PROGRESS REPORT AND PROJECT NARRATIVE

PROGRESS REPORT

Project #2011-51181-30850

The overall goal of the Northern Grapes Project (NGP) is to enhance and support growth and development of wineries and vineyards in cold-climate regions of the Midwest and Northeast through trans-disciplinary research and outreach addressing four broad areas: 1) Varietal performance and resulting fruit and wine flavor attributes in different climates; 2) Applying appropriate viticultural practices to achieve consistent fruit characteristics for winemaking; 3) Applying winemaking practices to their unique fruit composition to produce distinctive, high quality wines that consumers like and purchase; and 4) Understanding consumer preferences and individual/regional marketing strategies that to increase sales and growth of wines made from cold-climate cultivars and sustainable profitability of wineries and vineyards. In the first two years (and no-cost 3rd year extension) of a planned 5-year project, we've invested in field and laboratory trials, and provided outreach programming with an aggregate audience of 6,450 across the project region. In this report, hyperlinks point to more detailed summaries on our web site http://northerngrapesproject.org.

Baseline evaluation and economic impact survey. The NGP baseline survey, the key project evaluation instrument, was distributed in spring 2011 and used to evaluate economic impact of wineries and the cold climate cultivars. Surveys (n=611) revealed 5,900 planted acres and 199 wineries, with an aggregate economic impact of $401 million in 2011. Eighty percent of both vineyard and winery businesses were less than 10 years old; and 36% (vineyards) or 45% (winery) were less than 4 years old. Fully 50% of both white and red grapes were less than 4 years old, indicating rapid potential growth in supply.

Outreach: We completed most activities outlined in the Extension timeline (p7, Appendix B) for years 1 and 2, and are extending through 2014, with additional funding from the NY Specialty Crops Block Grant program. The *Northern Grapes Webinar* series, which has presented 18 monthly programs to 50-150 participants per program from 40 states, is most often cited as a key project impact. Three *NGP Symposia* were presented in MN (2012, 250 attending), NY (2013, 150 attending) and MN (2014, 350 attending). *NGP Enterprise Workshops*, which include field days and workshops (25 each year), were held in all project states. The Northern Grapes website and 9 issues (to date) of the quarterly newsletter *Northern Grapes News* provide project updates to clientele across the project region.

Research: The project established 49 field studies in 11 states, winemaking trials with over 300 fermentation lots; began to elucidate the changes that occur in gene expression and metabolite production during the grape berry ripening process; and surveyed customers in tasting rooms to learn about drivers of customer behaviors and satisfaction. Specifically by sub-objective:

Objective 1: Document cold climate varietal performance in variable climates and understand the resulting sensory characteristics of the fruit and wines.

Obj 1a. Evaluate cold climate cultivar performance under a wide range of climates throughout the Upper Midwest and Northeast to match cultivar with site. (Collaboration with the USDA NE-1020 Coordinated Grape Variety Trial project). We collected detailed data on weather and standardized vine phenology, bud mortality, disease, and yield at 13 locations, spread across nine states. Fruit samples from five cultivars (Frontenac, Frontenac gris, Marquette, La Crescent, and St. Croix) were collected at veraison and

harvest and analyzed for fruit chemistry (organic acids, titratable acidity, sugars, and pH). The NE1020 project currently runs through 2017.

Fruit Ripening Profiles of Cold Climate Wine Grape Cultivars (MN). Most cold-hardy cultivars exhibited more rapid sugar accumulation and slower acid degradation than *Vitis vinifera* cultivars over 4 years in Minnesota. Accumulated growing degree-days could explain most of the variation in soluble solids and titratable acidity content. Results were published in *NGP News*.

Obj. 1b. Characterize changes in fruit composition during the ripening phase and how they influence grape chemistry/quality at harvest.

Fruit composition during ripening from genomics to sensory (SDSU and UMN)**:** The fruit composition team tracked changes in fruit composition in Marquette and Frontenac during fruit ripening–from gene expression through sensory analysis. 1) In 2012 and 2013, Frontenac and Marquette berries were sampled five times from veraison to harvest. Standard maturity indices (pH, Brix, TA) were recorded, and RNA was extracted from all samples. Transcriptome analysis using RNA sequencing identified tissue (pulp vs skin) and cultivar specific (in both skin and pulp) patterns of differentially expressed genes particularly in aroma, stilbenoid and anthocyanin biosynthesis genes. Samples were provided to UMN for metabolite analysis (Hegeman lab). Whole berries and wines were provided for sensory and GC-MS olfactometry analyses (Vickers and Koziel labs).

Characterization of volatile aroma compounds (IA): GC-MS and simultaneous olfactometry was used to identify compounds and characterize aromas (through human olfaction) in Marquette, Frontenac, St Croix wines. Over 100 compounds producing 21 distinct aromas were identified in Marquette wines; 90 compounds producing 20 aromas in Frontenac wines; and 80 compounds producing 25 aromas in St. Croix wines. Volatiles from Frontenac, Marquette, and St. Croix grapes varied with time as grapes matured.

Obj. 1c. Intensify pre-release evaluations of elite selections from the University of Minnesota and private breeding programs. This sub-objective was dropped from our plan of work due to the 7% budget cutback.

Objective 2: Develop and extend research-based vineyard management practices that allow sustained production of high quality fruit from cold climate cultivars.

2a. Evaluate crop and canopy management strategies to minimize fruit acid content and improve fruit composition in these high-acid, high-sugar cultivars.

Marquette and Frontenac training system trials (NY): We compared two high-wire training systems, Top Wire Cordon (TWC) and cane-pruned Umbrella Kniffen (UK) and one mid-wire system Vertical Shoot Positioning (VSP). VSP-trained Frontenac vines yielded less than TWC vines in 2012 and UK vines in 2013. Fruit maturity indices (brix, pH, TA) were not significantly affected by training system, but sun-exposed clusters had up to 2° higher brix, and 2 g/L lower titratable acidity than shaded clusters. Yield of Marquette in 2013 trained to TWC and UK was double that of VSP-trained vines. VSP fruit had higher soluble solids, but titratable acidity and pH were unaffected.

Frontenac, La Crescent, and Marquette training system trials (IA): These trials tracked labor inputs as well as yield and fruit composition for TWC, VSP and two divided training systems, Scott Henry (SH) and Geneva Double Curtain (GDC). Labor requirements to train Frontenac and La Crescent vines to vertically oriented training systems (VSP & SH) were 60-80% higher (10-12 additional h/acre) than for the GDC and TWC. Frontenac had increased yields on VSP and SH systems than on TWC and GDC, while converse results were observed for La Crescent.

Effects of spacing, training, and pruning on vine performance and fruit quality of St. Croix (CT): Crop yield for St. Croix was significantly higher using GDC and TWC training methods versus VSP. In 2013, this result was partially due to increased berry weight and reduced vine and fruit damage due to downy mildew for the training system treatments.

Training system trials (NE): Most northern grape cultivars performed better on a TWC or GDC system than on VSP. Yields and soluble solids were significantly higher for Frontenac, Saint Croix, and Marquette trained to GDC and titratable acidity was reduced. These advantages were attributed to better canopy architecture and improved sunlight penetration.

Canopy management practices to improve light interception and quality of Frontenac, La Crescent and Marquette (IA): Post bloom removal of axillary (lateral) shoots in the fruiting zone required two-fold more labor than post-bloom or pre-bloom shoot thinning. However, lateral shoot removal also increased light penetration into the fruiting zone and improved fruit quality indices of soluble solids and total acidity more than shoot positioning or shoot thinning.

Influence of crop load on the quality of Frontenac, La Crescent and Marquette (IA): Trials using shoot thinning on TWC-trained vines to adjust crop load showed effects on Frontenac only. Shoot thinning to six shoots/ft. of cordon, produced a higher number of clusters and a higher overall yield than did thinning to five or four shoots/ft. in 2013. Pruning weights and fruit quality indices will be analyzed.

Cluster thinning to improve quality of Frontenac and Marquette (WI): Cluster thinning reduced yield and increased soluble solids in Frontenac and Marquette in 2011 and 2012, but did not significantly affect titratable acidity of juice pH.

Frontenac and La Crescent cluster thinning trials (NY): Yield was reduced by half on vines thinned to one cluster per shoot, but little to no effect on fruit chemistry was observed. Even un-thinned vines may not be at their optimal cropping potential, which could explain the lack of differences in fruit chemistry.

Marquette crop load and training system trial (MI): Marquette grown on a TWC trellis produced high yields without excessive 'hang time' in 2013. Moreover, fruit maturity was only partially impacted by high yield (reduced brix only) while fruit maturity levels of phenols, color compounds, TA and pH were not compromised. Vine growth and vine size were not impacted by the crop load treatments.

2b. Determine optimal mineral nutrition and soil management practices for cold climate cultivars.

Soil (2012) and tissue samples (2012 and 2013, three sample dates) were collected from 16 commercial vineyards in five states (MN, ND, SD, IA, NY) and results correlated with yield and juice composition metrics. Significant correlates included YAN and leaf N; pH and K. Sandy soils had lower pH and higher TA than fine-textured soils.

2c. Develop sustainable pest management recommendations based on cold climate cultivar copper and sulfur sensitivity and disease resistance.

Two plantings of northern cultivars were established in Madison and Sturgeon Bay, WI in 2012 and will be ready for evaluation of susceptibility to diseases in 2015 and 2016. In preliminary tests, Marechal Foch and Leon Millot were sensitive to sulfur and Brianna was sensitive to copper, while 10 other cultivars show little or no sensitivity to either sulfur or copper.

Objective 3: Develop and optimize winemaking practices to sustainably produce and market distinctive, high quality wines from cold climate cultivars.

3a. Optimize deacidification methods for cold climate cultivars.

Enology labs in NY and MN are evaluating both biological and chemical methods of reducing acidity during the winemaking process. A key goal is to selectively reduce malic acid and retain tartaric, if possible.

Chemical deacidification (NY) of high-malic grape must using calcium carbonate or the commercial additive Sihadex in the double-salt method did not selectively remove malic acid.

Biological deacidification (NY and MN): Commercially available *Saccharomyces* yeast strains with reported malate-consuming properties were used in fermentation trials with cold climate grape cultivars. All the yeasts tested showed some reduction in malate concentration, but LalvinC (Lallemand) showed the highest reduction in malic acid (up to 35%). Another promising strain for reducing acidity in aromatic white wines was the Exotics® strain (Anchor Yeast.)

3b. Minimizing herbaceous or 'hybrid' aroma (Mansfield). This sub-objective was dropped from our plan of work due to the 7% budget cutback.

3c. Enhancing wine sensory profiles.

Assess yeast strains for selected cold-hardy cultivars (NY and MN): As little is known about which yeast strains will work best with of the cold-hardy cultivars' unique juice chemistry, we are conducting trials with Frontenac, Marquette, La Crescent, and Frontenac gris, using yeasts selected for their ability to enhance desirable aromas in each cultivar. In 2012 wines, differences in wine chemical parameters (pH, TA, and % EtOH) within each cultivar were slight, and varied by region rather than yeast strain. Sensory evaluation of wines produced in Minnesota did not indicate difference in preference, though sensory differences were evident. Further sensory evaluation, grouping Minnesota wines with those from other regions, will be performed in 2014.

Enhancement of red wine structure and mouthfeel through the addition of enological tannins (IA): The addition of enological tannins at different levels and times during the fermentation of Marquette and Frontenac wines was evaluated in Marquette wines. Phenolic profiles for all treatments showed some increase in the levels of tannins and total anthocyanins. Wine chemistry was not impacted by the additions, indicating they have little if any effect on the fermentation kinetics. An industry tasting of treated Marquette wines indicated that the additions for all treatments resulted in a fuller bodied wine.

