**Ext Apps before Revision 7/6/22: $90,292.00**	**Increase 135.61%**			

Approp Code	Appropriation Desc	Activity Code	Activity	Object Code	Req'd Expense	Object	Approp FY2020 Budget	Expenditures FY 2021 Budget	Approved FY 2022 Budget	FY2023 proposals	Activity Totals	% total Budget/Notes			With 1/3 DC salary
BCEAAJ025	CWIDB Program costs	7701	CWIDB Admin	*	*	DC Salary and benefits	$155,863.18	**$141,137.11**	**$170,000.00**	**$150,500.00**	FY22 s.b. approx $145,000	Increase of 1.03 on salary = *1.33 incl benefits; Long bill provides 3% raise in salary	$83,371.52		$50,166.67
				2522-2259 fleet and Parking								$1,797.95	$1,330.71		
				2510-2513 In-state emp								$5,236.13	$2,699.87		
				2520-2523 In-state non-emp								$7,453.29	$3,761.08		
				2530-2533 OOS emp								$2,771.65	$945.12		
				3950 gasoline								$41.85	$39.44		
					*	Travel: emp, non-emp, plus fleet mileage	$15,000.00	**$427.00**	**$16,000.00**	**$12,000.00**		$17,300.87	$8,776.22		
				4180	*	Meeting costs/official functions	$2,500.00	**$0.00**	**$4,000.00**	**$3,000.00**		$3,956.86	$1,753.68		
				2630-2631	*	Communication	$1,750.00	**$1,730.00**	**$2,000.00**	**$2,000.00**		$1,841.67	$2,159.06		
				3140-3145		IT equipment and software	$2,500.00	**$143.18**	**$2,500.00**	**$2,500.00**		$2,294.14	$15.61		
				4140		Dues and Membership	$2,000.00	**$2,300.00**	**$2,000.00**	**$2,000.00**		$1,570.00	$2,050.00		
				4220		Registration fees	$1,000.00	**$135.00**	**$1,250.00**	**$1,250.00**		$1,119.98	$300.00		

		3110-3121, 3128, 3132		supplies & materials, incl office	$2,750.00	$3,000.00	$2,276.00	$3,000.00		$1,917.45	$3,039.00	
		3123		Postage and shipping	$1,500.00	$1,750.00	$359.00	$2,000.00		$1,793.65	$690.80	FY19 YTD: $1661
BCEAAJ025	**CWIDB Program costs**	**7701 CWIDB Admin**							**$178,250.00**	**19.51%**		
				Total CWIDB Admin, 7701		**$222,592.60**	**$282,700.00**	**$300,692.00**	**$268,542.00**	**29.39%**	**18.41%**	**$168,208.67**
BCEAAJ025	CWIDB Program costs	7702 Wine Research	*	CSU Viticulture Research	$230,000.00	**$219,984.20**	**$248,138.00**	**$255,125.00**		includes salaries for APV project		
			*	Consumer Survey	$18,000.00	**$8,475.00**	**$9,000.00**	**$9,000.00**				
				SCBG projects	$0.00							
				Phylloxera	$0.00							
				Economic Impact Study	$0.00	**$20,000.00**	**$0.00**	**$0.00**				
				Phylloxera education (seminar, web site, etc.)	$0.00							
BCEAAJ025	**CWIDB Program costs**	**7702 Wine Research**						**$264,125.00**	**$264,125.00**	**28.91%**		
BCEAAJ025	CWIDB Program costs	7703 Wine Mkt & Adv		Cultivator (new spending for FY20)	$193,000.00	**$156,540.00**	**$171,000.00**	**$191,500.00**				
				Brochure printing and fulfillment	$15,000.00	**$0.00**	**$15,000.00**	**$2,000.00**		Mktg team rec: cut the brochure compeltely		
				Supplies and Materials	$2,000.00	**$0.00**		**$2,000.00**		point of sale, SWAG		
				Personal Services	$0.00	**$696.00**		**$0.00**		match for John Fielder photography, Jan. 2021-Jan. 2022; app. 10/8/20		
				CTO Statewide Mktg Grant Match			**$25,000.00**	**$0.00**		according to FY22 rules, this match would get us a $40,000 grant		
				KS Salary and Benefits	$50,000.00	**$49,583.00**	**$55,000.00**	**$54,500.00**	FY2022 S.b. $50,000	Compression pay inc of 1.0819% for remainder of FY2022. Increase of 1.03 on salary for FY2023, +approx $21,000 benefits		
BCEAAJ025	**CWIDB Program costs**	**7703 Wine Mkt & Adv**						**$250,000.00**	**$206,819.00**	**22.63%**		
BCEAAJ025	CWIDB Program costs	7704 Wine Events & PR		Media trip	$19,000.00	**$0.00**	**$10,000.00**	**$15,000.00**		**$20,000.00**		
				Governor's Cup Competition	$23,000.00	**$0.00**	**$25,000.00**	**$25,000.00**		**$25,000.00**		
				Governor's Cup Case Tasting	$0.00	**$0.00**	**$10,000.00**	**$10,000.00**		**$10,000.00**		
				Trade and Media tasting(s?)	$0.00			**$5,000.00**				
				Slow Food Nation	$0.00							
				Taste of Vail	$0.00		**$5,000.00**	**$2,000.00**				
BCEAAJ025	**CWIDB Program costs**	**7704 Wine Events & PR**						**$57,000.00**				
				Total Mkt and Events (7703+7704)				**$307,000.00**	**$307,000.00**	**33.60%**	**39.09%**	**$357,166.67**
				Business Development	$0.00		**$5,000.00**					
				Quality Projects (Videos)	$0.00		**$15,000.00**					
				Vit Extension Specialist	$15,000.00	**$12,837.00**	**$50,000.00**	**$33,949.06**	revised 7/6/22 with CSU Ext budget	SCBG funding ends Sept 2022		
				VinCO Sponsorship	$5,000.00	**$18,000.00**	**$5,000.00**	**$5,000.00**				

		SCBG: hybrid cultivar camps matching funds	$2,000.00	$3,000.00				
		Phillips-Rhodes Grant	$0.00	$0.00				
BCEAAJ025 CWIDB Program costs	**7705 Wine Quality**	**Quality Assessment**		**$41,949.06**	**$41,949.06**	**4.59%**		
		Total Resch & Develop + Qual (7702+7705)		**$306,074.06**	**$306,074.06**	**33.50%**	**38.99%**	**$356,240.73**
Total Internal Appropriation: CWIDB Program costs BCEAAJ025					**$791,324.06**			
Total Fund 2260		**Internal and External Appropriations**						$881,616.06
				$913,766.06	**Wine Dev Fee + Misc Rev**		**108.14%**	
		Total Salary and Benefits	**$190,720.11**			**20.87%**		

CWIDB FY 2023 Proposed Cultivator Budget

RFP in 2019, contract renewed FY2020

PRIORITIES/TASKS	Cultivator Budget Contract Year 2020	Cultivator Budget Contract Year 2021	Cultivator Budget Contract Year 2022	Proposed Cultivator Budget Contract Year 2023	Cummulative Total for Life of Contract	Comments	monthly fee or date due
Deep Dig and Branding Work	$25,000	$25,000	$0	$0			
Governor's Cup Promotion & Marketing (not event production costs)	$10,000	$10,000	$10,000	$12,500		Plan to use same creative with minor updates, but some new displays will likely need to be created. Does this include media sponsorships?	
Rack Card/Brochure	under branding		$5,000	$0		CWIDB opted to cut the 2022/2023 brochure	
Agency Fees and Misc design work	$5,000	$5,000	$19,000	$20,000		updating graphics, copy, and any additional updates for advertising.	
Logo refresh				$3,000			
Website Design and Digital Maintenance	$15,000	$23,000	$15,000	$15,000			
Activities map on website				$0			
Quiz on websiet				$0			
Agency Account Management & Planning	$6,000	$6,000	$6,000	$7,200			
POS and Collateral				$5,000		agency fees; materials add'l	
Media trip	$0	$0	$0	$0			
Photography and Asset Development	$10,000	$0	$0	$0			
Media Buys (Explore Communications)	$58,000	$50,000	$52,000	$52,800			
Media Buys (Cultivator)				$5,000		social media ads using Fielder photos	
Public Relations (Voca PR)	$64,000	$64,000	$64,000	$66,000			
Promotional Events	$0			$5,000		trade and media tasting(s?)	
TOTAL Actual or PROPOSED BUDGET	$193,000	$183,000	$171,000	$191,500	$738,500		
CO Proud Recovery Grant			$25,000		$763,500		

PROJECT PROPOSAL

July 1, 2022 – June 30, 2023

TITLE:

CSU Viticulture and Enology Program for the Colorado Wine Industry

PRINCIPAL INVESTIGATORS

Horst Caspari[1], Claudie Bertin[2], Peter Bennett Goble[3], Russ Schumacher[3]

JUSTIFICATION

There are two major threats to the economic viability of the Colorado grape industry: grape phylloxera (*Daktulospheira vitifoliae*) and cold temperature damage. A lack of land suitable for grape production represents a serious limitation to the growth of the industry. The research in this project focuses on the two major threats and the limitations to vineyard expansion.

