Project Title: Northern grapes: Integrating viticulture, winemaking, and marketing of new cold-hardy cultivars supporting new and growing rural wineries.

Project Type: CAP

Focus Areas:

1. Research in plant breeding, genetics, and genomics to improve crop characteristics, such as product, taste, quality, and appearance; environmental responses and tolerances; nutrient management, including plant nutrient uptake efficiency; pest and disease management, including resistance to pests and diseases resulting in reduced application management strategies; and enhanced phytonutrient content. (10%)

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

3. Efforts to improve production efficiency, productivity, and profitability over the long term (including specialty crop policy and marketing). (85%)

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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 propose 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."

Outreach plan: In partnership with local industry groups in 12 states, we will 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* (4-6 annually) delivered live electronically and archived on eXtension; 4) A *Northern Grapes Project Newsletter* (4-6 annually) with updates on project results; and 5)*Northern Grapes Owner's Manual Publications*. We will disseminate results through the eXtension Grape Community of Practice (Appendix E) and existing extension outlets (Appendix E) in the Northeast and Upper Midwest.

Potential economic, social, and environmental benefits: This project will directly benefit 1,200 growers and 300 wineries, representing 3,300 grape acres and currently producing 1.2 M gallons of wine annually (Appendix A). These retail businesses in rural areas provide new employment opportunities and tourism-related economic impact nearly equaling the direct economic impact of wine and grape sales. 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.

Stakeholder involvement: Project objectives were shaped by planning workshops held in Vermont and Minnesota (70 attendees) in 2009 and 2010, funded by an SCRI Planning Grant entitled "Addressing research and extension needs of the emerging cold climate wine industry in the Upper Midwest and Northeast" (Appendix A), where producers identified top challenges in grape and wine production from cold climate cultivars and sales and management of their wines in retail tasting rooms. Letters of support for project objectives have been provided by 19 state-based producer organizations, and 25 producers and producer groups have pledged $244,000 in direct and in-kind support for on-farm research (12 producers, five states), co-sponsorship of project symposia at winter conferences (five states, $90,000), and commitments to the Project Advisory Council (Appendix C). Producer groups will participate in project evaluation surveys (Appendix B) and tasting room research surveys (Obj. 4).

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Introduction

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 3,300 acres of vineyards in the upper Midwest and Northeast, 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. Current efforts in research and extension are fragmented across 12 states. Similar needs are found in both the Upper Midwest and Northeast, 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 two 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) and (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).

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) will 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 intergrate "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 (^{o}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 2007; MKF 2008). 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 produced quality wine. Since 2000, cold climate winemaking and grape production has grown from a handful of wineries and a few hundred vineyard acres to a conservative estimate of 3,152 vineyard acres and 349 wineries in 14 states (Appendix A). For example, recent estimates of the total economic impacts of the wine industry, including tourism, were estimated to be $36.1M in Minnesota (Gartner & Tuck, 2008) and $234M in Iowa (MKF 2008). Complete economic impact for all states is not available but, conservatively, direct economic benefits across the Upper Midwest and Northeast are in excess of $300 M, with an additional indirect economic impact of $300M, since Iowa and Minnesota represent about one third of the acreage and number of wineries identified at our planning meetings (Appendix A).

This CAP project will bring together 37 research and extension professionals in viticulture, plant breeding and genetics (production), enology (processing) and economics/marketing (consumers and products) from thirteen institutions, in partnership with producer groups from 12 states (Appendix D). We will 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 genomics to improve crop characteristics, describe and develop systems to remove non-technical barriers that inhibit full exploitation of genetic potential of specialty crops (10%); (2) Efforts to address threats from pests and diseases, develop integrated pest management tools (5%); and (3) Efforts to improve efficiency, productivity, and profitability over the long term, improve understanding and application of nutrition, economic, social science and marketing factors influencing consumption of specialty crops (85%).**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 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 (^{o}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, Nail, Sabbatini, Domoto, Read, Fennell, Berkett, Harbut, Iungerman, 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, Illinois, Massachusetts, Michigan, North Dakota, Nebraska, New York, Pennsylvania, South Dakota and Vermont, and an additional two plantings in New York and Illinois (Sites and cultivars listed in Appendix G).

***i. Weather data* and *vine phenology, productivity, and maturity* (Years 1-4, Martinson, Nail, Sabbatini, Domoto, Nonnecke, Read, Fennell, Berkett, Iungerman, Shoemaker, Schloemann and Hatterman-Valenti).** 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 (^{o}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* (Years 1-3, Dharmadhikari and Mansfield).** Berry samples from cultivars Frontenac, Marquette, La Crescent, St. Croix and Frontenac gris (veraison and harvest) at eight NE1020 sites and a commercial vineyard in Iowa will be analyzed for sugars, organic acids, minerals (K) yeast assimilable nitrogen, and herbaceous aromas at Iowa State University and Cornell.

***iii. Winemaking* (Years 2-4, Dharmadhikari and Mansfield)**. Research-scale wines will be produced following standard winemaking protocols for white, rosé, and red wine (Luby et al., 2006) to allow comparison among research vineyard sites.

***iv. Sensory profile analysis* (Years 2-4, Koziel and Cai).** 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).

v. Data analysis **(Year 2- 5, 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 indicess 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. **Pitfalls and limitations:** 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, Cai, Fennell, Ge, He, Hegeman, Cook, Vickers, and Ye).