Objective 4: Identify strategies to support sustainable development of businesses based on cold climate cultivars, from the individual winery to regional agri-tourism.

4a. Facilitate development of successful marketing strategies for cold climate wines in based on target consumer characteristics, on-site marketing, and branding.

The tasting room experience and winery customer satisfaction. (NY) We surveyed tasting room visitors in six wineries in New York and Iowa to shed light on the drivers of customer satisfaction and the relationship between improved customer satisfaction and tasting room sales performance. We found that a focus on service is the most effective strategy to increase customer satisfaction scores, and that a "highly satisfied" visitor purchases one additional bottle of wine and spends an additional $10 in a given visit, in comparison to a "satisfied" visitor.

Wine consumer market surveys (MI): 15 Michigan tasting room visitor survey and 6 state random household member survey. Awareness of wines made from cold-hardy grapes is low, about 30% among wine drinkers and only 10% across the general adult population. But, those who have tasted them tend to like them. Survey results demonstrate the strong interdependence of wineries and other tourist dependent

enterprises. Survey data will provide a baseline for tracking change in consumers' behavior and perceptions over time and provide extensive insight to guide marketing strategy.

Brand research for cold hardy wines. (MN) Given the recent introduction of cold hardy grapes and the rapid emergence of a vibrant and expanding winery industry in the NGP states, it is essential to understand how branding can enhance marketing efforts. A February 2014 study evaluated branding attributes in sample NGP wines in a consumer survey, where different attributes were revealed in sequence (e.g. tasted blind, region identified, grape characteristics revealed). Results will inform the planned branding workshops.

4b. Identify strategies and techniques for wineries and winery associations to work successfully with each other in wine trails and with other community and regional organizations for rural economic development and effective marketing.

Survey of wineries and non-winery tourism businesses in 25 emerging wine regions ***(MI)***. Collaboration is very important to the success of emerging wine regions and individual wineries, but collaborators place different values on the outcomes of collaboration. Because of this, motivation to collaborate may be lower for some and collaboration is unlikely to see the requisite commitment from all parties unless it addresses the needs of all. We have a better understanding of how and where other wineries are collaborating as well as the return on investments from their collaborative efforts.

4c. Quantify the current economic impact of the cold climate grape and wine industry on rural communities and assess the impacts of state policy and law that impede or advance its development.

Baseline monitoring for the cold hardy grape and wine industries ***(MN)***. This study highlights the importance of the wine grape growing and locally-sourced winery industries in the *NGP* states. Wineries are the primary driver of economic impact. Cold-hardy wine grape vineyards and locally-sourced wineries remain a small portion of the total economic engine of the industries. However, survey results published in related NGP publications document the recent growth of the industries. The results also indicate growth is expected to continue in the cold-hardy wine and grape growing industries for the foreseeable future.

Policy Analysis for the Wine Industry in the US and in the Northern Grape Project States Specifically (MN). Policy issues, including government regulations, were listed as one of the primary barriers to winery operations in our baseline survey. The intent of the policy research component of the project was to uncover differing policies and analyze their effects on winery operations. We've completed this, and expect publication by July 2014.

4d. Develop a quality enhancement program for cold climate wines with focus on eliminating wine flaws that impact market acceptance, with an eye towards developing an industry driven wine quality assurance program. This sub-objective was dropped from our plan of work due to the 7% budget cutback.

Why a complete five year project term is important: Vineyard studies need a minimum of three years data to draw robust conclusions because annual climatic conditions vary and cropping level and training system modifications often take a year to establish (Year 1). In the original term, we have collected two years of field data. Disease management plantings established in WI in Year 1 of our project (2012) will be mature and ready for evaluations in 2015. Sensory evaluation of wines made in vinification trials lags one year beyond the fermentation. Funding two more years of the project will protect the original investment, and allow the project team to complete field and winery experiments that require multiple years' data.

PROJECT NARRATIVE

Executive Summary:

1.) Project Title: NORTHERN GRAPES: INTERGRATING VITICULTURE, WINEMAKING AND MARKETING OF NEW COLD-HARDY CULTIVARS SUPPORTING NEW AND GROWING RURAL WINERIES.

2.) Project Type: CAP

3.) Focus Areas:

1. Research in plant breeding, genetics, and other methods to improve crop characteristics. (5%)

2. Efforts to identify and address threats from pests and diseases, including threats to specialty crop pollinators. (5%)

3. Efforts to improve production efficiency, handling and processing, productivity, and profitability over the long term (including specialty crop policy and marketing). Project specifically addresses "Development of wine grape cultivars suitable for the production in the northern tier of the United States." (90%)

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5.) Critical need and long-term goals: Cold climate wine grape cultivars with *Vitis riparia* parentage, released since the mid 1990s, have created new and rapidly-expanding winery industries in New England, northern New York, and the Upper Midwest, regions that include New York, Massachusetts, New Hampshire, Connecticut, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Nebraska, South Dakota, and North Dakota. The long-term viability of these new specialty crop cultivars will depend upon a coordinated research and extension effort to remove non-technical obstacles to successful commercialization through viticultural, enological, and business management practices. We have begun to address stakeholder needs for *V. riparia*-based hybrids using a systems-based approach to refine viticultural practices specific to their growth habit and fruit chemistry, develop processing techniques appropriate for their unique juice composition, and develop marketing and business strategies for sustainability and profitability in this emerging industry, with the following long-term goals:

- In five years, production and sales of wines made from cold climate cultivars will double.
- Improved quality resulting from better growing and winemaking practices will improve customer retention and drive repeat sales.
- Enhanced breeding and cultivar evaluation will result in an accelerated pace of cultivar release.
- Cold climate cultivars will establish unique regional marketing identities in their area.
- Wineries will understand and apply business and tasting room management practices that drive sales and profitability.
- Wineries and vineyards will successfully transition from "startup" to "sustainably profitable."

6.) Outreach plan: In partnership with local industry groups in 14 states, we will continue to transfer project deliverables through: 1) *Northern Grapes Symposia* co-organized with industry groups at annual winter conferences; 2) *Northern Grapes Enterprise Workshops* with hands-on field and classroom meetings covering viticulture, winemaking, and marketing; 3) *Northern Grapes Webinars* (6 annually) delivered live electronically and archived on eXtension; 4) A *Northern Grapes Project Newsletter* (4 annually) with updates on project results; 5)*Northern Grapes Owner's Manual Publications,* 6)*Northern Grapes Project* website, which will house all material generated by the project. We will disseminate results through the eXtension Grape Community of Practice and existing extension outlets (Appendix E) in the Northeast and Upper Midwest.

7.) Potential economic, social, and environmental benefits: Project objectives, shaped by planning workshops held in 2009 and 2010(Appendix A), will directly benefit 1,200 growers, representing 5,900 grape acres, 23 state-based producer organizations (Appendix D) and 300 wineries currently producing 1.5 M gallons of wine annually. Producer groups will participate in project evaluation surveys (Appendix B) and marketing research surveys (Obj. 4). Adoption of research-based recommendations and outreach from this project will improve grape quality, foster improved winemaking practice tailored to cold climate cultivars' unique attributes, and increase sales by providing consumer-based information to market and brand cold climate wines. A vibrant retail winery sector will strengthen rural economies throughout the Upper Midwest and Northeast through job creation, tourism-based expenditures, and contribution to the tax base. Environmental benefits include research-based optimization of fertilizer and pest management inputs.

8.) Logic Model:

Situation: New cultivars have made possible grape and wine production in cold climates. Varietal performance, specific viticultural and winemaking practices, and marketing/consumer information are needed to support industry growth and development. Research and outreach will enhance and support growth and development of wineries and vineyards in cold climate regions of the Midwest and Northeast

Inputs	Outputs		Outcomes-Impact		
	Activities	Participation	Short	Medium	Long
• Planning sessions in VT, MN with stakeholders in 13 NE and Midwest states 2009 • 23 State and Regional grape and Winery associations • CAP Project Funding, USDA-SCRI (2011-2013) • 100% Match from 13 institutions and in-kind from industry cooperators and advisory committee members (2011-2013). USDA funding: Current proposal 2014-2016; Cornell and 9 other subcontracted universities; 100% Match from institutions and cooperators	Multidisciplinary studies will address: • Varietal performance and flavor attributes • Applying appropriate grape production practices to achieve consistent fruit characteristics • Applying winemaking practices to unique fruit composition to produce high quality wines that consumers like and purchase • Understand consumer preferences, and individual/regional marketing strategies to increase sales and growth and sustained profitability of wineries and vineyards • Complete outreach plan, with Northern Grapes Webinars, Newsletters, Research Reports, Field days and Symposia	• Scientists in four teams: -Viticulture, including Plant pathology and Nutrition -Fruit composition: Genetics, Metabalomics, sensory - Enology - Economics: tourism, behavioral economics • Industry cooperators: 15 vineyards; 6 wineries • Project Advisory Council members (15): representing research (2), extension (3) and industry (10). • NE-1020 Working Group Coordinated grape variety trials project	• Matching cultivar with climate attributes • Recommendations of costs and benefits of vine training systems. • Cropping and canopy management practices to improve fruit composition • Winemaking: cost-effective methods for deacidification, appropriate yeast strains for specific cultivars, skin contact and enological tannins for quality enhancement. • Enhancing sales in tasting rooms • Regional marketing and quality control plans • Data on collaboration impacts on growth and profitability	• Aroma components and flavor development during ripening characterized from genetics to metabalomics to sensory to inform new cultivar screening and biomarkers for assessing grape maturity and harvest decisions. • In five years, production and sales of wines made from cold climate cultivars will double • Improved quality resulting from better growing and winemaking practices will improve customer retention and drive repeat sales • Extension collaboration will reduce duplication and provide expertise across state lines.	Long Term: • Continued cultivar evaluation will result in accelerated release of improved cultivars • Cold climate cultivars will establish unique regional marketing identities in their area • Wineries will understand and apply business and tasting room management practices that drive sales • Wineries and vineyards will successfully transition from 'start-up' status to 'sustained profitability'

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Introduction

In 2011, the SCRI provided two years of funding followed by a one year no-cost extension for our five year CAP project, *Northern grapes: Integrating viticulture, winemaking, and marketing of new cold-hardy cultivars supporting new and growing rural wineries.* We are asking for an additional two years of funding to support the objectives laid out in the original proposal. The additional support will enhance and protect the $2.5 M in federal funds and $2.5M in industry matching funds already invested in the project, and solidify collaborative efforts of the project team well beyond the end of the project. Our original rationale and objectives remain the same:

New cold hardy grape cultivars released since 1996 by the University of Minnesota and private breeders have created a new cold climate grape industry with over 300 wineries and 5,900 acres of vineyards in the upper Midwest and Northeast (Tuck and Gartner, 2013a; Tuck and Gartner, 2013e; Tuck and Gartner, 2014a), where it previously was impossible to grow grapes due to extreme winter low temperatures. These cultivars derive their cold-hardiness genes from *Vitis riparia*, a wild grape species native to North America, which have been introgressed into a *V. vinifera* genetic background. Although this new, cold climate grape and wine industry is poised for growth, successful cultivar commercialization and rural economic development require that the following challenges be met:

The grape cultivars are new to growers. Most of the *V. riparia*-based Minnesota cultivars and so-called 'Swenson' hybrids developed by private breeders have been released since the mid 1990s. Significant departures from the growth habit and fruit chemistry of *V. vinifera* require optimization of growing practices and vinification to realize the potential of this native U.S. germplasm.

The grape cultivars are also new to consumers. The wine market is dominated by products branded by the varietal name, and consumers may be wary of these new, unfamiliar cultivars. The successful retailing of wines made from the new cultivars will require informed marketing at the level of the winery and collaborative industry strategic planning.