Grape phylloxera is an aphid-like insect that feeds on grape roots. Phylloxera is native to the northeastern United States and many American grape species are tolerant to phylloxera. However, the European grape (*Vitis vinifera*) has no tolerance and phylloxera feeding on roots will eventually kill the vines. The first recording of phylloxera in a commercial vineyard in Colorado occurred in August 2015. During a routine Grape Commodity Survey, personnel working for the Cooperative Agricultural Pest Survey (CAPS) found phylloxera on leaves of hybrid vines in Larimer county. In November 2016, CSU personnel assisting a grower in Mesa County discovered phylloxera on the roots of young *Vitis vinifera* vines. In subsequent surveys by CSU, phylloxera was discovered in 15 further vineyards in Mesa County, three vineyards in Delta County, and one vineyard in Montrose County. Also, aerial phylloxera was found in a second Front Range vineyard in 2018. Phylloxera has been found in vineyards planted with hybrid as well as *Vitis vinifera* cultivars. It is likely that in some vineyards phylloxera has been present for more than 10 years.

Phylloxera represents a major threat to the Colorado grape and wine industry. Vineyards in Mesa, Delta, and Montrose County produce >95 % of Colorado's grape crop. Since 2017, 83 % of new vineyards with *Vitis vinifera* cultivars have been planted using grafted vines. Severe cold damage in October 2020 has led to a significant removal of own-rooted *Vitis vinifera* vines during 2021. In some instances own-rooted vines were replaced with grafted *Vitis vinifera* vines while in other instances the replacement was with cold-hardy interspecific cultivars. And in some cases vines were replaced with other crops. Although the vineyard area planted with own-rooted *Vitis vinifera* cultivars is declining, about 60-70 % of the vineyards in Western Colorado remain planted with own-rooted vines of European cultivars, making them susceptible to phylloxera damage.

Initially, feeding of phylloxera on roots of susceptible grape vines leads to reduced vine vigor and lower yields. However, phylloxera feeding, in combination with fungal and bacterial infections of the damaged root system, will eventually kill the vines. While phyto-sanitary practices and insecticide applications can slow the spread of phylloxera, the long-term solution is the removal of own-rooted vines of cultivars that are not phylloxera tolerant (all *Vitis vinifera* and some hybrid cultivars) and then replanting with susceptible cultivars grafted to tolerant rootstocks or with

[1]Department of Horticulture and Landscape Architecture
[2]Agricultural Experiment Station – Western Colorado Research Center
[3]Department of Atmospheric Science
Colorado State University, Fort Collins, CO 80523

tolerant hybrid cultivars. In fact, vines on about half of the more than 20 phylloxera-infected sites have been pulled and either replanted with grafted or hybrid grape vines. At least three vineyards have been converted to peach orchards.

While there is a large body of research on the performance of rootstocks in many grape growing areas around the world, there is very limited information for Colorado. Only two replicated rootstock studies have been conducted in Colorado prior to 2017. The first, using Chardonnay grafted to four different rootstocks, was planted at the Western Colorado Research Center – Orchard Mesa (WCRC-OM) in 1992/93. The second, planted in 2009 also at WCRC-OM, uses Viognier grafted to five different rootstocks. In spring 2017, a rootstock trial with Cabernet Sauvignon grafted to 11 different rootstocks was planted on a collaborating grower's site. A duplicate of this trial was added at a second collaborator's site in the spring of 2018. Another rootstock trial with Souzao grafted to 7 different rootstocks was planted at a third collaborator site in spring 2019. Still, more rootstock trials covering a range of cultivars and locations (soil types, climates) are needed so that local rootstock recommendations can be developed. Rootstock trials are long-term in nature; it will require at least 8 to 10 years before sound recommendations can be developed – even longer if there are years with significant cold damage like from the October 2020 event.

Three other rootstock-related questions are also being addressed: how to best manage the graft union; what is the best method for replanting; and what is the interaction between rootstock and irrigation inputs.

Other projects will focus on areas that were identified through industry-wide research surveys as having the highest priorities. A survey conducted by the Colorado Wine Industry Development Board (CWIDB) in March 2014 identified "responding to cold injury" and "variety selection" as the highest- ranked research priorities. Other areas identified by at least one-third of the participants included vine training/retraining, pruning practices, and irrigation techniques and related issues. For enology, the top priorities identified were, in descending order, microbial concerns and spoilage prevention, varietal wine profiles unique to Colorado, quality control, and winery best practices and procedures.

Similarly, in a follow-up survey in 2015, the two top-ranked responses on viticulture research priorities were "Suitability of grape varieties for Colorado (cropping reliability, cold hardiness)", and "Cold temperature injury mitigation and avoidance". When asked which topics were of greatest interest and/or benefit respondents identified "Varietal selection" as clear #1, followed by "Responding to cold damage" and "Site selection". In the most recent industry survey conducted by CSU Extension in 2019 "Varietal selection" and "Site selection" were ranked first and second with "Preventing cold damage" ranked ninth. Clearly those three topics are closely linked.

The current proposal builds on and expands the research efforts that have been underway since the original Four Corners Project. The proposal has both short-, medium-, and long-term components. Essential to the research is the infrastructure that has been build up over the past >30 years, both on Colorado State University Agricultural Experiment Stations and on grower cooperator sites. Many of the projects outlined below are interconnected such as cultivar trials and larger production blocks used as the source of bud wood for cold hardiness evaluations; larger production blocks used as the basis for studies on methods to increase cold hardiness, soil and irrigation management, bud break delay; and results from specific cold hardiness projects that provide information on acclimation/deacclimation of cultivars not previously tested.

RESEARCH PROGRAM

I. Cropping reliability

The emphasis in this project is to develop techniques that reduce the risk of crop losses due to cold temperature injuries. Cold temperature injuries include damage caused by winter freezing injury as well as late-spring or early-autumn frosts that are the primary cause for Colorado's low and undependable yields. Grape growers repeatedly have identified research on grape cultivars suitable for Colorado's climate and responding to cold injury as the top two research priorities.

Research efforts to address the phylloxera crisis also falls into the category of cropping reliability. With phylloxera feeding on roots of *Vitis vinifera* cultivars the vine vigor declines, and with it the yield potential. Ultimately, dying and dead vines will need to be replanted with vines grafted to phylloxera tolerant rootstocks, or phylloxera tolerant cultivars. New rootstock trials covering a range of cultivars, soil types, and climates are required to develop rootstock recommendations for Colorado's growing conditions. Further projects investigate practices of how to protect the graft union against cold damage, options for replanting, and rootstock / irrigation interactions.

Cropping reliability can also be affected by crop load. Crop load effects can be both seasonal and multi-year. The rate at which fruit ripens is in part determined by crop load – high crop loads delay ripening while ripening is advanced with light crop loads. When high crop loads delay ripening until very late into the growing season or fruit is picked after a killing frost, then there is little or no post-harvest time for vines to accumulate carbohydrates into perennial tissues. Lack of carbohydrates may reduce cold hardiness and negatively impact regrowth the following spring. Impacts from a single year are generally minor but repeated over-cropping may reduce vine vigor and yield in the long run. In some instances Colorado grape growers have been unable to sell their grapes as fruit failed to fully ripen prior to a killing frost. Timely reductions of the crop load might have resulted in earlier ripening, and a fruit quality suitable for sale.

Examples of cultivars that generally ripen at the very end of Colorado's growing season include Cabernet Sauvignon and Chambourcin. In 2019, about 50 % of Cabernet Sauvignon and more than half of Chambourcin was picked after an unusually early killing frost on 11 October. Chambourcin now ranks 9th or 10th in planted area in the state. It is a very fruitful cultivar – we frequently observe 3 clusters on a shoot – capable of producing very high yields. The question of what crop loads can consistently ripen under the growing conditions of the Grand Valley is being investigated in a crop load study with Chambourcin.

