PROJECT PROPOSAL

July 1, 2015 – June 30, 2016

TITLE:

CSU Viticulture and Enology Program for the Colorado Wine Industry

PRINCIPAL INVESTIGATORS

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JUSTIFICATION

In March 2014, the Colorado Wine Industry Development Board (CWIDB) conducted an online wine industry research survey. Among other questions, participants were asked to rank past research efforts in viticulture and enology as well as future research priorities. For viticulture, consistently two themes – responding to cold injury and variety selection – were ranked highest. 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.

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 on Colorado Agricultural Experiment Station and in-vineyard grower cooperator sites. Many of the projects outlined below are interconnected such as variety 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 trellis/training systems, soil and irrigation management, bud break delay; and results from specific cold hardiness projects that provide information on acclimation/deacclimation of varieties 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 have identified research on grape varieties suitable for Colorado's climate and responding to cold injury as the top two research priorities.

1. Grape varieties and clones suited to Colorado temperature conditions

Since 2004 we have greatly expanded the number of varieties under testing. The first-ever replicated variety 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 2009 as part of

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the USDA Multistate NE-1020 project (see below). Also in 2009 and as a part of NE-1020, 26 "new" varieties were planted at the WCRC Orchard Mesa site. An additional replicated trial focused on cold-hardy, resistant varieties was established on a grower cooperator site in Fort Collins in 2013 to identify grape varieties that can be grown successfully along the Front Range. And in 2014, a fourth trial focused on cold-hardy, resistant varieties was established with a grower-cooperator in the Grand Valley.

Unless mentioned otherwise, the work performed during the funding cycle includes standard vineyard management (e.g., dormant pruning, training, canopy management, crop adjustment, and harvest), crop growth response measurements (e.g., pruning weight, yield, bunch number, berry weight, juice parameters), as well as small-scale, varietal wine making for quality characterization. Wines made from the variety trials will also be used for industry training/education (e.g., workshops on "Tannin, acid, color and flavor extraction management for cold hardy cultivars," and "Variety evaluation and blending for wine niches"), as specified in the industry survey. Vines in the various variety trials are also the source of bud wood used for cold hardiness evaluations (see below).

- Rogers Mesa variety trial. (Caspari and Menke)

  A new vineyard was planted at the Rogers Mesa site in the spring of 2004, with additional vines added in the spring of 2005 and 2006. Results from this study have been presented annually at the Annual Meeting of the Western Colorado Horticultural Society (WCHS) and VinCO. An overview of the trial and results to date are available on the Viticulture Webpage.

- Multi-state evaluation of wine grape cultivars and clones. (Caspari and Menke)

  This long-term (2003-2017), USDA multi-state research project (NE-1020) 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 varieties were established in 2009 at Rogers Mesa, and 26 varieties at Orchard Mesa. Results have been presented annually at the joint WCHS / VinCO meetings, and are available on the WCRC Viticulture Webpage.

- Variety evaluation for Front Range locations, Fort Collins. (Caspari and Menke and grower cooperator)

  A new vineyard was established on a grower cooperator site in Fort Collins in 2013 to identify grape varieties 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. We expect to harvest the first crop and make small-scale wine lots from four varieties in fall 2015.

- Cold-hardy, resistant varieties for the Grand Valley. (Caspari and Menke and grower cooperator)

  A new replicated variety trial was established in 2014 on a grower cooperator site near Clifton to identify grape varieties that can be grown successfully in cold Grand Valley sites. Initial focus during 2015 following establishment is on vine training.

- Clonal trial with Cabernet Franc. (Caspari, Menke and grower cooperator)

  Cabernet Franc is one of Colorado's most-planted varieties, and varietal wines made from this variety have received national recognition. A recent review of data from Colora-

do's annual grape growers survey from 2000 to 2014 showed that Cabernet Franc was the only variety that produced above-average yields in all 15 years, and returned the greatest average revenue per acre. Furthermore, according to data from the 2014 Grape Growers Survey, Cabernet Franc is the only variety out of the top ten planted varieties that is still expanding acreage. It may indeed be one of the best-suited Vitis vinifera varieties for Western Slope region.