Vineyards and wineries are small and young. With many businesses less than ten years old, education and outreach are needed now to foster a strong start and sustainable investments.

The industry is dispersed across Upper Midwest and Northeast. Establishing these new products in the marketplace will require a unified interstate effort. Prior to the start of the *Northern Grapes Project,* efforts in research and extension were fragmented across the Upper Midwest and Northeast. Similar needs are found in both areas, and no state has sufficient resources to single-handedly support the necessary research and extension.

Our vision is to develop grape production, winemaking, and marketing practices suited to the unique characteristics of these *V. riparia*-based cultivars marketed through retail tasting rooms and their niche in the U.S. wine market. Economically viable small wineries rely on wine sales that result from a production chain of vineyard establishment (selection of the right cultivar for the climate), effective growing practices (producing ripe, disease-free fruit), and appropriate processing (winemaking practices adapted to the cultivars) to produce a quality product and consumer experience. The success of an individual winery is also dependent upon collective action and promotion by the industry because they are tourism-based businesses. Groups of wineries are

more powerful attractors of tourism dollars than individual wineries, and success often involves networking for regional tourism promotion. Vibrant winery communities in the Upper Midwest and Northeast will anchor further economic development in rural areas and create jobs for rural residents. This project will interface with three related projects that address viticulture and enology needs in the same geographical regions: (1) the USDA-NIFA supported project NE1020 Multi-state Evaluation of Winegrape Cultivars and Clones (Objs. 1a, 1b, and 2c) (2) the USDA-NIFA SCRI 2010 funded project "Improved grape and wine quality in a challenging environment: An eastern US model for sustainability and economic vitality" (Wolf et al., 2010), which focuses on different cultivars but has a Northeastern and Mid-Atlantic geographic focus (Obj. 1a), and (3) USDA-NIFA SCRI 2011 funded project "Accelerating grape cultivar improvement via phenotyping centers and next generation markers" (Vitis Gen) which focuses on genotype by sequencing and SNP marker development and application for breeding. (Reisch et al, 2011)

Project objectives:

- Document cold climate varietal performance in variable climates and understand resulting fruit and wine sensory characteristics.
- Develop and extend research-based vineyard management practices to produce high quality fruit from cold climate cultivars.
- Develop and optimize winemaking practices to sustainably produce and market distinctive, high quality wines from cold climate cultivars.
- Identify consumer demographics and marketing strategies to support sustainable development of businesses based on cold climate cultivars.

Stakeholder Input: Input from industry and academic stakeholders was facilitated by a USDA/NIFA SCRI planning grant ("Addressing Research and Extension Needs of the Cold Climate Wine Industry") awarded to co-PIs Martinson and Luby in 2009. This grant funded planning workshops in Vermont and Minnesota during the winter of 2009-2010 with over 70 leaders from 15 industry groups in 13 states as well as research and extension personnel. An additional online survey collected data on industry demographics and priorities. Research and extension personnel synthesized the industry input into project objectives (Appendix A). During the project, stakeholder participation in the Project Advisory Council (Appendix C) has provided input and will continue to monitor progress and set the overall direction for the project. In addition, direct participation of stakeholders in research through grower demonstration plots and collaborations are included in Objs. 2 and 4.

Background. The recent development and commercialization of cold climate wine grape cultivars has created several new and rapidly-expanding wine industries in New England, northern New York, and the Upper Midwest, areas previously considered too cold for wine grape cultivation (Luby et al. 2006, Justis 2006, Anonymous 2008, Thompson 2006). They include four cultivars released by co-PI Luby at the University of Minnesota (Frontenac, Frontenac Gris, La Crescent, and Marquette; Hemstad and Luby, 2003; Hemstad and Luby, 2005) and several others (e.g., Edelweiss, Prairie Star, St. Croix, St. Pepin, and Brianna) developed by private breeders in the Midwest. Since their introduction in the mid 1990s, these cultivars have created an enormous amount of private investment and economic activity in rural areas throughout the Northeast and Upper Midwest. These cultivars have inherited from their *Vitis riparia* parentage the unique ability to withstand winter low temperatures as cold as -40º C (-40 ºF) (Hemstad and Luby 2000), and they possess cold

hardiness superior to hybrids between *V. vinifera* and other native *Vitis* species (Reisch et. al. 2001). However, in addition to enhanced cold-hardiness, *V. riparia*-based cultivars differ from other wine grape cultivars in viticulturally and enologically significant ways. These differences require the modification of cultural practices and winemaking techniques, with evaluations on a larger scale than was possible during the process of breeding and selection.

Viticulture: The two primary viticultural challenges for *V. riparia* hybrids in cold climate regions are the production of ripe fruit (higher sugar, lower acids) and desirable flavor and aroma compounds and precursors. The growing environments for the new *V. riparia*-based hybrids share cold winter temperatures, but other climate characteristics (e.g., heat accumulation, rainfall, timing of fall frost) may differ widely, and the shorter, northern growing seasons can delay fruit maturity and produce lower quality grapes, unsuitable for quality wine production. However, *viticultural practices* can be used to increase the reliability of ripe fruit production by adjusting crop level and increasing sunlight exposure of clusters, for example by manipulating bud numbers (through pruning) and managing shoot vigor and canopy density to optimize shoot number and density. Fruit exposure to sunlight can reduce disease and directly increase favorable and reduce unfavorable flavor-active compounds associated with shading (Dokoozlian and Kleiwer 1995a, 1995b; Vanden Heuvel et al., 2004). Grapevine training systems strongly influence vine growth and fruit composition through impacts on the percentage of leaf area and clusters well-exposed to sunlight (Reynolds and Vanden Heuvel 2009). Low-wire cordons and vertical shoot positioning (VSP), suitable for the upright growth habit of *V. vinifera* cultivars, have been adopted by novice growers, but this canopy manipulation increases labor requirements and costs (Smart and Robinson 1991). High-wire cordons may be more suitable to these cultivars' procumbent growth habit (Hemstad and Luby 2003, 2005; Anonymous 2006), offering better light exposure to leaves and clusters (Reynolds and Vanden Heuvel 2009) and fewer hand labor inputs (Martinson and Vanden Heuvel 2008). The molecular and chemical processes of grape berry ripening are being studied using genomics, transcriptomics, and metabolomics approaches to identify key genes and pathways. Co-PI Fennell has used transcriptomic and metabolomic methods to dissect developmental processes (growth cessation and dormancy) and developed the web-based VitisNet tool to integrate "omics" data and identify genes and biochemical pathways involved in grapevine growth (Victor et al., 2010; Sreekantan et al., 2010; Grimplet et al., 2009). **For the *V. riparia*-based cultivars, key research questions are: What range of fruit chemistry and maturity can be produced across the climatically variable Upper Midwest and Northeast, and what viticultural practices positively influence fruit maturity and chemistry?**

Enology: Modern winemaking protocols are based on *V. vinifera* grapes but, compared to traditional cultivars, the fruit of *V. riparia*-based cultivars contains high acids and soluble solids and a different phenolic profile, and they produce wines with low tannins, pigments, and unique sensory attributes (Mansfield et al., 2008). To produce high-quality, attractive wines, winemaking practice needs to be adapted to the unique fruit composition of these cultivars. The combination of high acidity and high soluble solids (°Brix) presents challenges in producing balanced wines with favorable flavor attributes, requiring additional manipulations to prevent wine instability. In addition, winemaking practices can be altered to accentuate varietal characteristics through winemaking practices (e.g., yeast strain, skin contact during fermentation) and selection of wine style, including fortified wines, sweet wines, late-harvest and dessert wines. **For wineries, key research questions are: What**

methods produce wines that appeal to consumer palates, and what product styles are preferred by consumers of cold climate wines?

Business management and marketing: Wine and grape production can diversify farms from commodity crop and livestock production to value-added retail enterprises. Most cold climate wineries are small (1000-3000 cases), geographically dispersed over a wide area, and new to the tasks of producing wine and marketing their products to the public. Their success will depend on demand for their products, and they face a formidable task in attracting and retaining customers. Many small wineries depend upon tourism and can themselves serve as engines for rural economic development (MKF 2008, Stonebridge 2010, Rimerman 2012, Tuck and Gartner 2014). The success of individual wineries in attracting repeat sales and loyal customers depends upon 1) perception of quality, and lack of flaws and 2) the overall tasting room experience. Research by co-PI Gomez has demonstrated that purchasing decisions are influenced not only by the wine sensory characteristics, but also by packaging, presentation, and, for direct sales from tasting rooms, consumer experience (Gomez 2010) and the regional or product reputation. **For wineries, the key research questions are: Who consumes these wines, and what drives their preference and satisfaction? In addition, outreach is needed for effective marketing, branding, and regional strategies for tourism.**

RATIONALE AND SIGNIFICANCE

New grape cultivars have made the creation of wineries and vineyards possible in areas where it was previously too cold to grow grapes in the Northeast and Upper Midwest. However, their differences from traditional *V. vinifera* cultivars and older hybrids (growth habit, fruit chemistry) require the adaptation of growing and winemaking techniques to produce quality wine. Since 2000, cold climate winemaking and grape production has grown from a handful of wineries and a few hundred vineyard acres to our project's estimate of 5,900 vineyard acres and 349 wineries in 14 states (Tuck and Gartner 2014). In the 12 project states, Tuck and Gartner (2014) estimated an overall economic impact of $1.5 billion, and 28,200 jobs from wine grape vineyards and locally-sourced wineries in 2011. Economic impact cold-hardy varieties in project states (excluding value added from other wine grapes) was estimated at $401 million, generating 12,600 jobs, and including $140 M of winery-related tourism. Another, more inclusive estimate of economic impact in Iowa only (Rimerman & Co, 2014), showed an economic value of $420 million in 2012, an increase of 79% from the $234 million economic impact estimated in 2008.

This CAP project has brought together research and extension professionals from 12 Midwestern and Northeastern states in viticulture, plant breeding and genetics (production), enology (processing) and economics/marketing (consumers and products) in partnership with 23 producer groups from 14 states (Appendix D). We will continue to focus on applied studies of: 1) evaluation of the capabilities and adaptability of the new cultivars; 2) viticultural techniques to produce high-quality fruit; 3) winemaking practice to produce novel, high quality wines that consumers will buy; and 4) marketing and business practices effective for the small-scale direct-sales winery businesses of stakeholders and promoting rural tourism.

This project addresses the following SCRI focus areas: (1.) Research in plant breeding, genetics, and other methods to improve crop characteristics (5%); (2.) Efforts to identify and address threats from pests and diseases, including threats to specialty crop pollinators (5%); (3.) Efforts to improve

production efficiency, handling and processing, productivity, and profitability over the long term (including specialty crop policy and marketing). [Specifically, "Development of wine grape cultivars suitable for the production in the northern tier of the United States."] (90%)

Our approach will deliver an assessment of cultivar performance and characteristics and recommendations for viticultural, winemaking, and marketing/economics, delivered in diverse, user-friendly formats by the researchers and extension specialists in 12 states.

Approach: General Methodology

Farming for flavors: Our multidisciplinary approach will link measures of viticultural performance **(Obj. 1)** and practice **(Obj. 2)** with fruit composition and wine sensory characteristics, because the success of winemaking practices **(Obj. 3)** is ultimately measured by consumer hedonic response (i.e., like or dislike) to the final product. Understanding how individual wineries interact with their surrounding communities **(Obj. 4)** and their economic impact are key to their future growth and development.

General methodology for vineyard studies: The standard viticultural methods for evaluating vine performance (NE1020 protocol, Appendix G) used in Objs. 1 and 2 are described below**.** Treatments and protocols specific to each sub-objective will be described in the appropriate section. To describe vine performance, measures of phenology, vegetative growth (grown pruning weight, shoot growth), yield and fruit composition at harvest are needed.