1. Grape cultivars and clones suited to Colorado's climatic conditions

Since 2004 we have greatly expanded the number of cultivars under testing. The first-ever replicated cultivar trial in Delta County was planted at the Western Colorado Research Center (WCRC) Rogers Mesa site in 2004. This trial was expanded with new entries in 2008 as part of the USDA Multistate NE-1020 project (see below). Also in 2008 and as a part of NE-1020, 26 "new" cultivars were planted at the WCRC Orchard Mesa site. An additional replicated trial focusing on cold-hardy, resistant cultivars was established on a grower cooperator site in Fort Collins in 2013 to identify grape cultivars that can be grown successfully along the Front Range. And in 2014, a fourth trial focused on cold-hardy, resistant cultivars was established with a grower-cooperator in the Grand Valley. At the Rogers Mesa site the 2004 planting was removed in the spring of 2018, but we are continuing with the cold-hardy cultivars in the 2008 NE-1020 planting. While the NE-1020 ended in 2017, a continuation of this multi-state project was approved by NIFA for another five years (now called NE-1720).

- Multi-state evaluation of wine grape cultivars and clones.

  This long-term (2017-2022), USDA multi-state research project (NE-1720) is the continuation of NE-1020 (2003-2017). The project tests the performance of clones of the major global cultivars and new or previously neglected wine grape cultivars in the different wine grape-growing regions within the U.S. and is a collaboration of more than 20 states. All participating states follow the same experimental protocol. In Colorado, 10 cultivars were established in 2008 at Rogers Mesa, and 26 cultivars at Orchard Mesa. Results have been presented annually at the joint WCHS / VinCO meetings, and are available on the WCRC Viticulture Webpage. Results from the 2015 through to 2021 seasons were also included in prior semi-annual and annual reports to the CWIDB.

  Three poorly performing cultivars (Garnacha tinta, Tocai Friulano, Verdejo) were removed in winter 2020/21 from the trial at Orchard Mesa. Five new entries [Agria (synonym Turan), Arinto de Bucelas, Corvina Veronese, Sagrantino, Teroldego] grafted to rootstock SO4 were added in April 2021.

  Three recent new cultivar releases from the breeding programs at the University of Udine and Institute of Applied Genetics, Udine, Italy, were planted in late April 2022. The three new entries are interspecific cultivars having good to very high tolerance to powdery mildew. The cultivars are Cabernet Volos (Cabernet Sauvignon x Kozma 20-3) grafted to SO4, and Fleurtai (Friulano x Kozma 20-3) and Soreli (Friulano x Kozma 20-3), both grafted to 101-14. Although these cultivars were not planted within the same block where the NE-1720 trial is located, the same experimental protocols will be followed.

- Cultivar evaluation for Front Range locations, Fort Collins.

  A new vineyard was established on a grower cooperator site in Fort Collins in 2013 to identify grape cultivars best suited along the Front Range. The first results for bud survival following extreme temperature events in early November 2014 and early January 2015 were presented at VinCO 2015.

  A severe freeze event on 11 May 2015, when most cultivars were near or already past bud break, caused significant cold damage to emerging shoots and near 100 % crop loss. Many cold-damaged vines needed to be retrained during the 2015 growing season. Milder minimum temperatures during the 2015/16 dormant season resulted in no bud damage, and there were no late spring freezes. Fruit was harvested from all cultivars, and six varietal wines were produced. Dormant season cold damage was again minimal in 2016/17, but a series of late spring frosts caused damage to all cultivars, leading again to very low yields. Additionally, vine vigor at this site is much less than desired, contributing to the low yields.

  Initial results were presented at VinCo 2017 and annual updates have been and will be included in reports to CWIDB. All vineyard work in 2022-2023 will again be carried out by a student intern from Colorado State University.

- Cold-hardy, resistant cultivars for the Grand Valley.

  A new replicated cultivar trial was established in 2014 on a grower cooperator site near Clifton to identify grape cultivars that can be grown successfully in cold Grand Valley sites. The focus during 2015 following establishment was on vine training. All cultivars produced at least a small amount of fruit in 2016, and nine varietal and one blended wine was produced. All cultivars produced a crop in 2017, but yields were down on average by 23 % compared to 2016 while harvest was nine days earlier. Only Noiret and Traminette had higher yields in 2017 than 2016. Nine varietal wines and one blended wine were produced. Average yields in 2018 increased by nearly 3 ton/acre over 2017, and varietal wine was produced from all 12 cultivars. In 2019 yields were down >40 % over 2018. Again, 12 varietal wines were produced. Significant bud damage was found on Cayuga White, Chambourcin, and Traminette following a record low temperature event on 30 October 2019, illustrating the need to better understand acclimation and deacclimation pattern of not just *Vitis vinifera* cultivars but also the so-called cold hardy cultivars as well. Yields in 2020 were down 45 % on average for all cultivars except Vignoles (no change) and Arandell (102 % increase, albeit from a very low base). All cultivars with the exception of Arandell (85 %), Cayuga White (74 %), and Noiret (88 %) had more than 90 % primary bud survival following the record cold event in late October 2020. When considering secondary buds, all cultivars had >90 % fruitful buds.

Although bud damage from the October 2020 freeze event was minor and there were no further damaging cold events during the remainder of the 2020/21 dormant season, several cultivars had a high percentage of vine dieback in spring 2021. Eight cultivars produced a bigger crop in 2021 compared to 2020 while four cultivars yielded less. Surprising at this site is the frequency of dieback of St Vincent vines that has happened in 2017, 2018, 2019, and 2020. After eight years only 29 % of St Vincent vines are still alive.

2. *Mitigating damage from grape phylloxera*

- Interplanting of grafted vines.

Once vineyards planted with own-rooted *Vitis vinifera* cultivars become infested with phylloxera, vine vigor and productivity will start declining. It may take several years from the initial infection for symptoms to appear. Currently it is not known how fast phylloxera spreads throughout a vineyard following initial infestation under Colorado conditions. Based on experiences in other areas of the world it is reasonable to assume that it will take at least 5-10 years from infestation before vine productivity has declined to such a low level that it requires replanting. Generally at this point, vines are pulled in fall shortly after harvest, then the vineyard is prepared for replanting with grafted or phylloxera-tolerant cultivars the next spring. With this approach, similar to a newly planted vineyard, the first crop is expected in year 3. Another option, however, is to interplant with vines of the new cultivar 2 to 3 years before the anticipated removal. While at that time the vineyard productivity is already declining, vines are still productive enough to not yet warrant removal. With good management, the interplanted vines can be grown so that at the end of the second or third season, when own-rooted vines need to be removed, canes can be tied to the cordon wire, and a crop can be produced the following season. The advantage of the interplant approach is that there is no two year break in crop production. However, it requires good management of the interplanted vines.

A new trial to evaluate the interplanting approach was established in early May 2017 at WCRC-OM. A total of 120 dormant Chardonnay (clone 99) vines grafted to SO4 rootstock were interplanted in a block of Chardonnay planted with own-rooted vines in 1991. Phylloxera was discovered in this block in December 2016. For several years prior to the discovery of phylloxera, vine vigor and yield have been severely depressed at the northern end of the block while the southern part was not affected. Original vine spacing is 5 feet, and interplants were planted midway between the existing vines. As this block is also used for the cover crop / irrigation study (see below), some areas of the block are drip irrigated while other areas are irrigated by micro-sprinklers.

Vine establishment in year 1 was very good. All vines established, and many vines had >0.5 m shoot growth. Graft unions were covered with soil in late fall. However, ten percent vine mortality was observed in spring 2018. Graft unions were uncovered again and vines were pruned in late spring 2018. Graft unions were again covered with soil in late fall 2018 and uncovered in spring 2019. Approximately one third of the surviving vines had sufficient growth in the second season to lay down at least one cane at the beginning of the third growing season. Vine growth was better in 2019 so that new canes could be tied to the cordon wire in spring 2020, and mature vines were removed. Yields were still low in 2020 but these younger vines have had less cold damage from the October 2020 freeze event than mature Chardonnay vines grafted to four different rootstocks growing in the same block. Some missing vines were replaced with new vines in spring 2021. Yield in 2021 was 0.56 ton/acre, slightly more than the yield of mature grafted vines growing in the same block, and twice the state-wide average for Chardonnay. Yield of vines from this study will be determined again in 2022 and compared to that of vines of the same age from the 2017 planting-depths study (see below), as well as the yield of the grafted mature vines.

- Develop planting and maintenance practices for grafted vines that reduce management costs and vine losses due to cold temperature damage to the graft union – 2017 study.