Most older-aged blocks of Cabernet Franc are planted with clone FPS 01. While this clone is high yielding and appears to have very good cold hardiness, it is also considered as having lower fruit quality. Since no information on Cabernet Franc clonal performance is available in Colorado, a trial with four clones (FPS 01, 04, 09, 11) was established in 2009 on a grower cooperator's vineyard[2]. We will determine the yield and yield components from one eight-vine panel per replicated row. At harvest, berry and must samples will be analyzed for juice pH, soluble solids concentration, and titratable acidity. Approximately 250 lbs of fruit per clone will be used for triplicate small-scale wine lots. Wines will be used for future analysis, formal wine evaluations, and industry tastings.

2. 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 varieties that are best suited to Colorado's climate (see variety trials above) is a fundamental component for avoiding cold injury.

- Characterizing cold hardiness. (Caspari and TBD)

  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. Since 2004, we have been testing bud cold hardiness during dormancy of Chardonnay, Syrah, Chambourcin, Rkatsiteli that differ in rate and timing of acclimation and deacclimation, as well as mid-winter hardiness. For the past two years, we have done the first-ever characterization of the seasonal pattern changes for Aromella. Additional varieties are being tested under the "Advancing cold hardiness" project (see below). Results are made available via our Webppage, and growers are using this information when deciding if freeze/frost protection is needed. We will continue the controlled freezing tests during dormancy in the 2015/16 season.

- Advancing cold hardiness. (Caspari and TBD)

  Cold injury to buds and trunks frequently occurs in late-fall prior to vine tissues reaching maximal cold hardiness. One approach to reduce this type of cold damage is to advance cold hardiness acclimation. Several recent studies have shown that a new plant growth regulator product containing 20% abscisic acid (ABA)[3] can advance cold acclimation. Initial trials by M.S. candidate Ms. Anne Kearney tend to confirm earlier bud cold acclimation in three-out-of-four tested varieties. However, the best timing for the ABA application differed between varieties. Initial results are very encouraging, but more research is needed on

[2] The trial was set up as a randomized complete block design with 10 full-row replications, and a total number of 500 vines per clone.

[3] ProTone, manufactured by Valent BioSciences.

the best timing, concentrations, and differences in varietal response. We are collaborating with several other research groups evaluating the potential of ABA to increase cold hardiness. The 2014/15 season trials will be repeated in 2015/16, and depending on outcome, the best two or tree methods will be further tested during dormancy in 2016/17.

- Delaying deacclimation and bud break. (Caspari and TBD)

  Late-spring freezes, as in 2011, 2013, and 2014, can cause significant crop losses. Varieties 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. Currently we are evaluating the potential of the above-mentioned growth regulator (ProTone) to delay bud break in Chardonnay. Laboratory tests in February/March 2015 have shown a rate-response for delaying bud break, with delays as long as several weeks at the highest concentration tested. Field trials will be undertaken in early April 2015, and depending on the outcome, we plan to repeat these trials in the spring 2016.

3. Alternatives to bilateral VSP to optimize yield and quality with different trellis/ training systems.

- Training system and pruning method effects on grape yield and wine quality of Syrah. (Caspari and Menke)

  Vines with bilateral cordon, spur pruned, and trained into a Vertical Shoot Positioning (VSP) system are the standard in Colorado. Our research on bud survival, shoot density, and yield following cold events in 2009, 2013, and 2014 show a limited capacity of this system to overcome high levels of cold damage. From 2010 to 2012, we have demonstrated the advantages of simple adjustments to change the bilateral VSP to a quadrilateral system. As a result, many growers are now training to four cordons or canes. Other training/trellis systems (Pendelbogen, Sylvoz, Lyre, High Cordon, Low Cordon, and Geneva Double Curtain) have been tested since 2006 using own-rooted Syrah vines growing at the Orchard Mesa site.