Phenology, vine vegetative growth and vigor: Dates of 50% bud burst, bloom, veraison and harvest will be recorded. Vegetative growth will be measured by standard methods for leaf area, shoot growth rates, and dormant pruning weights. Following dormant pruning, the number of nodes retained on each vine will be recorded and bud number adjusted as appropriate. One-year cane prunings will be collected and weighed to obtain *pruning weights*, a measure describing relative *vine size*. Following bud burst, the number of *live shoots* emerging from retained nodes will be recorded, and *live shoots per retained node* will be calculated as a measure of winter bud injury. Where appropriate, a subset of shoots will be tagged and their length measured during the active growth phase as a measure of *shoot vigor*. The number of clusters per vine will be counted before bloom. If the experiment involves *shoot or cluster thinning*, post-thinning count of shoots and clusters will be made. Extended Point Quadrat Analysis (EPQA; Meyers and Vanden Heuvel, 2008) will be used to measure the light environment within the canopy, including % exposed clusters, average number of leaf layers, and % of canopy light interception, and will be used to evaluate cropping level, canopy management, and training system treatments (Obj. 2).

Yield components: At harvest, clusters per vine will be counted, and a sample of 100 berries per experimental unit will be collected and weighed to calculate yield components (clusters per vine, cluster weight, berry weight, berries per cluster). *Crop load* will be calculated using the Ravaz index (Ravaz, 1930: crop per vine divided by pruning weight).

Primary fruit chemistry: Depending upon the experiment, berry samples will be collected (50-100 berries minimum) from each replicate at designated times during fruit development and at harvest.

Standard maturity indices (^{0}Brix, pH, titratable acidity [TA]) and levels of malic and tartaric acid will be determined using standard methods described in Zoecklein et al., 1995.

Research wine production: To allow comparison of cultivars among regions and inform optimization of vinification methods, research-size wine lots will be produced following standard winemaking protocols (Luby et al, 2006) unless otherwise noted.

Objective 1: Document cold climate varietal performance in variable climates and understand the resulting sensory characteristics of the fruit and wines.

Target outcomes:

- Vine performance metrics in variable climates at ten sites across the Midwest and Northeast to inform vineyard site selection and match cultivars to specific sites.
- Analysis of fruit composition and wine sensory characteristics during ripening using standard (fruit chemistry) and novel (GC-olfactometry, gene transcript, and metabolomic) approaches to assess fruit maturity and inform harvest decisions.
- Identification and characterization of novel flavor and aroma-active compounds to define typical ranges for cold climate cultivars.
- Genetic and metabolic markers to phenotype the fruit chemistry of cold climate germplasm and advanced selections in the University of Minnesota breeding program and enhance screening and selection of cold climate cultivars suitable for wine production.

1a. Evaluate cold climate cultivar performance under a wide range of climates throughout the Upper Midwest and Northeast to match cultivar with site. (Collaboration with the NE1020 project, Martinson, Ferrandino, Sabbatini, Nonnecke, Read, Fennell, Bradshaw, Hazelrigg, Atucha, Hatterman-Valenti, Burrows, Dharmadhikari, and Mansfield)

Issue: Variable climate interacts with vine genetics to produce a range of fruit composition and flavor components in different environments, resulting in different wine sensory characteristics and styles. While these new cultivars withstand low winter temperatures, they are being planted in environments that vary dramatically in growing season length and heat accumulations. *Under what conditions will growers be able to consistently deliver ripe fruit to wineries, and how will differing climates affect juice and wine characteristics?* We will collaborate with the USDA-NIFA supported *NE1020: Multi-state Evaluation of Winegrape Cultivars and Clones* project (NE1020) for evaluation and standard winemaking and sensory analysis from cold climate cultivars and University of Minnesota numbered selections in Connecticut, Iowa, Michigan, North Dakota, Nebraska, New York, Pennsylvania, South Dakota and Vermont, and an additional plantings at Willsboro, New York. (Sites,cultivars listed in Appendix G).

i. Weather data **and** ***vine phenology, productivity, and maturity*** **(2015-2016, Martinson, Ferrandino, Sabbatini, Nonnecke, Read, Fennell, Bradshaw, and Hatterman-Valenti, Schloemann).** Weather equipment located at each field site will provide data on temperature (hourly), rainfall, and leaf wetness. Data on phenology (timing of budburst, bloom, veraison, and harvest), yield, winter injury, and standard maturity indices (°Brix, pH, TA, acid composition) will be collected over four growing seasons (see general methodology above) according to the protocols established under the NE1020 project (Appendix G). Each planting comprises 4 to 12 cold climate

cultivars in a replicated design with six replications of four-vine plot units. We will focus on the most widely planted red (Frontenac, Marquette, and St. Croix) and white (Frontenac gris and La Crescent) cultivars as standards, but we also will include other cold climate cultivars and University of Minnesota numbered selections available in these trials.

ii. Fruit chemistry analysis (2015-2016, Dharmadhikari and Mansfield). Berry samples from the cultivars Frontenac, Marquette, La Crescent, and St. Croix (veraison and harvest) at eleven NE1020 sites will be analyzed for pH, titratable acidity, °Brix, and berry volume and weight. In addition, sugars (glucose and fructose) and organic acids (citric, malic, and tartaric) will be analyzed using HPLC for each sample. All analysis will be conducted at Iowa State University

iii. Sensory profile analysis **(2015-2016, Koziel).** Juice and wine aroma profiles from a selection of the sites will be characterized using solid phase microextraction coupled with multidimensional gas chromatography-mass spectrometry-olfactometry for simultaneously chemical and sensory analysis (Cai et al, 2007; Cai et al., 2009). This method, which couples identification of flavor and aroma-active compounds with detection and description by humans, will identify aroma compounds associated with these new cultivars. Pigments will be assayed using the procedure of Adams et al. (2004), and tannins will be measured by following Harbertson et al. (2002).

iv. Data analysis **(2015-2016, Martinson).** We will use multiple regression to relate weather information (first and last frosts, heat unit accumulations, winter low temperatures) to varietal performance (yield, maturity, fruit composition, and wine characteristics) and risk factors (damaging winter temperatures and spring/fall frosts). We will define *minimum* and *optimum* ranges of climate parameters for each cultivar, based on four years of data from ten vineyard sites in collaboration with the project enologists. Fruit characteristics and maturity will be related to the *length of growing season* (number of consecutive days above 0° C) and several measures of *heat unit accumulations,* (summarized by Jones et al. 2010). Standard growing degree-days have been used by the industry since Winkler et. al (1974) used them to classify California climate zones. We will use additional indices, such as the average growing season temperature (Jones et al. 2010), biologically effective GDD (Gladstones, 2004), and the Hughlin index (Hughlin, 1978), to determine if alternate climate indices provide a better fit to the data, and materially improve predictions. Winter minimum temperatures (a measure of cold injury risk) will be correlated with *live shoots per retained node*, an indirect measure of bud hardiness. We will also coordinate with the currently funded SCRI project *Improved grape and wine quality in a challenging environment: An eastern U.S. model for sustainability and economic vitality* (Wolf et al., 2010), which will generate GIS-based, site suitability maps for the Northeast and mid-Atlantic region.

Limitations and pitfalls: Inevitable differences in management (particularly disease management), data collection, and site-specific issues will occur and may affect the validity of comparisons among different plantings and sites, although standard NE1020 protocols for vineyard management and data collection should minimize this problem.

1b. Characterize changes in fruit composition during the ripening phase and how they influence grape chemistry/quality at harvest (Koziel, Fennell, Hegeman, Vickers).
Issue: Standard maturity indices (°Brix, pH, TA) provide basic information to guide harvest decisions. However, *flavor maturity* is only weakly correlated with these standard measures and is quite variable

across different cultivars (Boulton et al., 1996; Strauss et al., 1987). Flavor maturity can include many different types of compounds, including seed and tannin maturity, pigments (Harbertson et al., 2002), and volatile aroma compounds present in grape juice and those formed from precursors during fermentation. **It is critical to establish baseline gene, metabolite and sensory information for these cultivars to identify characteristics that can be used to develop biomarkers for fruit ripening that move beyond °Brix, pH and TA.** Moreover, cold climate cultivars are likely to have novel compounds from their *V. riparia* ancestry that contribute to wine flavor and aroma. We will link traditional industry grape chemistry targets and a discovery-driven, holistic berry development analysis to provide benchmarks and novel information on the genetic and molecular basis of fruit maturation and quality. We will link analyses of gene expression (transcript) with minor (aromatic) and major metabolites, and relate them to sensory changes during ripening**.** This systems approach will provide information not captured in a standard targeted strategy (Weckwerth et al., 2004; Hegeman, 2010) and is more economical than the number of viticultural trials required to test multiple combinations of cultivar, crop load, shading, and training systems over multiple years.

Outcomes: Baseline cataloging the primary metabolites (sugars, and organic and amino acids) and secondary metabolites (tannins, flavonoids, anthocyanins, stilbenes, other phenolics, and terpenoids) and pH will provide industry benchmarks for this new group of cultivars. These measures of fruit maturity will be directly useful in developing biomarkers for selecting high quality cultivars, measuring the impact of viticultural and winemaking practices (Obj. 2a), and enabling wineries make wines adapted to more precisely-defined fruit characteristics. **These types of correlations will be important for providing a baseline framework of wine characteristics for future analysis of different vintage conditions.** Correlation of gene expression and metabolite production with other characteristics (e.g., sugar content) will inform practices (e.g., timing of harvest). A novel and comprehensive library of grape chemistry compounds and their "meaning" (as it correlates to sugar content, for example) will enable development of the next generation of field-portable devices to sample/analyze growing grapes for harvesting decisions.

Development of maturity indices. Comprehensively track what genes are activated, what metabolites are produced, and what sensory descriptors develop at what time during the ripening process for Frontenac gris and La Crescent. Sample collection and data collection for Marquette and Frontenac were completed in 2012-2013.

i. Transcriptomic and metabolomic analysis **(Fennell and Hegeman).** 2014-2015, a 50 berry sample will be collected from each of two cultivars (Frontenac Gris and La Crescent). Comprehensive tracking of fruit ripening parameters and associated transcriptome (active genes) and resulting metabolites (flavors and aromas) will be conducted on a different cultivar each year, and the remaining cultivar samples will be stored for future studies. Samples will be taken for transcriptome and metabolome analyses from veraison, 20, 22, 24 and 26^0Brix (Table 1 below). Pre-veraison and veraison samples will be collected as whole berries into liquid nitrogen. The 20, 22, 24, and 26^0Brix samples will be separated into pulp and skin samples and flash frozen in liquid nitrogen. Transcriptomic analysis (Fennell) and metabolomic analysis (Hegeman) will use aliquots of the same replicate samples (n=4). RNA will be extracted (Tattersall et al., 2005) and RNA submitted to Cornell Genomic Facility for library construction and 100 bp single read sequencing. Raw sequence reads will be processed and quality filtered using FastX-FasQ and Cutadapt (Martin 2011). Quality

reads will be analyzed using TopHat/Cufflinks and published annotated grape reference genome and differential expression determined using Cuffdiff (Jaillon et al. 2007; Trapnell et al. 2012). . The expression data will be normalized using R software (Gentleman et al., 2004) and analyzed using the linear models method and empirical Bayes moderated F statistics (Smyth, 2005). A parallel metabolomic analysis of berry development will be performed using two complimentary types of chromatography, and mass spectrometric (MS) instrumentation will be used for measurement of metabolites to increase coverage, as follows: 1) an ultra performance liquid chromatography quadrupole -Orbitrap hybrid mass spectrometer; will be used in concert with 2) a gas chromatography time-of-flight mass spectrometer and well-established protocols (Hegeman, 2010; Kimball and Rabinowitz, 2006; Roessner et al., 2000; Weckwerth et al., 2004). Metabolites will be identified using a combination of accurate mass measurement (Hegeman et al., 2007) and comparison of MS/MS data with an in-house metabolite spectral library (Cui et al., 2008). Spectral features will be identified and quantified using a combination of software packages including MarkerLynx and the R package XCMS (Smith et al., 2006)

ii. Volatile metabolite analysis **(Koziel):** Emissions of grape volatiles such as terpenes, benzenes and C6 alcohols will be sampled at timepoints indicated in section *i* (Table 1) and from the grape berry will be collect in the laboratory from destructive sampling of berry skin and pulp. In 2014 and 2015 Frontenac gris and La Crescent berries will be sampled from NE1020 plots in Iowa and South Dakota at the six fruit development stages. Aroma compounds may be bound to sugar molecules in pulp and skins (Gunata et al., 1985a, 1985b; Wilson et al., 1986), therefore, berry skin and pulp samples will be used to measure bound aromatics. Fruit aromatic metabolite development will be subjected to simultaneous chemical and sensory analysis using multidimensional GC-MS-olfactometry to identify and quantify specific aromatic compounds (Cai et al. 2007; 2009).