In Colorado, where low temperatures can cause trunk injuries, the graft union needs to be protected during the coldest part of the year to avoid lethal damage to the cultivar. Common methods of graft union protection are hilling up soil around the graft union or covering the graft union with mulch materials. After the risk of cold temperature damage has passed, the graft union needs to be uncovered to avoid self-rooting from the scion. Due to the semi-arid climate of western Colorado, the top part of the soil is very dry and hot during the growing season. Dry and hot soil conditions are generally not conducive for root growth. A field study to test the effect of planting depths, in combination with irrigation method, on the propensity of self-rooting was established at WCRC-OM in early May 2017. Chardonnay (clone 99) grafted to SO4 rootstock was planted with the graft union 2” above ground (Control = standard practice), or with the graft union 2”, 4”, or 6” below the soil surface. Half the vines are irrigated by drip, the other half by micro-sprinkler. There are 10 single-vine replications per treatment. Drip emitters are positioned so that the trunks are not wetted during irrigation events, while micro-sprinklers wet 100 % of the vineyard floor area.

Initially, for treatments with the graft union below the soil surface, the planting hole was only partially filled so that the graft union did not get covered by soil. In late fall 2017, more soil was added to those holes right up to the level of the soil surface. Graft unions will remain covered for the remainder of the experiment. Graft unions of Control vines with graft unions placed 2” above the soil were covered with soil in late fall 2017 and uncovered in late spring 2018. Four vines were lost in the first growing season and/or after the first winter: one control vine; one vine with graft union at 2” below ground; and two vines with the graft union at 4” below ground. Two of the lost vines were drip irrigated and two were irrigated by micro-sprinkler. Prior to hilling up soil around the graft unions again in fall 2018, root development from the scion and the rootstock was evaluated on 5 vines per treatment. Soil was carefully removed down to the graft union and slightly beyond. All vines had some roots emerging out of the scion. Root development varied from just one small root to numerous, strong roots in the scion part. No root development occurred on Control vines where the graft union is 2” above ground.

Graft unions were again uncovered in late spring of 2019. Vines were pruned and canes tied to the fruiting wire in mid-April 2019. Drip irrigated vines had better growth in 2018 as tied down canes covered about 82 % of the fruiting wire compared to only 69 % for vines irrigated by micro-sprinklers. The better growth of drip irrigated vines resulted in more than twice the yield in 2019 compared to micro-sprinkler irrigated vines. Root development from the scion and the rootstock was evaluated again on 5 vines per treatment prior to hilling up in fall 2019. In contrast to previous years graft unions were protected by a mound of tree wood chips. Half the graft unions (5 reps each for drip and sprinkler irrigated vines) were again uncovered in May 2020 while the other half was not uncovered.

Vines with drip irrigation once again had higher yields in 2020 than vines with sprinkler irrigation (2.22 versus 1.42 t/acre). Control vines averaged 2.18 t/acre compared to an average of 1.69 t/acre for treatments with the graft union below ground. Prior to hilling up in fall 2020, root development from the scion and the rootstock was evaluated again on the same 5 vines per treatment that were last evaluated in fall 2018. All Control vines needing hilling up were covered before the extreme cold event in late October 2020.

Half the graft unions were again uncovered in late spring of 2021. Grafts that had been covered with wood chip mulch since October 2019 were briefly uncovered to check for the presence of scion roots (none were found), and immediately covered up again. This treatment tests the hypothesis that no scion rooting will occur under a wood chip mulch even when graft unions remain covered.

Six vines did not break bud in spring 2021, however all pushed shoots from above the graft union and were retrained during the 2021 growing season. The average yield in 2021 was down only 13 % compared to 2020. Drip irrigated vines again had higher yields than vines with sprinkler irrigation (1.85 versus 1.30 t/acre); however the difference was much smaller than in previous years. Vines with sprinkler irrigation were slower to establish but after five growing seasons there are no more differences in cordon length and canopy fill.

Half the graft unions were again covered in fall 2021 and uncovered in early May 2022. Grafts that had been covered with wood chip mulch continuously since October 2019 were briefly uncovered to check for the presence of scion roots (none were found), and immediately covered up again. We will continue to collect data on scion root formation, vine survival, and fruit yield and quality.

- Develop planting and maintenance practices for grafted vines that reduce management costs and vine losses due to cold temperature damage to the graft union – 2021 study.

A new study to evaluate if graft unions can be covered indefinitely without causing scion rooting was initiated in spring of 2021 in three rows of the Chardonnay block at the Orchard Mesa site that was initially planted in 1992. Half the vines in this Chardonnay block were own-rooted with the other half grafted to four different rootstocks. The own-rooted vines were starting to decline due to phylloxera damage. Following the record-breaking cold event in late October 2020 the decision was made to pull out all own-rooted vines rather than to retrain already declining vines during 2021. Instead, 120 dormant Chardonnay vines (clone 37.1) grafted to rootstock SO4 were planted on 21 April 2021.

This experiment is a modification of the 2017 study (see above). Half the vines are planted with the graft union 2" above the soil surface (Control = standard practice) while the other half are planted with the graft union 2" below the soil surface. Unlike the 2017 study, the planting holes for the treatment 2" below soil surface were not filled up entirely, leaving the graft union exposed. In fall of 2021 those holes were filled up to the soil surface. Half the holes in this treatment were filled with soil, the other half with wood chip mulch. Graft unions will remain covered throughout the experiment. Graft unions of half the Control vines were covered in fall 2021 soil while graft unions of the other half of the Control vines were covered with wood chip mulch. Temperature data loggers were placed at the height of the graft unions of eight vines: four Control vines (two with soil and two with mulch cover) and four vines with the graft unions 2” below the soil surface (two with soil and two with mulch cover). In addition, two temperature loggers were placed at cordon height. Temperatures were recorded from 6 October 2021 to 3 May 2022. The lowest temperature recorded at a covered graft union was 21.2 F, whereas the minimum temperature at cordon height was 3.5 F. Soil and wood chip mulch provided the same thermal protection of the graft union. Where the graft union was above ground (Control) the dormant season minimum temperatures were about 5 F colder than where the graft union was at 2” below ground.

In early May 2022, for each covering treatment (soil or wood chip mulch) of the Control, half the graft unions were uncovered while the other half remained covered. These treatments will be applied to the same Control vines for the remainder of the experiment. Graft unions placed 2” below ground will remain covered throughout the experiment. We will collect data on scion root formation, vine survival, and fruit yield and quality for a minimum of five years.

- 2009 Rootstock trial with Viognier.

A rootstock trial with Viognier (clone FPS 01) grafted to 5 different rootstocks as well as own-rooted Viognier was planted at WCRC-OM in late April, 2009. Some replanting took place in the spring of 2010. The trial is set up with a randomized block design with seven replications, and four vines per replication. Vine x row spacing is 5 feet x 8 feet. Vines are irrigated by drip. The following rootstocks are included: 110 Richter, 140 Ruggeri, 1103 Paulsen, Kober 5BB, and Teleki 5C.

About half the vines needed retraining from the ground following the October 2020 extreme cold event. Only one out of the surviving 103 vines had no growth during the 2021 growing season. Yields in 2021 ranged from 0.04 ton/acre with rootstock 140 Ruggeri to 1.75 ton/acre with rootstock Teleki 5C. Yields in 2022 should recover to 50-100 % of normal.

- 2017 Rootstock trial with Cabernet Sauvignon.

A new rootstock trial with Cabernet Sauvignon (clone 33) grafted to 11 different rootstocks was established in spring 2017 on a grower cooperator’s vineyard in the western part of Orchard Mesa using green potted vines. The site is located about 1.5 miles East of WCRC-OM. The following rootstocks are included: 110 Richter, 140 Ruggeri, 1103 Paulsen, 1616C, 101-14 Mgt, 3309 Couderc, Riparia Gloire, Salt Creek, Schwarzmann, SO4, and Teleki 5C. The trial is set up as a randomized complete block design with 5 replications, and 5 vines per replication. Vine establishment in year 1 was very good (255 out of 258 vines planted). Missing vines were replanted in spring 2018 from surplus vines grown in pots at WCRC-OM.

Initially, the grower cooperator was responsible for all practices related to vine establishment under the guidance of the State Viticulturist. Vines were dormant pruned in March 2019 by CSU staff. No yield data was collected in 2019. Vines were dormant pruned and pruning weights determined in March 2020. Yield and fruit quality was determined at harvest in 2020. Vine survival at harvest was 248 out of 258 vines planted originally. Pruning weight data was collected in early February 2021. In 2021, there was no bud break on cordons or higher regions of the trunks. All surviving Cabernet Sauvignon vines pushed shoots from near the graft union and required retraining. At the end of the 2021 growing season, 10.5 % of vines showed no sign of life.

- 2018 Rootstock trial with Cabernet Sauvignon.

  A new rootstock trial with Cabernet Sauvignon (clone 33) grafted to 11 different rootstocks was established in May 2018 on a grower cooperator's vineyard in the central part of Orchard Mesa using dormant field-finished vines. The site is located about 3.5 miles Northeast of WCRC-OM. The trial is set up as a randomized complete block design with 6 replications, and 4 vines per replication. Missing vines on three rootstocks were added in spring 2019.