  For each training system, we are determining the time required for dormant pruning, yield per vine, and basic juice parameters. Separate wines will be made from each trellis/pruning system. Harvested fruit will be used to create different wine blends with other *V. vinifera* and cold-hardy, resistant varieties. Those blends will be used for industry tastings and educational events.

  Since 15-20% of Colorado's vineyard area has recently been planted to cold-hardy resistant varieties – most of which having a "droopy" growth habit and are thus not suited for VSP trellising – this training/trellis system block will serve as an instructional resource for workshops on pruning and training of varieties with downward shoot growth habits.

4. Identifying areas suitable for expanded wine grape production

- Western Slope microclimates suitable for wine grape production. (Doesken and Caspari)

  The high elevation of Colorado's Western Slope in combination with frequent sunshine, low humidity, and diurnal temperature fluctuations offer unique growing conditions for some varieties of wine grapes. Unfortunately, only small areas are likely available with appropriate soils, available water, and microclimatic conditions that minimize the occurrence of damaging spring freezes and mid-winter extreme cold events. This project offers an initial approach to identify areas with medium- and high-potential for expanded grape produc-

tion by examining climate trends to assess the likelihood of improved or reduced site potential.

The first-year of this analysis will be limited to Montezuma County and adjacent areas in southwestern Colorado where interest in potential wine grape production expansion is high. The following approach and tasks are proposed: (1) Map historical areas of fruit production and gather indigenous knowledge of wine grape production success and failures, (2) Identify where water is available, (3) Map known temperature and wind weather data sources, (4) Overlay existing USDA plant hardiness zone map to narrow down regions of greatest potential, (5) Use Geographic Information System software to identify elevation/slope/aspect characteristics for areas with most favorable growing season climatic conditions and provide climate statistical characteristics, (6) Identify known dates of damaging freeze conditions, (7) Use regional high-resolution, mesoscale atmospheric model to map wind and temperature patterns over the terrain for typical-winter-night conditions and then for extreme event identified in 6 above, (8) compare results to limited initial model results, (9) Develop a first-cut site suitability map, 10) Utilizing available climate records for this area, examine historic trends in local climate data. Are conditions trending towards more suitable or less? (11) Explore the potential for microclimate mapping using a combination of low-cost temperature sensors installed within a vineyard and satellite imagery of surface temperatures on clear nights, (12) Engage Grand Junction National Weather Service Forecasters in this study with the intent of improving local frost and freeze forecasting for the region.

If this initial study findings prove successful, additional resources will be sought from additional funding agencies. A report of findings, including a first-cut suitability map, will be submitted to the Colorado Wine Industry Development Board, and results will be shared at one or more appropriate conferences (e.g WCHS annual conference / VinCO 2017).

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.

- Water use by young grapevines. (Caspari and TBD)

  There is a lack of understanding of the water needs for grapevines in the Colorado climate. Irrigation inputs vary widely from too little to grossly excessive watering. An understanding of grapevine water use is needed to develop sound irrigation practices. In addition, irrigation management can influence both grapevine growth and fruit quality. In previous studies using the heat-pulse technique, we determined peak daily water use to be ~8 L per day for mature grapevines trained to VSP and spaced 5’ in the row. However, no data are available on vine water use of newly-planted vines throughout the first growing season.

  In 2014, we initiated a study using potted Noiret vines to determine water use by a mass balance approach. Depending on water requirements, vines are watered two or three times a week until water drains freely from the pots, pot weights are determined when drainage has ceased, and weights determined again prior to the next irrigation. Shoot lengths and leaf numbers are determined twice a month so that water use can be related to canopy development. A second trial will determine the vineyard water use requirements in the “Vineyard floor management – soil and irrigation” study (see below).

- Vineyard floor management - soil health, fertility, and water requirements (Caspari, Schipanski, Stromberger, and TBD)

  Approximately 40% of the vineyards in Colorado are drip irrigated. While drip and sub-surface 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 the variety trial at Rogers Mesa (see Viticulture Webpage) show a very strong effect of soil condition and irrigation system on yield and fruit quality[4].