iii. Juice and wine sensory analysis **(Vickers and Smith).** At 24 and 26 °Brix 50% of the fruit will be harvested, cooled, and shipped at 4°C to the University of Minnesota (Table 1). Samples for standard chemistry (Obj. 1a) and additional samples for juice sensory description will be rated for aroma, sweetness, acidity, bitterness, flavor descriptors, and astringency by ten trained panelists. Wine will be made from the two cultivars each year using standard protocols at the University of Minnesota Research Winery for two maturity levels (24 and 26^{0}Brix) (Table 1), and they will be rated for aroma, sweetness, acidity, bitterness, flavor descriptors, and astringency by ten trained panelists.

Table 1. Frontenac Gris and La Crescent will be sampled for fresh weight (fwt), dry weight (dwt), berry diameter, cluster and berry photo documentation, transcript analysis, metabolite analysis, aroma profiling (volatile metabolites), and sensory analysis. The South Dakota NE1020 planting has six replicates of these cultivars and four will be used for these studies.

Berry Development Stage	Transcript	Metabolite	Volatile Metabolite	Sensory	Winemaking
Lag phase (prevéraison)	X	X	X		
Véraison (color change)	X	X	X		
20 °Brix*	X	X	X	X	
22 °Brix*	X	X	X	X	
24 °Brix*	X	X	X	X	X
26 °Brix*	X	X	X	X	X

*Samples at 20-26 °Brix will be collected and separated into pulp and skins for individual analysis.

iv. Integrated data analysis **(Hegeman, Fennell).** We will use a multivariate regression method (multiple O2PLS) to integrate analysis of transcriptomic, metabolomic, volatile metabolite, and sensory data (Bylesjö et al., 2007; 2009; Zamboni et al. 2010). Ripening characteristics identified by the statistical analysis and relevant to maturity indices will be mapped and identified to determine key metabolic pathways in ripening of these *V. riparia* based cultivars (VitisNet, Grimplet et al. 2009).

Limitations and pitfalls. To mitigate the risk of crop loss due to inclement weather, samples for all cultivars will be collected in 2014 and 2015. In the event of winter weather extremes La Crescent may be replaced by Brianna, another aromatic white grape with greater freezing tolerance. Fruit chemistry will vary from year to year, therefore this study will focus on developing baseline information for berry ripening profiles for each cultivar individually using samples collected at the same time and location, providing the uniformity needed to obtain correlations of gene expression and metabolites throughout the ripening profile. Both cultivars will be collected in first year and analyzed in fall and winter of second year. Alignment of the hybrid cultivars transcripts with the V. vinifera reference genome may result in some RNA-seq read loss. However we have already completed transcriptomic analysis of Marquette and Frontenac skin and pulp samples by described method and obtained 80-85% read alignment to reference genome. Analysis identified significant differential expression difference between Marquette and Frontenac and tissue types during ripening. In addition, we have developed de novo transcriptomes for these cultivars using Velvet and CAP3 assemblers to identify unique transcripts for these hybrids.

Objective 2: Develop and extend research-based vineyard management practices that allow sustained production of high quality fruit from cold climate cultivars.

Target outcomes:

- Guidelines for choosing training systems, canopy management, and cropping level adjustments to minimize acidity and promote maturity, suitable for the procumbent growth habit of *V. riparia* –based cultivars.
- Nutrient diagnostic criteria for cold climate cultivars.
- Sustainable pest management recommendations based on disease resistance and copper and sulfur sensitivity of cold climate cultivars, including the unique prevalence of anthracnose.

2a. Evaluate crop and canopy management strategies to minimize fruit acid content and improve fruit composition in these high-acid, high-sugar cultivars (Nonnecke, Read, Sabbatini, Atucha, Martinson, Wallis, Hatterman-Valenti, Burrows).

Issue: Vine training, pruning, and canopy management are the viticultural tools that growers use to influence crop level and fruit characteristics at harvest. In the Northeast and Midwest, fertile soils and ample (but unpredictable) rainfall can produce excess vigor that leads to shaded canopies and fruiting zones. While growers of *V. vinifera* cultivars have several tools, *designed for V. vinfera's upright growth habit* to promote cluster sunlight exposure, these practices are not appropriate for *V. riparia*-based cultivars that have intermediate to drooping (procumbent) growth habits. In addition, *V. riparia*-based cultivars retain high acids and low soluble solids during short growing seasons. Viticultural practices to moderate acids and avoid ripening delays are needed for *V. riparia*-based

cultivars. Using Obj. 1a results on fruit chemistry and flavor development as a baseline, we will test the utility of using viticultural manipulations to promote favorable fruit composition at harvest.

i. Identify training systems suited to cold climate cultivars **(2015-2016, Nonnecke, Martinson, Read, Atucha).** We will compare vine performance, yield, light interception, disease incidence, and fruit composition in coordinated, replicated trials in established commercial vineyards or pre-existing university blocks in Iowa, Nebraska, and New York. Each trial will include three to five of the following treatments (according to space available and local conditions): High Wire Cordon (HWC) with shoot positioning; HWC without shoot positioning; mid-wire cordon with standard Vertical Shoot Positioning (VSP); mid-wire cane-pruning with VSP; vertically divided (Scott-Henry or Smart Dyson), with shoots trained upward and downward; Geneva Double Curtain (GDC; horizontally divided, high cordons); and Umbrella Kniffen (UK; head-trained, with arched canes, tied). Buds will be adjusted to a standard range (per linear foot of canopy), and shoot density will be adjusted after budburst to 5-6 shoots per linear foot of canopy (15 per meter). In the HWC-shoot positioned treatment, shoots will be combed downwards between bloom and fruit set. In the VSP blocks, shoots will be tucked or positioned with moveable catch wires three times during canopy development, and shoots will be tipped as needed when they extend >1 foot above the top wire of the canopy. Detailed records of labor inputs will be used to analyze costs associated with each system. Harvest data (cluster counts, crop weight, and berry weights) will be used to calculate yield components. Canopy density and light interception will be evaluated through extended point quadrant analysis (EPQA) (Meyers and Vanden Heuvel 2008). Basic fruit maturity indices (^{0}Brix, pH, TA) will be collected 2-3 weeks preharvest and at harvest. Fruit from selected treatments will be vinified and evaluated.

a. New York Trial **(Martinson).** *Location:* Coyote Moon Vineyards, Clayton, New York, planted 2008. *Treatments*: Three training systems (HWC, mid-wire VSP, and Umbrella Kniffen). *Cultivars:* Marquette and Frontenac. 2015-2016.

b. Iowa Trial **(Nonnecke).** *Location:* Snus Hill Vineyards, Madrid, Iowa. *Treatments:* HWC+ shoot positioning, mid-wire cordon with standard VSP, and vertically-divided (Scott-Henry) canopy. *Cultivars:* Marquette, Frontenac, and La Crescent. 2015-2016.

c. Nebraska Trial **(Read)**. *Locations:* Czechland Vineyards, Crete, Nebraska, and Univ. Nebraska (Lincoln). *Treatments:* HWC, GDC, VSP, Smart-Dyson, Scott-Henry. *Cultivars:* Frontenac and St. Croix. 2015-2016

d. Wisconsin Trial (Atucha). *Location:* UWM West Madison Research Farm. *Treatments:* VSP, HWC and Scott Henry. *Cultivars:* Frontenac, Marquette, La Crescent, Brianna. Est. in 2012, ready for data collection in 2015.

ii. ***Canopy and cropping level management*** **(2015-2016, Nonnecke, Martinson, Atucha).** Modifying the canopy light environment and cropping level through basal cluster zone leaf removal, shoot thinning, and shoot tipping (summer hedging) can improve fruit composition but incurs extra labor and production costs. Because they directly reduce yield by removing a portion of the potential or actual crop, to be economically viable they must produce measurable positive changes in fruit composition that produce better wines, more valued by consumers.

Crop load adjustment: Under what conditions will crop thinning moderate acidity and assist growers in avoiding delays in ripening? Cluster thinning to reduce cropping level may be needed to avoid delays in ripening and reduce the normally high acidity at harvest, particularly in cooler years and regions. In cooperators' vineyards, we will use the following two approaches to evaluate the impact of crop load adjustment on fruit composition at harvest:

a. Timing and severity of crop reduction **(Martinson, New York, 2015-2016).** We will collect an additional two years of data (we have data from 2012 and 2013 on Frontenac) on the effect of the timing and severity of cluster thinning in two trials (Cultivars: Frontenac; La Crescent or Brianna) in a selected commercial vineyard in northern New York. We will vary timing and severity to provide targets for crop adjustment. Four treatments will be applied: 1) no cluster thinning; 2) heavy pre-bloom thinning (30-40%; 1- 1.5 clusters/shoot); 3) heavy thinning at fruit set (30-40%1-1.5 clusters/shoot); and 4) at veraison (green harvest of lagging clusters only). Plots will be hand harvested and yield components determined as described in the general methodology. In both the New York and Iowa trials, basic fruit composition parameters (^{0}Brix, pH, TA) will be measured at three time points between veraison and harvest. Malic and tartaric acid composition and yeast assimilable nitrogen (YAN) will be determined at harvest.

b. *Timing and severity of crop reduction* **(Nonnecke, Iowa, 2015-2016).** In Iowa, La Crescent and Marquette cultivars will be used in 2015-2016. Treatments and methodology as described above for the NY study.

c. *Impact of cluster thinning and shoot positioning on yield and fruit composition* **(Atucha, Wisconsin 2015-2016).** On a VSP-trained vineyard, four crop load adjustment and canopy management treatments have been established on four cultivars (Marquette, Frontenac, Brianna, and La Crescent): 1) Hedged and shoot-positioned, no cluster removal; 2) 10% reduction in cluster number, hedged & shoot positioned; 3) 20% cluster removal +hedged/shoot positioned; 4) No hedging, shoot positioning, and no bud removal. Data from conversion year (2012) and one cropping year (2013) collected; two more cropping years (2015 – 2016) requested.

iii. Grower extension demonstration plots. **2015-2016. Martinson (NY), Burrows (SD), White (IA), Hatterman-Valenti (ND) and Read (NE).**

Based on early results from field trials described above, we will involve stakeholders in additional grower demonstration trials using a subset of thinning, canopy management, or training comparisons in unreplicated treatments in adjacent rows (e.g., shoot thinning vs. no thinning; cluster thinning versus 'no thinning', or HWC training versus standard VSP training). Extension educators will work with participating growers to apply the treatments, collect cropping data, shoot density, yield, and fruit chemistry (^{0}Brix, pH, TA), and possibly arrange for separate wine lots to be made at a commercial winery for comparative tasting by the group at winter meetings.