  Initially, the grower cooperator was responsible for all practices related to vine establishment under the guidance of the State Viticulturist. Vine losses, presumably the result of cold temperature injury, have been very high in this block. More than 100 vines were lost after the 2019/20 dormant season. An additional 20 vines showed no sign of scion growth by the first week of June 2021. Seventy replacement vines were planted on 24 June 2021. All surviving vines needed retraining from just above the graft union. There was no crop in 2021. At the end of the 2021 growing season there were 47 missing vines (17.8 %).

- 2019 Rootstock trial with Souzao in a challenging soil.

  A new rootstock trial with Souzao (clone 1) grafted to 7 different rootstocks was established in spring 2019 on a grower cooperator's vineyard in the western part of Orchard Mesa using green potted vines. The site is located about 2 miles Northeast of WCRC-OM. The location for this trial is a former hay field that has not been irrigated for 10 years. Although the soil is classified as Gyprockmesa clay loam, the soil in this specific location is very sandy with a high percentage of large gravel, and at present highly alkaline. Gravelly areas within vineyards with predominantly Gyprockmesa clay loam are common on Orchard Mesa. Also, in the past many vineyards have been established on sites that had not been irrigated for many years, and this trend is likely to continue. Therefore, this site presents an opportunity to investigate the performance of a smaller set of rootstocks when grown in challenging soil. One or two rootstocks from the main genetic groups used in rootstock breeding (*V. berlandieri* x *V. rupestris*; *V. berlandieri* x *V. riparia*; *V. riparia* x *V. rupestris*, *V. solonis* x *V. riparia*) will be evaluated.

  The trial is set up as a randomized complete block design with 6 replications, and 4 vines per replication. Vines are irrigated by micro-sprinklers. Initially, the grower cooperator is be responsible for all practices related to vine establishment under the guidance of the State Viticulturist.

  Fifteen out of 168 vines died during the first growing / first dormant season. Vine mortality was highest when grafted to rootstock 1103 Paulsen (7), followed by 1616C (4), and one each for rootstocks 110 Richter, 101-14, 3309 C, and 5C. There were no losses on rootstock SO4. Graft unions had not been protected prior to the October 2020 freeze event and an additional 12 vines were lost. In 2021, there was no bud break on canes and all live vines resumed growth from buds right at the graft union. Five vines, left over from the original planting and kept in pots at WCRC-OM, were planted on 25 June 2021. There was no crop in 2021 but strong vegetative growth so that most vines could be retrained onto the cordon wire. Percentage bud break is high in spring 2022, and we expect to harvest the first crop in the fall of 2022.

- Crop load study with Chambourcin.

  A crop load study with Chambourcin was initiated in the spring of 2020 at WCRC-OM. Briefly, own-rooted Chambourcin vines planted in 2014 were thinned to one inflorescence per shoot at the end of bloom or one cluster per shoot at veraison, or not thinned (Control). Vine x row spacing is 5.7' x 9'. On average, thinning removed 44 % of inflorescences/clusters. Thinning at veraison reduced yield by 44 % while thinning at bloom reduced yield by only 18 %. This lower yield reduction of bloom compared to veraison thinning was due to a 25 % increase in cluster weight with bloom thinning. The higher cluster weight was the result of increased fruit set (+19 %) and slightly larger berry weight (+5 %). The 2020 growing season was very hot, resulting in an unusually early harvest. Thinning effects on fruit quality were minimal.

  The thinning study was repeated in 2021 using the same vines as in 2020. However, there was one modification – half the vines in the bloom thinning treatment were thinned just prior to bloom and the other half at the end of bloom. The study was replicated in another Chambourcin planting with GDC training at WCRC-OM as well as in a planting at a commercial vineyard about 2 miles East of the research center.

  As expected, thinning reduced yield per vine. However, the effect was not uniform for all thinning treatments with the highest reduction in yield with thinning at veraison and the lowest reduction with pre-bloom thinning. Pre-bloom and bloom thinning resulted in a higher fruit set but no change in the average berry weight. As a result, the average cluster weight was higher with pre-bloom and bloom thinning compared to the Control and veraison thinning. The 2021 growing season was again very hot, resulting in an unusually early harvest. Thinning effects on fruit quality were minimal except a darker juice/must color compared to the Control. At all three sites, pruning weight was higher than the Control with per-bloom and bloom thinning but was inconsistent with veraison thinning.

  Thinning effects on fruit yield, fruit composition, and pruning weights will again be determined for the 2022 growing season.

3. *Cold temperature injury mitigation and avoidance.*

Low yields and large year-to-year yield fluctuations are characteristic of Colorado grape production, even in the Grand Valley AVA, due to cold temperature injury. The research projects outlined below will identify best methods to either avoid cold injuries altogether, or mitigate cold temperature negative effects on vine survival, yield, quality, and vineyard economics. It should be noted that the identification of cultivars that are best suited to Colorado's climate (see cultivar trials above) is a fundamental component for avoiding cold injury.

- Characterizing cold hardiness.

  There are substantial varietal differences in cold hardiness. Understanding the patterns of acclimation, mid-winter hardiness, and deacclimation is a prerequisite to developing strategies that reduce cold injury. Staring in 2004, we have tested bud cold hardiness during dormancy of Chardonnay, Syrah, Chambourcin, and Rkatsiteli that differ in rate and timing of acclimation and deacclimation, as well as mid-winter hardiness. From 2014 to 2016, we have done the first-ever characterization of the seasonal pattern changes for Aromella. During the 2015/16 dormancy period we conducted four tests each for Albarino and Souzao, and the first test for Chambourcin growing in the Grand Valley. Albarino and Souzao were chosen as empirical evidence after the 2013 extreme cold events from the NE-1020 cultivar trial at Orchard Mesa as well as from a commercial vineyard nearby suggested that these cultivars have relatively good cold hardiness. In fact, we found equal or better cold hardiness compared to Chardonnay on three separate dates in January and February 2016 when Albarino and Souzao were tested within 1 or 2 days of the test with Chardonnay. Greater cold hardiness of Albarino compared to Chardonnay was indeed confirmed in 5 separate freezing tests during the 2016/17 dormant season, in 4 out of 5 tests during the 2017/18 dormant season, and in 5 out of 6 tests during the 2018/19 dormant season. In contrast, during the 2019/20 dormant season Albarino was less cold hardy than Chardonnay until mid January. This confirms observations from the 2017/18 and 2018/19 dormant seasons that Chardonnay buds are more cold hardy than buds of Albarino early in the dormant season, indicating a faster acclimation of Chardonnay in fall compared to Albarino. In spring, however, Chardonnay deacclimates earlier and faster and is less cold hardy than Albarino.

In the fall of 2016, in collaboration with Dr. Ioannis Minas, Pomologist at WCRC-OM, we developed and tested a new differential thermal analysis (DTA) system to determine cold hardiness (Minas et al., 2016). Generally, there is good agreement in cold hardiness values derived from DTA and those derived from the oxidative browning method (our standard method). The addition of the DTA system allows us to run cold hardiness tests for more cultivars at a time. During the 2017/18 and 2018/19 dormant seasons we used both the DTA as well as the oxidative browning method. In 2018/19 we included several cultivars from both the 2008 NE-1020 planting at WCRC-OM and the 2013 Grand Valley cultivar trial not yet characterized under Colorado growing conditions. The same cultivars were also tested in 2019/20 and 2020/21 and will be tested again during the 2021/22 dormant season. Results are made available via our Webpage, and growers are using this information when deciding if freeze/frost protection is needed.

- Delaying deacclimation and bud break.

Late-spring freezes, as in 2011, 2013, 2014, 2017, and 2020 can cause significant crop losses. Cultivars that break bud early are most at-risk (e.g. Marquette, Cabernet Franc, Chardonnay, and Gewürztraminer). Cultural practices that delay bud break will reduce the risk of crop losses, and thereby increase the profitability of growing grapes in Colorado's high elevation. In a previous study with an experimental, non-registered formulation of abscisic acid (ABA) applied in late fall we observed a significant delay in bud break the following spring. As ABA is now registered for grapes (ProTone; 20 % a.i. ABA) we tested a late season application of ABA in fall of 2019. No difference in bud cold hardiness was observed between ABA-treated vines and Control vines in mid October and early December, however in late March and early April buds from ABA-treated vines were 3 to 5 F more cold hardy. There was a slight (less than 2 days) delay in bud break on ABA-treated vines.