  To further investigate the effects of different soil and irrigation management on long-term vineyard productivity and vine and soil fertility, an experiment was initiated in the fall of 2013 in the Chardonnay block at the Orchard Mesa site that was planted in 1992. These vines have been drip irrigated since planting, with initially a crested wheatgrass cover crop planted in the inter-row area. Over time the grass has been replaced by weeds and/or bare soil. Vine vigor is low in many areas of the block - a situation not uncommon in older commercial vineyards. After the 2013 harvest, the irrigation system from drip to sprinkler, and four replicated cover crop treatments established: two different grass-only cover crops; one grass-legume mix; and one legume mix. During the 2014 growing season the vineyard was sprinkler irrigated to optimize the establishment of the cover crops. In spring 2015 one of the grass-only treatments ("Hycrest" crested wheatgrass) will be returned to drip irrigation as is common in many drip irrigated vineyards.

  This project is long-term and most of the research is intended to be done by Masters candidates. During 2015 we will determine stand establishment success (percentage of cover crop, weeds, and bare soil), biomass production, grape yield and quality, irrigation water amount, vine nutrient status, and amount of vegetative growth. Soil samples for microbial analysis will be taken in June, August, and October from inter-row areas and immediately under the vines. Replicated small-scale wine lots will be produced for future analysis and industry tastings.

  As mentioned above, parts of the variety trial at Rogers Mesa have had different soil / irrigation management for 11 years, creating significant impacts on grape yield and quality. We will determine the effects of those cover crop and irrigation treatments on soil and vine characteristics. In addition to soil microbial analysis (see above) we will also take samples for soil chemical and physical testing (pH, salts, organic matter, nitrate, extractable plant nutrients, texture analysis by hydrometer method, and total C/total N.

[4] 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.

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. Further, we will train CSU Extension agents to assist growers with basic viticultural questions. Specifically, we will offer four training sessions for CSU Extension agents – two for Front Range locations, and two for the Western Slope. The tentative schedule and locations for other workshops are:

Alternative grape trellis/training systems – Grand Junction, August 2015 (Caspari)

Grape berry sensory evaluation – Grand Junction, mid August to mid September (Menke)

Variety evaluation and blending for wine niches – Grand Junction, December 2015 (Menke and Caspari)

Tannin, acid, color and flavor extraction management for cold hardy cultivars – Front Range location, March 2016 (Menke and TBD)

Grape pruning – Grand Junction, March 2016 (Caspari)

Grape pruning – Hotchkiss, March or April 2016 (Caspari)

Grape pruning – Fort Collins, April 2016 (Caspari)

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 seven 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 variety trials in grower vineyards. Once vines are fully mature, these sites will be used for industry education, such as the scheduled grape pruning workshop in April 2016 in Fort Collins. The replicated clonal study with Cabernet Franc is another example where the research is sited in a commercial vineyard. Yet another grower is collaborating in our study on advancing cold hardiness. Another example of industry collaboration are three different vineyard sites where we monitor temperature profiles. We will continue to use the vineyard at the Western Colorado Research Center at Orchard Mesa 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 a number of years. The survey will again be conducted in late autumn / early winter 2015. The data will be compiled, summarized and presented to the CWIDB as well as at the VinCO 2016 meeting. A summary will also be available via the viticulture web page.

DURATION

The duration of this project will be from July 1, 2015 through June 30, 2016. 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 quarterly progress reports and up-to-date articles 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 OUTLINE

July 1, 2015 –June 30, 2016

Salaries & Fringe[1]	$197,866
Domestic Travel	$5,375
Materials and Supplies[2]	$13,000
Other Direct[3]	$16,957
Equipment[4]	$12,639
Total Direct Costs	$245,837
Indirect Costs @ 10 %	$24,584
TOTAL BUDGET	**$270,421**

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 $270,421.

[1] 25.4% of salaries for faculty and professional staff; 7.2 % for graduate research assistants; 0.6% for student hourly.

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

[3] Soil analysis costs; graduate student tuition.

[4] Items in excess of $5,000 (e.g., Rondo sample changer $12,639).