Limitations and pitfalls: Conducting trials in stakeholder vineyards presents some limitations and potential pitfalls in data interpretation because of layout (varietal blocks) and single training systems. Therefore, statistical analysis of the data will be limited to comparisons within cultivars and training system, and inferences between cultivars and/or training system can only be made at the local level.

However, cultivar and training system differences could be tested when pooled for multi-state comparisons.

2b. Determine optimal mineral nutrition and soil management practices for cold climate cultivars (Rosen, Nonnecke, Burrows, Hatterman-Valenti, Martinson).

Issue: Unbalanced mineral nutrition (e.g., potassium and nitrogen) due to lack of or excessive nutrient inputs can lead to undesirable grape juice properties, such as high or low acidity, high or low sugar, or low yeast assimilable nitrogen. Cold hardy grape cultivars are so new that optimal mineral nutrition and soil management practices have not been established, with growers using the critical values based on other grape species, *V. labrusca* and *V. vinifera* (Wolf, et al., 2008; Christensen et al., 1978). In addition, the best tissue type to assess nutritional status (petiole vs. leaf blade) for all grape species has recently been a matter of debate (Ness, 2008). Optimum mineral nutrition will improve vine growth and fruit chemistry as well as reduce unnecessary nutrient applications, reducing grower input costs, and potential nutrient leaching into the environment.

Our goal is to establish nutrient diagnostic criteria and interpretations for recently released cold hardy grape cultivars and to determine the relationship between petiole/leaf nutrient levels and grape quality characteristics. Each state will sample a minimum of two of the three cultivars (Marquette, Frontenac, and La Crescent) in the study. Within each site, each cultivar will be sampled in blocks of at least 15 vines to provide three replications.

We have collected two years' data from 15 field sites. Vineyards in Minnesota, Iowa, North Dakota, South Dakota and New York were selected based on a variety of climatic conditions and soil types. Mature (>4 years old) Marquette, La Crescent, and Frontenac vineyards were selected for the study. To finish this project, we will collect soil and tissue samples from the same sites in 2015.

i. Soil sampling in research sites (2015). Prior to bud break, soil samples will be collected from the 0-8" (0-20 cm) and 8-16" (20-40 cm) depths in the rows within 3-4 feet (1-1.3 m) of the trunk of the vines. At least eight cores per cultivar replication will be bulked, mixed, dried at 40°C and sent to AgVise Laboratories (Northwood, ND) for analysis. For each sample, texture, pH, organic matter, extractable nitrate-N, P, K, Ca, Mg, sulfate-S, Fe, Zn, Cu, Mn, and B will be determined. Copies of the results will be provided to the growers and the University of Minnesota, where all results will be summarized and tabulated.

ii. Nutritional profiling of cold climate grape cultivars (2015). Petiole and leaf blade samples (30 leaves per replicate) will be collected at three times during the growing season: full bloom, 30 days after bloom, and veraison. Leaves will be separated into petiole and blade portions and then dried at 60°C. Prior to grinding, the dried samples will be weighed to allow the calculation of nutrient concentrations on a whole leaf basis. Dried samples will be sent to AgVise for determination of N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B. Results will be shared with the sender and the University of Minnesota, where results will be summarized and tabulated. Appropriate statistical procedures will be used to document critical nutrient levels in tissue and to determine if cultivars differ in their elemental composition.

iii. Correlation with yield, vine, and fruit parameters (2015-2016). Measurements of yield componentsand fruit composition (grape sugar content, pH, TA, and yeast assimilable nitrogen) will be collected. In New York (Martinson) and Iowa (Nonnecke) data will be collected from experiments described in Obj. 2a. Grapes will be harvested at the time deemed appropriate by the grower. Total yield for each replicate will be recorded and five clusters sampled for juice analysis. The five clusters will be frozen and sent to the University of Minnesota for measurement of grape sugar content (^{0}Brix), pH, TA, and yeast assimilable nitrogen. Correlation of these parameters with tissue nutrient concentrations and growth stages will be determined.

Limitations and pitfalls: The primary limitation of these surveys is the confounding of climate/weather conditions, soil types, and grower practices, which limits the overall conclusions that can be drawn. Despite these drawbacks, the correlations between tissue nutrient concentrations and grape yield and grape juice quality will be valid.

2c. Develop sustainable disease management recommendations based on cold climate cultivar copper and sulfur sensitivity and disease resistance (McManus, Bradshaw, Hazelrigg).

Issue: Host resistance is the cornerstone of sustainable disease management, but information on cold climate grape cultivars is largely based on incomplete, anecdotal reports. The Minnesota cultivars are at least moderately resistant to some diseases (Hemstad and Luby 2000), but the range of resistance to important diseases such as downy mildew, powdery mildew, black rot, anthracnose, and Botrytis bunch rot has not been tested. These diseases can be prevented with fungicides, but the choice of fungicides, rates used, and optimal timing of applications depend on the susceptibility of the cultivar. Without reliable information on disease susceptibility, conservative growers will overspray relatively resistant cultivars and more lenient growers will suffer crop losses from insufficient protection. Our goals are to characterize the disease susceptibility of cold climate grape cultivars and to determine the sensitivities of cold climate grape cultivars to copper- and sulfur-based fungicides.

Approach. Replicated cultivar trials will be conducted in Vermont and Wisconsin. TheNE1020 cultivar planting at the University of Vermont Horticulture Research Center (USDA hardiness zone 5a) consists of eight cultivars (Frontenac, La Crescent, St. Croix, Marquette, Prairie Star, Corot Noir, Petite Pearl, and Louise Swenson) in six replicate blocks managed under NE1020 protocols. The Vermont vineyard is managed with a minimal IPM program to prevent complete crop loss and deterioration of vine health while allowing for disease expression in order to evaluate cultivar susceptibility to disease. By applying 4-5 fungicide applications per season in this vineyard, differences in cultivar susceptibility to powdery mildew, downy mildew, and phomopsis were observed while maintaining acceptable fruit quality (Berkett et al., 2013). As this vineyard matures and disease inoculum increases, we expect incidence of those diseases as well as black rot, angular leaf scorch, and anthracnose may increase as well. In Madison and Sturgeon Bay, WI (USDA hardiness zones 5a and 5b, respectively), we established two vineyards in 2012 for the purpose of disease research. These are replicated plantings of Frontenac, La Crescent, St. Croix, Marquette, Frontenac gris, Lacrosse, and Brianna, along with Valiant, a cultivar known to be highly susceptible to the major diseases. Vineyards in both states are equipped with weather stations to monitor environmental conditions. Disease incidence, severity, and area under the disease progress curve, will be assessed on untreated vines in Wisconsin and minimally-sprayed vines in Vermont using established methods (Berkett et al., 2005, 2007; Pearson, 1986; Weigle and Muza, 2010; Martinson et

al., 1991). Key diseases evaluated will include powdery mildew, downy mildew, black rot, Phomopsis cane and leaf spot, and anthracnose. Determining the sensitivity of varieties to copper- and sulfur-based fungicides is critical since these fungicides are effective against many diseases, are useful for fungicide resistance management, and are the most effective and economical option for organic growers. Our preliminary data indicate that northern varieties vary in sensitivity to copper and sulfur, but these experiments need to be repeated over multiple years and locations. We will monitor vines at least weekly and rate the incidence and severity of leaf and fruit injury at least three times per season.

Limitations and pitfalls: We will be relying on natural infections, which can be affected by weather. If insufficient disease is observed, we will incorporate controlled inoculations into the study. On the other hand, some diseases may become so severe that survival of the vines over winter is threatened. In such cases, we will evaluate diseases but then apply fungicides for the remainder of the season in an attempt to slow down the epidemic.

Objective 3: Develop and optimize winemaking practices to sustainably produce and market distinctive, high quality wines from cold climate cultivars.

Target outcomes*:*

- Improved practices for chemical and physiobiological deacidification of wines.
- Evaluation of yeast strains and their impact on wine sensory characteristics to develop recommendations for matching yeast and cultivar.
- Recommendations for skin contact and tannin additions to enhance varietal character and wine structure/mouthfeel.
- Recommendations for yeast assimilable nitrogen (YAN) concentrations for optimal wine volatile evolution.

Issue: The production of high-quality wines from cold climate grape cultivars requires winemaking practices targeted to reduce acidity, optimize yeast nutrition, enhance positive sensory characteristics, and produce balanced tannin profiles. The novelty of these cultivars, and their unique chemical matrix, means that the systematic assessment of potentially beneficial production techniques has previously been difficult or impossible. *How can new producers develop winemaking protocols that both meet their individual stylistic goals and consistently produce high quality regional wines?* This work will evaluate means of improving wine quality through (Obj. 3a) acid management techniques, (Obj. 3b) optimized yeast nutrition, (Obj. 3c) enhancing wine sensory characteristics through skin contract trials, and additions of enological tannins. Exploring these processing parameters systematically will provide regional winemakers with the tools needed to design effective winemaking protocols, minimizing the time and funds stakeholders waste in independent trial and error.

3a: Optimizing deacidification methods for cold climate cultivars (Mansfield).

Issue: In wine, biological deacidification is typically achieved through malolactic fermentation (MLF) via lactic acid bacteria (LAB) such as *Oenococcus oeni,* which decarboxylates L-malate to produce the milder acid L-lactate. In wines with high concentrations of malate, as is often found in cold climate cultivars, this can result in high lactate levels and an unpleasant wine sensory profile. Subsequently, alternatives to simple MLF, such as the use of *Schizosaccharomyces pombe* to convert

malate to ethanol, partial MLF, amelioration (juice dilution) or rated blends of MLF and non-MLF wines, may be preferred for quality cold climate wine production.

Methods: i. Physiobiological Deacidification: In 2015 and 2016, one lot each of red cultivars Marquette and Frontenac will be vinified following standard winemaking protocol, above, as a control. Two additional lots will be fermented using 71B (*Lallemand)* and other yeast strains known to partially metabolize malate. One lot each of white cultivars Frontenac gris and La Crescent will be vinified following standard protocol; at the end of fermentation, each lot will be divided in half, and one put through MLF. The MLF trial will then be back-blended with the control at various ratios (30%, 50%, 75%). Both red and white cultivars will also be used for amelioration trials, and all fermentations will be performed in duplicate.

3b: Optimizing yeast nutritional requirements for cold-hardy wine production (Mansfield):

Issue: Adequate yeast assimilable nitrogen (YAN), calculated as the sum of ammonia (AMM) and primary amino nitrogen (PAN) concentrations in the grape, is necessary for successful wine fermentation. YAN concentration varies by region, cultivar, and season, but initial surveys of riparia-based hybrids suggest that most have what is considered to be adequate or high YAN concentrations (Stewart, 2013). While the industry traditionally considers a YAN concentration at or above 200 mg/L to be sufficient to support fermentation, this number was extrapolated from a limited study performed solely on West Coast regions and cultivars (Butzke, 1998). Further, many producers are unable to measure their YAN concentrations in house, and extension surveys suggest that many add nitrogen prophylactically. As knowledge of fermentation metabolism grows, it has become evident that excessive YAN can depress wine quality, resulting in decreased aromatic complexity and varietal character, microbial instability and spoilage, and formation of potentially harmful ethyl carbamate and biogenic amines..

Methods: In 2014 and 2015, a selection of *V. riparia* cultivars will be be analyzed for initial YAN concentration and divided into 500mL aliquots for research-scale fermentations. AMM additions, in the form of diammonium phosphate (DAP), will be used to create three series (in duplicate) of five increasing YAN concentrations ranging from the initial juice YAN to 300 mg/L. Three different yeasts will be selected based on yeast trial data collected in years 1-3. Fermentations will be controlled for temperature and monitored for fermentation speed through yeast population and sugar consumption. Once fermentation is complete, all samples will be analyzed for standard chemical parameters (pH, TA, organic acids, % ethanol) and screened for volatile composition via GC-MS. Additional analysis for faults identification will be performed as necessary.