We repeated this trial in 2020 using Chardonnay vines growing at the Orchard Mesa site. However, the extreme cold event in late October 2020 caused high levels of bud and trunk damage and no data could be collected. Most vines required retraining from suckers during the 2021 growing season. We plan to repeat this trial in fall of 2022. A single foliar application of ProTone at a concentration that accelerates leaf abscission will be applied in late September / early October and compared to a control (foliar application of water and surfactant only). Cold hardiness will be evaluated several times during the dormant season and bud break will be evaluated in spring 2023.

4. *Identifying areas suitable for expanded wine grape production.*

The Colorado Climate Center proposes a continuation of their temperature investigation in areas of Colorado on the verge of being suitable for viticultural production. The largest limiting factor to expansion of the Colorado viticulture industry is cold nocturnal temperatures, particularly those occurring too early in the dormant season for vines to be properly cold tendered. The purpose of this investigation is to determine which pockets of land stay warmest on cold winter nights, and both make and revise recommendations for where viticultural activity has the highest probability of success.

In FY 2022 the Climate Center discontinued USB-501-PRO field data collection in favor of building our long-term data collection capabilities in areas of interest. Completed work in 2022 included the installation of two "CoAgMET-lite" stations in Montezuma County. These stations continuously measure temperature and relative humidity, are solar powered, and transmit data to our servers twice/day through a cellular modem. Data users can generate charts and graphs from these stations (LBN01 and CYA01), or get the raw data from our API. https://coagmet.colostate.edu/station/selector. The image below shows temperatures collected from the CYA01 station installed during FY 2022.

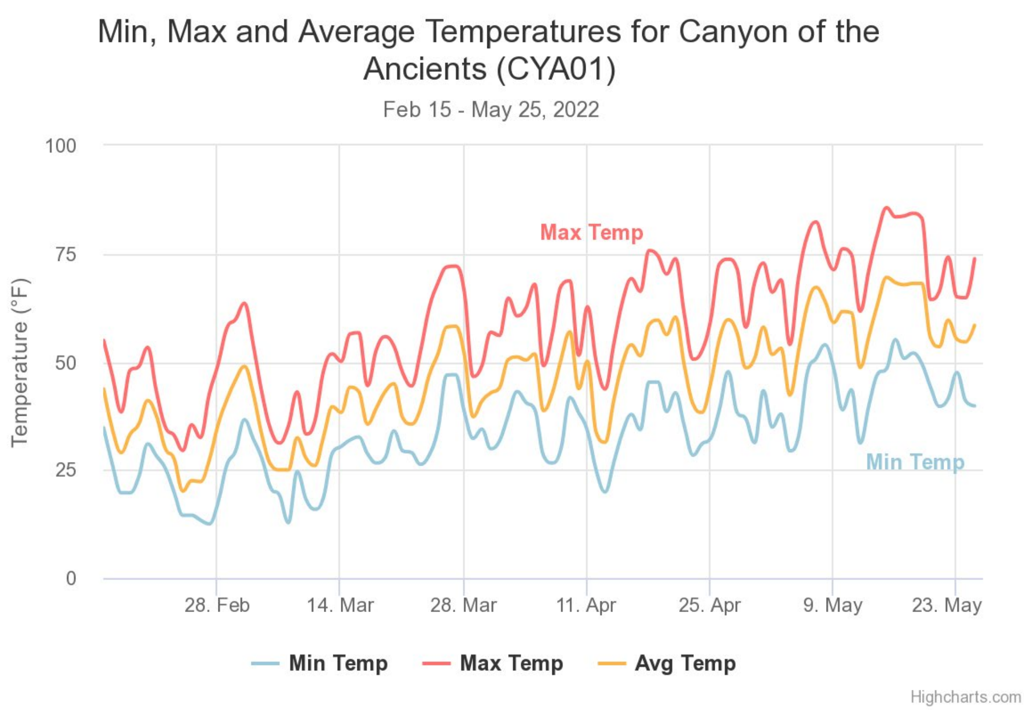

Fig. 1: Maximum, minimum, and average daily temperatures from CYA01 CoAgMET-lite station for Feb 15-May 25.

In FY 2023 the Colorado Climate Center proposes an expansion of CoAgMET-lite-style data collection in areas of interest identified during previous statements of work. This work will consist of three tasks: installation of two new CoAgMET-lite stations, analysis of any freeze events that occur in FY 2023, and an update to our "exploration opportunities" maps that includes recent data, and several different freeze thresholds.

Task 1 – Installation of two new CoAgMET-lite stations: The CCC proposes investing in long-term weather stations in areas where potential for expansion of the wine grape industry over time appears most feasible. Exact placement will depend on agreements with landowners, but we are planning installations in Huerfano County (lee side of Wet Mountains) and Montrose County (Paradox Valley).

The weather stations installed would use the same temperature sensors and data loggers as current CoAgMET stations, and transmit data wirelessly in to our servers.

In FY 2022 changes in costs due to supply chain issues limited expansion capabilities. This year, we have a quote from Campbell Scientific for the necessary equipment that is good through July 25th, 2022. This quote was used in our budget.

Task 2– Freeze Investigations: The CCC will monitor killing freeze events in Colorado. Potentially damaging events will be mapped using downscaled PRISM data and available weather station data. If no killing freezes occur, the CCC will use downscaled PRISM data and available weather station data to map minimum daily temperatures in viticultural areas for 1. The coldest mornings in fall 2. The coldest mornings in winter, and 3. The coldest mornings in spring near bud break.

Task 3 – Exploration Opportunity Maps: The CCC will add the most recent years of data to its "Viticulture Exploration Opportunities in Colorado" maps found here: https://climate.colostate.edu/climate_wine.html. These maps will include a range of killing freeze criteria rather than just one.

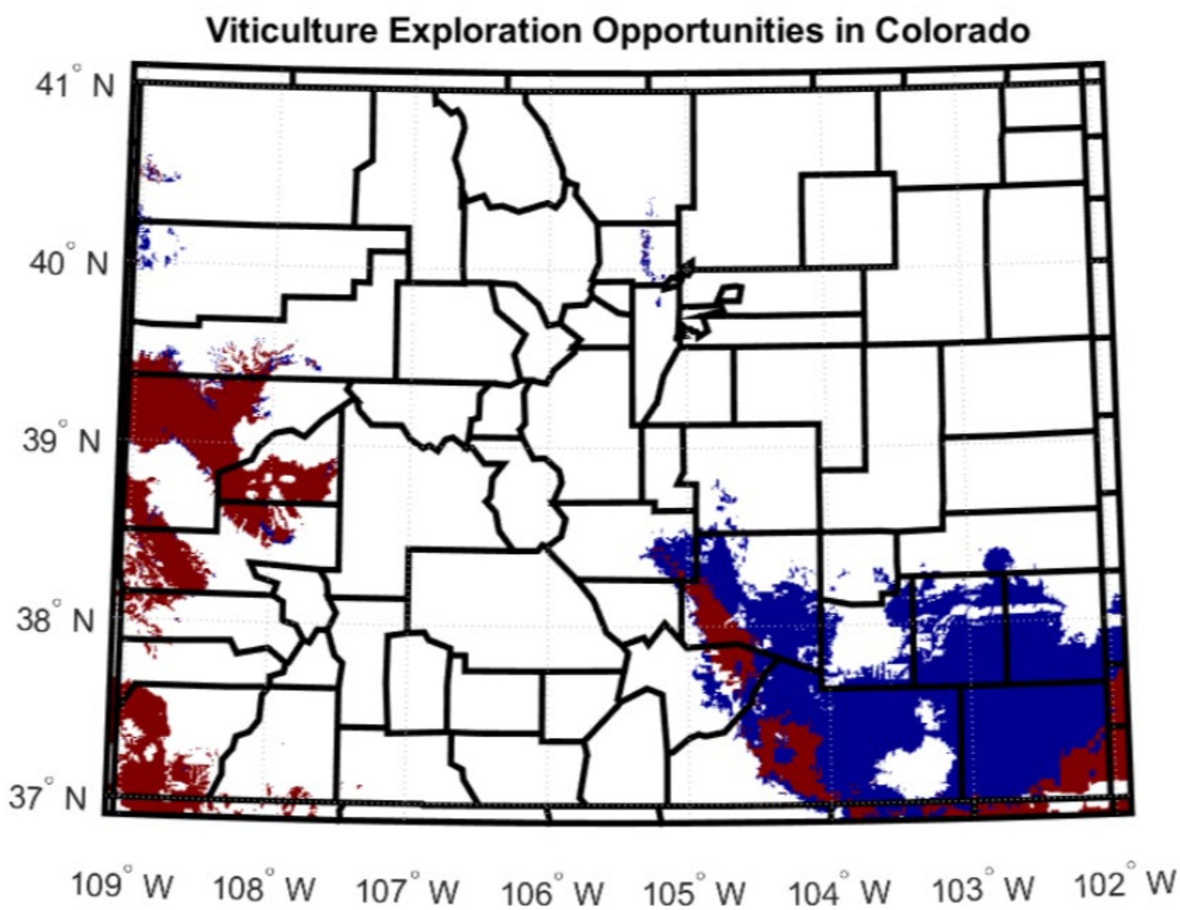

Fig. 2: Viticultural "Exploration Opportunities."