3c: Enhancing wine sensory profiles (Dharmadhikari, Koziel, Mansfield):

Issue: While regional and viticultural variables do impact wine aroma and flavor, the final sensory profile is also heavily influenced by processing parameters. The need for further assessment of even simple processing variables is reflected in data collected at stakeholder meetings; for example, the most common stakeholder request, both during SCRI planning meetings, and in extension interactions with regional industry, is for further evaluation of yeast strain suitability for wine production from new cold-hardy winegrape cultivars. Physical processing parameters are also of interest; in aromatic cultivars, pre-fermentation skin contact has been found to increase the

concentration of flavor precursors. However, skin contact treatments can also increase phenolic extraction from skin, contributing what can be excessive astringency and bitterness. (Ramey et al. 1986). The use of this technique in aromatic cold climate cultivars has not been investigated. Finally, the low polyphenolic content in most red cold climate cultivars necessitates the addition of enological tannins to produce balanced wine structure and allow aging. Work in years 1-3, and additional research with red hybrid grapes, indicates that non-*vinifera* species do not evince significant sensory changes following recommended additions of enological tannins, perhaps due to an enhanced capacity to bind, retain, and precipitate them from solution (Manns et al., 2013; Springer & Sacks, 2013). Because enological tannin additions represent the best and most commonly used means of enhancing hybrid red wine structure, color, and ageability, a greater understanding of this phenomenon is needed.

Methods: i. Yeast strain assessment: In 2012, 2013 (in progress), and 2014 , wines will be produced from La Crescent, Frontenac, Frontenac gris and Marquette, sourced from Minnesota, Vermont, and New York, using standard winemaking protocols. Yeast strains, selected for the potential to enhance aromatic intensity in whites and body and mouthfeel in reds, will be repeated across all three wine production regions and will vary each year. Finished wines will be analyzed sensorially using the Rank Order test to determine hedonic difference. If significant differences are found, descriptive analysis or projective mapping will be performed to develop sensory profiles for yeasts of interest.

ii. Skin contact trials on aromatic white cultivars: In 2013 (in progress) and 2014, aromatic white cultivars Edelweiss and La Crescent are divided into twelve 100lb grape lots. One lot will serve as a control, and will be vinified using standard winemaking protocols. Three treatments will be performed for each cultivar: one lot of must will be treated with an enzyme, one enzyme treated must and given 8 hrs skin contact at ambient temperatures, and a final lot of enzyme treated must given 16 hrs skin contact at ambient temperature. In addition to standard chemical analysis, all wines will be analyzed chemically for aroma constituents using the SPME-GC-MS procedure explained above, as this analysis will be responsive to aroma compounds identified in Obj. 1b. Wines will be evaluated sensorially using preference and/or difference tests.

iii. Assessment of tannin binding capacity of V. riparia-based hybrid wine grape cultivars: In years 4-5, a selection of *V. riparia* species from collections in NY and VT will be assessed for alcohol insoluble residue and analyzed for total tannin content via HPLC and spectrophotometric analysis. Binding capacity of insoluble solids will also be assessed to determine the percentage of additives lost during fermentation.

iv. Technology transfer: Wines produced for Obj 3c will be presented in informal sensory evaluation sessions to regional winemakers during 2015 and 2016. Results from all trials, as well as feedback from stakeholders involved in sensory evaluations, will be developed as e-newsletters for inclusion on the extension webpages of participating universities.

Expected Outcomes: In general, commercial winemakers working with new, cold climate winegrape cultivars have few resources addressing optimal winemaking processes for quality wine production. In recent years, fruit availability has been limited, and commercial demand has limited researchers' ability to perform large-scale, systemic evaluations of basic processing methods.

Subsequently, the data generated by this work will begin to satisfy the large stakeholder demand for basic processing recommendations and, as much as possible, provide direct experience with the effects of various treatments through informal sensory evaluations presented during targeted stakeholder events.

Objective 4: Identify strategies to support sustainable development of businesses based on cold climate cultivars, from the individual winery to regional agri-tourism.

Target outcomes:

- Descriptive profiles and preferences of wine tourists in cold climate wine regions.
- Identification of drivers of winery tasting room attributes, sales, and customer loyalty.
- Strategies for wineries and wine associations to work jointly with each other and community organizations for sustainable rural economic development.
- Individual and collective branding strategies and promotion of cold climate wines and wineries for increased consumer awareness.
- Metrics of economic impact and benchmarking of the cold climate wine industry and a credible analysis of policies directly affecting their industry.
- Vineyard production economics information and interactive online benchmarking tool for growers.
- A pilot wine quality assurance program for cold climate cultivars to increase consumer satisfaction and overall wine quality.

4a. Facilitate development of successful marketing strategies for cold climate wines based on target consumer characteristics, on-site marketing, and branding (Gartner, Gomez, Holecek).

Issue: Ultimately, the success of the cold climate wine industry will depend on demand for its products. Because most cold climate wineries in emerging wine regions depend primarily on tasting room sales, the target consumers of the product are often regional consumers or tourists. However, little is known about the consumer demographics and their purchase behavior or attraction to wineries in emerging new wine regions. In addition, another major obstacle for the cold climate wine industry is that the grape cultivars themselves are new and unfamiliar to most wine consumers, requiring assistance with outreach on marketing tools such as branding. **To support cold climate wine marketing and product development decisions, we will develop information on consumers and effective marketing in tasting rooms through surveys and initiate branding strategies for regions and individual wineries.**

i. Who are the consumers of cold climate wines? (Holecek & McCole, 2012-2016)
Information about consumer behavior and preferences is essential for marketing and product development of cold climate wines. It also provides benchmarks for future studies to assess the impacts of this project and changes in the industry over time, including changes in brand awareness, consumers' perceptions of the product, and the market penetration of cold climate wines. Surveys of over 1,500 visitors to Michigan tasting rooms were completed in 2012 and are summarized in Holecek & McCole (2014a, 2014 b, 2014c) and McCole & Holecek (2014). In 2013, a survey was administered to 400 members of the general population and results were presented in Holecek, McCole, and Tuck (2013). In 2015 and 2016, a survey study of tasting room visitors in regions that

feature wines made from cold-hardy grapes will be conducted using the Michigan study as an example.

ii. What tasting room marketing strategies produce customer satisfaction and loyalty? **(Gómez, 2012-2013)** We worked with collaborating wineries to develop a system to monitor the links between customer satisfaction and sales to guide tasting room marketing strategy. This Customer Information System (CIS) was developed in three phases: *Phase 1:* develop and implement a survey instrument to collect data on visitors' tasting room experiences; *Phase 2:* build capacity in wineries to compile and analyze customer data from the survey; and *Phase 3:* disseminate results, emphasizing the implications of the CIS for the marketing strategy of tasting rooms and sales performance.

The pilot study and customer survey phases were completed with participation of collaborators in Iowa and New York in 2012 and results published in Gomez and Kelly (2013)

iii. Branding research and outreach to cold climate wine regions and wineries **(Gartner, McCole, Holecek, and Gomez) (2016).** Our objective is to improve branding of cold climate wine regions and individual wineries to create a long-term image that appeals to target markets. In 2015, regional branding studies will be conducted at wine conferences in participating northern grapes project states to collect primary data from wineries owners and managers. This information will be combined with data analyzed from cold hardy wine tasting branding research (Song, Gartner and Hsu, forthcoming) and Gartner and Marlowe (planned for 2015) to ascertain important attributes for brand initiation both regionally and specific to individual wineries. In 2016 workshops will be offered to representatives of state grape and wine associations in the Upper Midwest and Northeast with a seminar on the branding process and a workshop on branding strategies for cold climate wines. Information obtained from the consumer surveys (Holecek & McCole (2014a, 2014b, and 2014c),cold hardy brand marketing studies (Song, Gartner, Hsu (2015) and Gartner and Marlowe, (2015) and winery owner/manager studies (2015) will be used to frame the demand side of the branding strategy, and tasting room attribute information. Gomez and Kelly (2013) will address individual strategies at wineries for increasing sales. In 2016, workshops for wineries will be held in participating states, in conjunction with wine conferences, to review the findings from the first initiative, provide a seminar on the branding process, and help participants develop their own winery branding strategy.

Limitations and pitfalls: The success will depend on implementation by the wineries and regional associations. Refinement of branding as consumer demographics change will be required over time.

iv. Impact of wine label branding on consumer willingness to pay. **(McCole, 2015 – 2016).** Experimental auctions will be conducted at wineries in cold-hardy U.S. wine regions to assess consumers' willingness to pay for wines based on packaging and label content. New wineries, especially in cold hardy regions, face difficult branding decisions related to wine names and other label and packaging content. The experimental auctions will provide data to help inform the decisions of winery leaders and help minimize the impacts of year-to-year trial and error that part of new wineries' conduct with their branding initiatives.

4b. Identify strategies and techniques for wineries and winery associations to work successfully with each other in wine trails and with other community and regional organizations for rural economic development and effective marketing (McCole).

Issue: Many wineries in the northern U.S. sell a large portion of their wines from tasting rooms. Winery owners have realized that a wine *region* is more likely to draw visitors than a single winery. Consequently, wineries need to collaborate for regional promotion through wine trails and special events. Moreover, there is potential for wineries to develop partnerships with non-wine tourism organizations and other rural attractions. The newer cold climate regions have not yet developed the knowledge-base to promote regional tourism. Our goal was to identify techniques to strategically position wine tourism within the matrix of regional tourism, increasing tasting room sales and supporting rural development.

What are the best practices for winery to winery collaboration? **(2012-2014, McCole)** This study involved semi-structured explorative interviews with 47 wineries in 2012 to learn more about the best practices for winery collaboration with other wineries. Using information gleaned from the interviews, an online survey was developed and administered to 163 wineries in emerging wine regions throughout the U.S. in 2013. Findings (McCole, 2014) showed the activities in which wineries most commonly collaborate, the benefits and barriers to collaboration and the return on investment of all the identified collaborative activities.

What are the best practices to enhance partnerships between wineries and tourism organizations? **(2012-2014 McCole)** This study involved semi-structured explorative interviews with 24 tourism businesses located in emerging wine regions throughout the U.S. in 2012 to learn more about the ways in which they collaborate with wineries. Using information gleaned from the interviews, an online survey was developed and administered to 376 tourism businesses located in emerging wine regions throughout the U.S. in 2013. Findings (McCole, 2014) showed the activities in which wineries and different types of tourism businesses most commonly collaborate, the benefits and barriers to collaboration and the return on investment of all the identified collaborative activities.

4c. Quantify the current economic impact of the cold climate grape and wine industry on rural communities and assess the impacts of state policy and law that impede or advance its development (Gartner & Lasley).

Issue: In contrast to most other processed food products, the economic climate for the cold climate grape and wine industry is strongly affected by both national and state regulations which may support or limit industry growth. In addition, accurate measurement of growth in the cold climate grape and wine industry is both a needed benchmark and the prime evaluation tool for the Northern Grapes Project.

What is the current and future economic impact of the cold climate wine industry? Our baseline project and economic impact survey, completed in 2012, resulted in overall statistics on acreage, production, and economic impact overall (Tuck & Gartner 2014a) and estimates for individual states (Tuck & Gartner 2013b, 2013c, 2013d, 2014b, 2014c, 2014d, 2014e, 2014f).

i. Repeat baseline and economic impact study (2016). The economic impact and baseline survey will be repeated at the end of the project in 2016. It will serve as the primary evaluation instrument to document project impacts, and will provide a measure of the growth of the northern grapes industry in project states over the life of the project. Methodology described in (Tuck & Gartner 2014a).

How do state policies and regulations affect the viability of the cold climate grape and wine industries? This study, entitled *Policy Analysis for the Wine Industry in the US and in the Northern Grape Project States Specifically,* was completed in 2012 and is summarized in Gartner et al. 2014.

i. Database. A free, public database of existing state laws and regulations will be made available in 2016.

Objective 4d. Complete a production economics study and develop an online, interactive tool for producers to benchmark their costs and returns (Gomez 2015-2016)

Issue: Small-scale startup vineyards have different cost structures than well-established commercial vineyards, and existing publications (eg. Gomez, 2014) aimed at *vinifera* grapes do not reflect practices and costs for Northern Grapes producers. An integrated research-extension approach will be employed in collaboration with stakeholders to provide benchmarks of production costs and returns, and make an interactive tool growers can use to benchmark their operation.

i. Determine production costs and returns (2015). We will determine the cost and return of producing cold hardy grapes in northern New York and in the Northern Midwest (Minnesota). We will focus specifically on Marquette and La Crescent, as representative cultivars. Estimates of the total investment in land, machinery, vineyard establishment and development costs, and annual operating costs will be developed of a variety of vineyard types. Returns will be calculated based on expected prices and yields. Methodology is that used in White (2011), which combine 1) interviews with grower panels, and 2) economic engineering using recommended practices.

ii. Online tool (2016). We will develop an online, friendly interactive tool where wine cold hardy hybrid grape growers can access the cost and return studies and include their own cost and return estimates to benchmark their cost performance. We will follow the California Cost & Return Studies (2012) and build an internet-based application will be developed in which costs are presented for specific operation size (small, medium, large), grape type (Marquette, La Crescent), and wine region (Northern New York, Northern Midwest). The user will have the cost information and will be able to easily calculate his/her costs for benchmarking. Moreover, the internet-based tool will be interactive. It will allow a vineyard manager to input their own costs and subsequently, the tool will elaborate a detailed net present value analysis for the vineyard manager under various scenarios of prices, costs, and yields.

Objective 4e. Develop a quality enhancement program for cold climate wines with focus on eliminating wine flaws that impact market acceptance, with an eye towards developing an industry driven wine quality assurance program (Dharmadhikari and Gartner).

Issue: The cold hardy grapes grown in the Upper Midwest, northern New York, New England, and Plains States can produce high quality wines with distinct characteristics. However, due to a shortage

of research-based information on vineyard management and winemaking practices for cold climate grapes coupled with a vast number of novice winemakers entering the business, producing consistently high quality wines throughout the region has been a challenging task. Additionally, the cold climate wines are new to the marketplace and their sales constitute a small portion of the total wine market. In order to garner a larger market share by building a solid reputation of superior wine quality, we propose to establish a voluntary and industry-led wine quality assurance program.

i. Establishment of the CCWQA (2015). A voluntary Cold Climate Wine Quality Assurance (CCWQA) will be created by the industry leaders from various states in cold climate regions. University extension programs will assist the industry as needed in structuring the organization. In Year 1 a survey will be taken to determine which states wish to participate in this program. Once the CCWQA is established, the membership will develop guidelines regarding wine quality standards, with the aim of eliminating wine flaws, procedures for wine evaluation by a trained industry panel, as well as packaging and promotion of quality wines. Benchmark trials will begin as soon as the guidelines have been approved.

ii. Implementation of the CCWQA (2016). In Year 2 trial runs and benchmarking will be tested. Finished wines will be evaluated against established standards. The data obtained from wine evaluation will be used to identify the major wine quality flaws and develop an effective outreach education program to improve wine quality. Once fully implemented, wines exceeding standards will be packaged with a quality designation and promoted in the market place to build brand identity and reputation. After establishment, the CCWQA program will be funded by entry fees and possibly a levy imposed on the sale of CCWQA wines. **Pitfalls and limitations.** Participation in the CCWQA plan may be limited by the cost of membership and whether it is perceived as encouraging competition or threatening (perhaps by wineries making poor quality wine). Low participation will increase the amount of time for brand recognition to occur.

EXTENSION PLAN

We will continue to partner with state and local winery associations (Appendix D) and the Project Advisory Council (PAC) (Appendix C) to provide comprehensive outreach and track the industry's progress and growth (see evaluation plan, Appendix B). We expect that application of research results generated by this project will improve grape quality and lower production costs, allow winemakers to produce wines appropriate to these cultivars and reduce flaws, and provide wineries with education on consumers and marketing to sell their products. Project team members will be required to participate in the following outreach activities:

a) *Northern Grapes* Symposia: We will jointly organize and present project results at least one winter industry conference each year in the Midwest and Northeast featuring multiple PDs discussing progress and findings in project objectives. State wine and grape associations have committed $58,500 in matching funds in the final two years of the project to support lodging and travel costs for speakers and conference promotion.

b) *Northern Grapes* Enterprise Workshops (2015-2016, and beyond project end)

i. Vineyard workshops: Summer workshops will be conducted at grower vineyards to highlight and discuss training systems, canopy management, mineral nutrition and disease management studies (Obj. 2).

ii. Winemaker workshops: Workshops will highlight progress in Objs. 1 and 3 and offer participatory sensorial evaluation of wine treatments (Obj. 3). Programming will include two day-long courses, one covering basic wine production from cold climate cultivars (general information about quality wine production and analysis for cold climate wine types) and one on specialty wine production (covering production of dessert wines, fortified wines, and sparkling wines from cold climate winegrapes). Both course will be centrally developed and presented regionally by Smith and Dharmadhikari in the Upper Midwest and Mansfield and Gerling in the Northeast.

iii. Workshops on branding, tasting room management, tourism partnerships, and consumer demographics will be developed by the consumers and economics group to cover managing and marketing through tasting rooms for winery owners, winery associations, and winery retail managers (Years 4-5, Obj. 4).

c) *Northern Grapes* Webinars: Each year, six monthly, one-hour webinars, accessible live over the internet via teleconferencing software will be held from November through April. Early presentations (Years 1-2) focused on basic topics in grape production, winemaking, and marketing/ business management. Many webinars in the no-cost extension year (Year 3) featured results from project studies, and will continue to do so as the project moves forward. All will be recorded and archived on the NGP and GCoP website. These presentations and interactions will provide input for the user's manual.

d) *Northern Grapes* Newsletter: Nine issues of the *Northern Grapes News* have been published to date, with continued quarterly electronic publication planned. Articles highlight project activities and news, and are targeted to our partner organizations and their members. This newsletter, with brief updates on different aspects of the project and preliminary results, will continue to be a means of soliciting participation in project activities and the primary venue for communicating with stakeholder groups.

e) *Northern Grapes* User's Manual Publications (grape production, winemaking, and marketing publications): Research-based growing, winemaking, and business management/marketing reports will be combined into comprehensive, web-based resources by the end of the project and beyond. Comprehensive research reports, recorded webinars, newsletter articles, and videos will be organized by topic area.

The following topics will be included, with others, based on input from the PAC:

- Climate-based indices for matching cultivar and site, derived from NE1020 data
- Standard and novel indices for grape maturity
- Recommendations for training, crop adjustment, and canopy management
- Mineral nutrition and tissue/soil testing protocols and standards
- Cultivar-specific flavor profiles and wine styles
- Pest management recommendations that incorporate host plant resistance
- Vinification techniques adapted to acidity of cultivars
- Developing a focused branding strategy for cold climate wines
- Quality assurance for cold climate wines

Northern Grapes Extension Linkages

f) eXtension Grape Community of Practice: Co-PIs and collaborators with extension appointments will participate in the eXtension grape CoP (www.extension.org/grapes). PD Tim Martinson, or designate, will attend the annual GCoP conferences. Chrislyn Particka, project manager, will coordinate posting to eXtension. The eXtension Grape CoP will serve as a home for the Northern Grapes newsletters, webinars, schedules of workshops, webinars and symposia, and the project publications described above. Materials will include modules on individual topics specific to cold climate wine production for on-line dissemination (i.e., analytical methods, vinification techniques). Modules will include video clips and other interactive features also housed on or accessible from enology extension webpages maintained by the University of Minnesota, Iowa State, and Cornell.

g) County and State extension, Industry organization-based programs: County and state-based extension educators have numerous venues (e-mail newsletters, web sites, field meetings) and, likewise, state industry organizations have modes of communication which we will use to continue to disseminate project results via the newsletter, webinars, User's Manual Publications and schedules of Northern Grapes workshops and symposia.

h) Project evaluation and impact surveys: Project evaluation metrics are described in Appendix B. As a major component, Drs. Bill Gartner and Paul Lasley will conduct surveys across all project states in Years 1 (completed) and 5 to measure changes in acreage, production, profitability, sales, practices, and employment in the cold climate wine industry. The follow-up survey will also include questions measuring other project activity impacts.

Table 2. Proposed extension activities and outputs. (Shaded blue completed; shaded red proposed)

		Project Year				
		Compled 2012-2014			Proposed 2015-2016	
Activity		1	2	3	1	2
Northern Grapes Symposia : Project symposia and winter meeting presentations jointly organized with project team and industry winter meetings (estimated attendance in parenthesis) in the Midwest and Northeast:						
Minnesota Grape Growers Assn. (3-600);$25K(done) $10K (proposed)		x	x	x	x	x
Viticulture 2013, NY Wine Grape Fnd. (600) $12K match (completed)			x			
Iowa Grape Growers Association (300); $15K match (2015-2016)					x	x
Eastern Winery Exposition (Feb 2015) Syr, NY;(300) $13K match					x	
New England Vegetable & Fruit Conf (Dec. 2015) (150) $5K Match					x	
Michigan Wine Industry Council $6K Match (Feb 2016)						x
Nebr. Grape Growers and Winemaker Forum (300)$15K match (2015-2016)					x	x
Wisconsin Grape Grower Association $6K match (2015-2016)					x	x
Illinois Grape Grower Assn $3.5K (2015 and 2016)					x	x
Northern Grape Enterprise Workshops – interactive, hands-on participatory workshops						
Vineyard workshops	Field meetings at vineyard sites and demonstration plots (Obj. 1, a, b; 2a,b,c): ND, SD, NE, MN, WI, IA, IL, MI, NY, VT, MA, CT)	x	x	x	x	x
Winemaker workshops	Two day-long shortcourses: Presented by Dharmadhikari (Upper Midwest), and Mansfield and Gerling (Northeast) (Obj. 3)					
	1. Basic Wine Production from Cold Climate Cultivars				x	x
	2. Specialty Wine Production: Production of dessert, fortified, and sparkling wines from cold climate wine grapes					x
Marketing/ Management	Branding Workshops Obj. 4a (Gartner)				x	
	Customer information systems/customer loyalty (4a) (Gomez)				x	x
	Winery marketing workshops (Holecek, McCole)				x	x
Vyrd & Winery	Regional 'best practices' workshops (MN GGA) $18K match				x	x
Northern Grape Webinars – Electronic seminars delivered to computer desktops Monthly November through April (6 annually) throughout project; archived at eXtension.						
	Basics of Grape Prod., Winemaking, and Retail management;	x	x	x		
	Years 3-5 Project-focused one-hour seminars. on project research results for industry audience			x	x	x
Northern Grapes Newsletter – Project updates and brief articles about project personnel, preliminary results, outreach events						
	4 issues per year; news format; contributions from Co-PIs	x	x	x	x	x
Northern Grapes Owner's Manual Publications – Cold-climate cultivar growing and winemaking practices produced and posted to eXtension GCoP.						
Research summaries posted on website			x	x	x	x
Content organized into multimedia (webinar, video, text) by topic area					x	
Finalize content and continued updates after end of project						x