Hybrids only recommended (blue): In order to be contoured as an exploration opportunity for cold-hardy hybrids, a grid cell must avoid all of the following freeze conditions in at least 50% of years:

- A hard spring freeze (28°F or lower) following bud break (estimated as May 15th)
- A fall freeze (32°F or lower) prior to harvest (estimated as September 30th)
- Rapid onset of seasonally-unprecedented cold air in fall (temperatures in October of less than 10°F where the previous seasonal minimum is at least 10°F higher, or temperatures of less than 0°F in November where the previous seasonal minimum is at least 10°F higher)
- Deep cold early in winter (below -15°F before January 1st)
- Extreme cold in mid-or-late winter (below -20°F after January 1st)

Exploration opportunities for European and hybrid grapes (red): In order to be contoured as an exploration opportunity for both European grapes and cold-hardy hybrids, a grid cell must avoid all of the following freeze conditions in at least 50% of years:

- A hard spring freeze (28°F or lower) following bud break (estimated as May 15th)
- A fall freeze (32°F or lower) prior to harvest (estimated as September 30th)
- A rapid onset of seasonally-unprecedented cold air in fall (temperatures in October of less than 10°F where the previous seasonal minimum is at least 10°F higher, or temperatures of less than 0°F in November where the previous seasonal minimum is at least 10°F higher)
- Deep cold early in winter (below -5°F before January 1st)
- Extreme cold in mid-or-late winter (below -15°F after January 1st)

II. Development of Integrated Wine Grape Production

1. Sustainable resources use

An Integrated Vineyard Production System requires a sustainable use of all resources, including soil, water, and air. The projects listed below are the continuation of our long-term program.

- Vineyard floor management - soil health, fertility, and water requirements.

  Approximately 40% of the vineyards in Colorado are drip irrigated. While drip and subsurface drip irrigation are the most water efficient methods of irrigation, the question arises how to manage the inter-row area. Precipitation in Colorado's semi-arid climate is generally insufficient to maintain a green cover crop. Many older vineyards were set up with drought tolerant grasses sown in the inter-row area, but over the years those grasses have died out and been replaced by weeds. Some growers opt to clean-cultivate the inter-row, others maintain bare soil through the use of herbicides or mow the resident vegetation. Bare soil or minimal vegetation cover in the inter-row is likely to degrade soil quality that potentially has negative impacts on vine performance. Results from a previous study at Rogers Mesa show a very strong effect of soil condition and irrigation system on yield and fruit quality[2].

[2] Sprinkler-irrigated vines with a grass cover crop growing in the inter-row area have produced on average 2.8 times more yield than drip irrigated vines with a bare soil inter-row area. Fruit maturity was almost always enhanced (berries higher in soluble solids and pH and lower in titratable acidity) under drip irrigation and bare soil. A preliminary analysis of data from the 2012 survey also suggests higher yields with furrow or sprinkler irrigation versus drip irrigation.

From 2014 to 2020 we investigated the effects of different soil and irrigation management on long-term vineyard productivity and vine and soil fertility in the Chardonnay block at the Orchard Mesa site that was planted in 1992. Results from this study have been presented in annual reports and industry conferences. Half the vines in this block were own-rooted with the other half grafted to four different rootstocks. The own-rooted vines were starting to decline due to phylloxera damage. Following the record-breaking cold event in late October 2020 the decision was made to pull out all own-rooted vines rather than to retrain them during 2021. Instead, dormant Chardonnay vines (clone 37.1) grafted to rootstock SO4 were planted on 21 April 2021. The setup of the cover crop and irrigation system trial remains in place. Over the next three years we will determine the impact of cover crop and irrigation method on young vine establishment, nutrient status (years 2 and 3), yield and fruit quality (first crop anticipated in year 3). There is, however, one modification to the irrigation method – in 2021 all newly-planted vines are being irrigated by drip irrigation to optimize first year establishment. Better vine establishment with drip irrigation was found in our 2017 study on graft union management (see above). Micro-sprinklers are still being used to irrigate the cover crops.

- Vineyard floor management – evaluation of low-growing grass cultivars.

  Results from the 2004 cultivar trial at WCRC-RM show a very strong effect of soil management and irrigation system on yield and fruit quality (see footnote on previous page). The hard fescue cultivar used in the study at WCRC-RM was Aurora Gold, a cool-season turf with a natural tolerance to Roundup. It is a low maintenance grass with good drought and shade tolerance. In the study at WCRC-RM, as well as the more recent study at WCRC-OM, Aurora Gold has produced a very dense, low growing turf with minimum weed presence, even in the absence of Roundup applications. Due to its low growing nature and the oppression of weed species it is very easy to manage. Over the years we have received many grower enquiries about this grass cover crop, and where to buy seeds. Unfortunately, in recent years seeds of Aurora Gold were no longer available although we recently found a source. Here we propose to evaluate five different grass cultivars (three different species) and one blend that are commonly available and have similar characteristics to Aurora Gold in a new study at WCRC-OM. Long-term, we want to develop recommendations for low maintenance grass cover crops for the Colorado grape industry.

  A new study was established in a mature vineyard block at WCRC-OM in the fall of 2018. Irrigation in this block was changed from dip to micro-sprinkler. Five different turf cultivars were sown: two creeping red fescues, two Chewing's fescues, and one hard fescue. A sixth treatment was a blend of creeping red, Chewing's, hard, and blue fescues. Turf cultivars were selected from a list provided by Dr. Tony Koski, Professor and Extension Turfgrass Specialist at Colorado State University. All grass cultivars have growth characteristics similar to Aurora Gold, i.e. low growth habit forming a dense turf, with good drought and shade tolerance. The experimental design is a randomized block with four replications per treatment. Each replication is ~210' long (half a row). The focus of this long-term study is on turf establishment, persistence, weed suppression, and drought and traffic tolerance.

- Evaluation of AgriPhotoVoltaics for grape production in Western Colorado.

This project is contingent upon the final approval of a Specialty Crops Block Grant ($152,643) currently under review by the USDA-AMS.

The long-term goal of this project is to determine if AgriPhotoVoltaic (APV) systems will provide benefits to wine grapes (and other perennial crops like tree fruit) in the hot, semi-arid growing region of Western Colorado. Prior research with APV using other crops (predominantly vegetables) has shown several key outcomes that are of great interest to Colorado's grape growers, especially in the context of increased risks of crop losses due to climate change: a) modification of crop and air temperatures; b) reduction in crop water use; c) small changes in yield when shading from solar panels is less than 50 % of full light; d) changes in crop composition; and e) significant production of electrical energy. If confirmed, those outcomes would reduce weather-related financial risks and improve farm profitability via diversification.

AgriPhotoVoltaics is a system that combines the production of agricultural goods and energy on the same land, thereby reducing the land-use conflict between energy and food production. The theoretical concept of APV was first introduced in 1981 but it wasn't until 2010 that the first experiments were started with vegetables near Montpellier, France. Since then, a rapid expansion of installations has taken place with an estimated 2,200 installations worldwide in 2020. Despite the large number of installations there is a lack of experimental data about the impact on crop production and quality. Of the few empirical studies published to date the majority are from greenhouses, vegetables and field crops, and none are from perennial crops like grapes and tree fruit.

Important findings indicate that agricultural yields of shade tolerant crops can be maintained near 100 %. Several studies with APV have shown that crop and air temperatures are reduced during the day but stay warmer at night. Both, cooler day and warmer night temperatures, might be beneficial to wine grapes in Colorado. Peak summer temperatures in the Grand Valley are expected to reach 110-115 F by 2050, resulting in more plant heat stress, higher incidence of fruit sun burn, and reductions in fruit quality (e.g. color of red grape cultivars). Higher temperatures also raise crop water demand, yet stream flows and water available for irrigation are expected to decline. Reduced evapotranspiration leading to higher soil water status and reduced irrigation requirements have been reported for vegetables grown under APV. The potential for water conservation and temperature modifications with APV could be of great benefit for grapes in semi-arid Western Colorado where multi-year droughts and repeated frost and freeze events have caused significant crop losses over the past 20 years. Grapes reach photosynthetic light saturation at 50 % or less of full sunlight. Given the very high light intensity in Western Colorado, the partial and intermittent shading from solar panels positioned above vines will likely not cause negative effects on photosynthesis, but due to the cooling effect reduce heat stress, crop water use, fruit sun burn, and negative impacts from excessive temperatures on fruit quality.

Cold temperature damage is the main reason for crop losses in vineyards in Colorado. In the last 20 years there have been nine low temperature events causing up to 80 % crop losses in vineyards. Since 2000, extreme low temperature events in fall have become more frequent and have resulted in significant cold injury to buds, and in some cases even losses of trees and vines. Rising temperatures due to global climate change extend the growing season in fall but at the same time delay vine acclimation. This delay in cold acclimation predisposes vines to cold damage if/when there are sudden drops in temperature. Due to the lack of acclimation buds, shoots, and trunks are now being damaged at much warmer temperatures than in years past. Based on the predicted changes in temperatures the risk for this type of cold damage will increase. APV systems may reduce this risk if indeed night temperatures remain elevated. Further, the structures required to hold the solar panels above the crop in APV systems could also be utilized to support frost netting (as well as bird netting, insect exclusion netting), potentially raising the temperatures even further by several degrees, thereby reducing or completely avoiding cold damage. Of note is that frost netting can be deployed even under windy conditions when wind machines - the traditional method of frost protection in Western Colorado - are not effective.

All vineyards in Western Colorado depend on irrigation for reliable production. However, long-term drought conditions are limiting how much water is available for irrigation, and rising temperatures due to global climate change will put further pressure on this strained water resource. Consequently, how APV systems may alter plant water use is of great interest to grape growers. Reductions in crop water use and/or increases in soil moisture have been reported for several irrigated crops. We anticipate that crop shading and lower crop temperatures under APV will result in lower vine water use, conservation of soil moisture, and reduced irrigation water requirements.

Research on APV is very limited and reports on the impact on crop composition are rare. No information is available for APV effects on the composition of grape berries. However, many studies have documented that excessive heat negatively affects grape and wine quality by reducing color (in red cultivars), acidity, tannins, flavonoids, in addition to increased fruit sun burn and berry shrivel causing yield losses. Hence, we postulate that lower temperatures under APV systems may have beneficial effects on grape quality, especially for early ripening cultivars. A delay in crop development and ripening which is frequently reported with APV will not be detrimental for cultivars ripening early to mid-season but might be detrimental for very late ripening cultivars.

Agricultural operations such as wineries and fruit packing and storage facilities are very high users of electricity. If electricity produced from APV systems can be used behind the meter it will lead to more financial resiliency from two factors: a) reduced costs to purchase electricity from the grid, and b) reduced risk of weather-related crop losses due to the temperature-mediating effect of the panels. Even in the event of crop failure growers would still receive revenue from the sale of energy back into the grid.

As a shade-tolerant plant, grapevines should be well suited to be grown in an APV system. High temperatures in Western Colorado frequently reach levels detrimental to photosynthesis and cause fruit sunburn. Shading and cooling through an APV system may indeed be beneficial for vine and fruit growth, and fruit quality.

The hypotheses for this project are a) that solar panels installed above grapevines in the semi-arid climate of Western Colorado reduce heat stress, cold temperature injury, fruit sun burn, and conserve soil water without reducing vine growth, fruit yield and quality; and b) that the addition of frost netting will greatly reduce crop losses from cold temperatures, especially the increasingly frequent extreme fall events and the less frequent late spring freezes. Frost netting can be used even during windy conditions when wind machines, which are the predominant method of frost protection, are not effective due to the lack of a temperature inversion.

Solar panels (60” x 40”) will be installed above 6 rows of Chardonnay grapevines at the Western Colorado Research Center. Vines range in age from 2 to 6 years and are trained to a Vertical Shoot Positioning system. Vines are cordon-trained and spur-pruned. Row spacing is 10’ with vines spaced at 5’. Irrigation is by drip or micro-sprinkler with grass and legume cover crops in the aisles. Row length is 440’. A 125’ long section will be covered by solar panels (APV) while the remainder will serve as control treatment (Control). Solar panels will be attached to a frame at a height of 14’, about 7-8’ above the top of the grape canopy.

Environmental conditions (solar radiation, air and soil temperature, relative humidity, soil moisture, wind speed) will be continuously measured in both APV and Control. Data will be publicly available via CSU’s CoAgMet and Viticulture program web sites. Frost nets will be deployed above the canopy numerous times during nights with either calm or windy conditions to investigate the effect on vineyard temperatures. Tests will be performed irrespective if there is a need for frost protection or not. In case of damaging frost events the severity of damage will be determined in both treatments. Potential impacts on bud cold hardiness will be determined via weekly controlled freezing tests during acclimation, in mid-winter, and during deacclimation. Vine phenology (time of bud break, bloom, veraison, harvest) will be monitored. Leaf physiological measurements (gas exchange, temperature, water potential) will be taken throughout the season. Vine growth, yield, and fruit maturation will be evaluated following standard viticultural protocols. Bird netting will be deployed in APV above the vines with nets also covering the outsides. The severity of bird damage will be compared to that with side and over-row netting used in the Control. Fruit ripening and fruit quality at harvest will be determined using FTIR analyses with an OenoFoss analyzer. Photovoltaic energy production of the APV system will be recorded and the monetary value calculated using local power prices.

ENGAGEMENT / OUTREACH / COMMUNICATIONS

The ever-increasing number of growers and wineries in the state means that individual consultations are a very inefficient, and costly way of providing information. We therefore propose to conduct our engagement / outreach primarily through industry workshops / seminars, formal presentations (e.g. at VinCO), and field days. We will also collaborate closely with the new Viticulture Extension Specialist, Charlotte Oliver, and assist her in developing her extension program.

Over the past two years, several workshops/seminars had to be postponed due to restrictions imposed in response to the corona virus pandemic. In collaboration with the Viticulture Extension Specialist, we plan to reschedule those events in early spring of 2023. The tentative schedule and locations are:

Grape pruning – Canon City, late March or early April 2023

Grape pruning – Fort Collins, late March or early April 2023

We will continue to use our web site to provide information resources for Colorado growers. Also, as part of the “Application of Crop Modeling for Sustainable Grape Production” project, current weather information from four vineyard sites in the Grand Valley is accessible to grape growers and the public via the internet. We will continue to service both the software and hardware for this weather station network.

1. Off-station research and demonstration plots

The uptake of new research results and new production techniques is fastest when growers are directly involved in their development. One way of involving growers in research is to establish research plots on grower properties. Since 2013, we have established two replicated cultivar trials in grower vineyards. These sites will be used for industry education, such as the scheduled grape pruning workshop in late March / early April 2021 in Fort Collins. Another example of industry collaboration are several different vineyard sites in the Grand Valley where we monitor temperature profiles. The three new rootstock trials (one planted in 2017, one in 2018, and one in 2019) add to the growing list of off-station research plots. In spring of 2021 we replicated a crop load study with Chambourcin underway at WCRC-OM on a grower-cooperator's site. We will continue to use the vineyards at the Western Colorado Research Center in the first or early stages of testing of new methods and/or trials that carry a high risk of crop damage.

2. Colorado Wine Grower Survey

Colorado State University has conducted this annual survey for more than 25 years. The survey will again be conducted in late autumn / early winter 2022. The data will be compiled, summarized and presented to the CWIDB as well as at the VinCO 2023 meeting. A summary will also be available via the viticulture web page.

DURATION

The duration of this project will be from July 1, 2022 through June 30, 2023. However, the research activities that occur during this period will be a continuation and expansion of the entire mission, goals and objectives of the Colorado Wine Industry Development Board.

RESULTS

Results of this project will be presented to the Wine Board directors in the form of semi-annual progress reports as well as reports at CWIDB board meetings. Up-to-date articles will be posted on the viticulture web page. Research results will also be presented to the general public locally through newsletter, web pages, presentations at CAVE and grower meetings, and/or state- and nation-wide through scientific presentations and journals.

BUDGET

July 1, 2022 –June 30, 2023

Salaries & Fringe[1]	$193,695
Domestic Travel	$2,933
Materials and Supplies[2]	$29,620
Other Direct[3]	$5,684
Total Direct Costs	$231,932
Indirect Costs @ 10 %	$23,193
TOTAL BUDGET	**$255,125**

Note: Budget line items are agreed to be estimates. This budget contemplates the potential that the budget as a whole can be adjusted by line item to the needs of the project without prior approval (e.g., substitution of funds within line items), but without exceeding the total budget of $255,125.

[1] 26.7 % of salaries for faculty and professional staff; 13.0 % for 1st Year Admin Pro; 25.9 % for non-student hourly; 0.2 % for student hourly.

[2] For field and laboratory research; includes chemicals, glassware, parts, plant materials, and vineyard materials.

[3] Graduate tuition for one semester; computer network service fees.