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 precurors during fermentaion. **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 ^{o}Brix, pH and TA.** Moreover, cold climate cultivars are likely to have novel compounds from their *V. riparia* parentage 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 vitcultural 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, athocyanins, 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 (Objs. 1c and 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 and a context for the analysis of fruit attributes for breeding stocks proposed in objective 1c.** 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 (Years 1-4). Comprehensively track what genes are activated, what metabolites are produced, and what sensory descriptors develop at what time during the ripening process for Frontenac, Frontenac gris, Marquette, and La Crescent.

i. Transcriptomic and metabolomic analysis **(Fennell and Hegeman).** In Years 1-4, a 50 berry sample will be collected from each of four cultivars (Frontenac, Marquette, La Crescent, and Frontenac Gris). 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 at pre-veraison, veraison, 20, 22, 24 and 26°Brix (Table 1 below). Pre-veraison and veraison samples will be collected as whole berries into liquid nitrogen. The 20, 22, 24, and 26°Brix 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 gene expression analyzed using the Nimblegen grape whole genome array according to standard Roche Nimblegen protocols. 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 linear iontrap-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 and Cai):** Emissions of grape volatiles such as terpenes, benzenes and C6 alcohols will be sampled at timepoints indicated in section *i* (Table 1, p. 15) as emissions from the grape cluster microenvironment in the field (*in vivo*) and in the laboratory from destructive sampling of berry skin and pulp. In Years 1 and 2, Frontenac and La Crescent berries will be sampled from NE1020 plots in Iowa and South Dakota at the six fruit development stages. In Years 3 and 4 additional plantings in Minnesota and Nebraska will be sampled in addition to Iowa and South Dakota to determine environmental impacts on aroma development. In the field, grape clusters will be enclosed in inert containers and volatiles will be collected with solid phase microextraction sampler. 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 taken simultaneously and extracted 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 Cook).** At 22 and 24°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 all four cultivars each year using standard protocols at the University of Minnesota Research Winery for two maturity levels (22 and 24°Brix) (Table 1), and they will be rated for aroma, sweetness, acidity, bitterness, flavor descriptors, and astringency by ten trained panelists.

Table 1. Frontenac, Marquette, La Crescent, and Frontenac gris will be sampled for fresh weight (fwt), dry weight (dwt), berry diameter, cluster and berry photodocumentation, 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	X
24 °Brix*	X	X	X	X	X
26 °Brix*	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* (He, Ge, and Ye).** 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 annually, even though we have budgeted for the analysis of ony one cultivar per year in Obj. 1b. 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. For breeding selections (Obj. 1c) with only a few vines available, information on genotype x environment interaction effects on metabolites will be based on sampling in multiple years. The numbers of replicate pools will be adjusted if necessary based on the metabolite variability measured in preliminary experiments. Variance will be measured by comparison between individual vines and across time points within a single vine to determine the numbers of required replicates.

1c. Intensify pre-release evaluations of elite selections from the University of Minnesota and private breeding programs (Years 1-3; Luby, Hemstad, Hegeman, Fennell, and Cook).

Issue: The major limitation to growing high quality wine grapes in the northern U.S. is the lack of genetic adaptation to cold in most commercial grape cultivars. *V. riparia* is a valuable source of cold hardiness (to -40°C), but it contributes undesirable fruit chemistry (acidity, tannins, and anthocyanins) to hybrids with *V. vinifera.* Implementation of metabolite-informed breeding will hasten the introduction of high quality, cold climate wine grape cultivars**.**

Approach. We will phenotype the fruit chemistry (acids, anthocyanins, phenolics, and related metabolites) of cold climate germplasm, including standard cultivars and 20 to 30 elite selections at the University of Minnesota Horticultural Research Center from breeding programs at the University of Minnesota, private breeder Elmer Swenson, and other breeders. Standard cultivars will include those used in Obj. 1b as well as St. Croix, St. Pepin, and Edelweiss, and several early ripening *V. vinifera* cultivars (Chardonnay, Pinot noir, Pinot gris, Merlot). In addition, four important available *V. riparia* ancestors (Rip2, Rip37, Rip89, Rip64) will be phenotyped to provide a basis for comparison with *V. vinifera* cultivars. Fruit from sun-exposed clusters will be sampled at two ripening points when °Brix levels are approximately 20 and 24 degrees in Years 1-3. Whole berries will be frozen in liquid nitrogen for later analyses, and a subsample of berries will be dissected to separate skin, flesh and seeds prior to freezing. Metabolites will be identified and quantified using chromatographic/MS methodologies described in Obj. 1b. In addition, pressed juice samples will be analyzed for standard fruit chemistry parameters including soluble solids (refractometer), pH and TA (pH meter and titration), and anthocyanins and phenolics (light spectrophotometry). Univariate analysis of variance and multivariate principal components analysis will be used to compare selections, ancestors, and standard cultivars as a basis for testing and cultivar introduction decisions. Metabolite and chemistry profiles will also be compared to profiles obtained in Obj. 1b to predict key similarities and differences contributing to varietal character in those standard cultivars.
Limitations and pitfalls: To mitigate the risk of crop loss due to inclement weather, all samples with will be collected annually, even though we have budgeted for the analysis of one cultivar per year. For breeding selections with only a few vines available, information on genotype x environment interaction effects on metabolites will be based on sampling in multiple years. The numbers of replicate pools will be adjusted if necessary based on the metabolite variability measured in preliminary experiments. Variance will be measured by comparison between individual vines and across time points within a single vine to determine the numbers of required replicates.

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 drooping 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 (Domoto, Nonnecke, Shoemaker, Read, Sabbatini, Harbut, Martinson, Iungerman, 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 **(Years 1-3, Domoto and Nonnecke, Nail, Martinson, Read).** 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 Connecticut, 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 (^{o}Brix, pH, TA) will be collected 2-3 weeks preharvest and at harvest. Fruit from selected treatments will be vinified and evaluated.

a. Connecticut Trial **(Nail).** *Location:* Gouveia Vineyards (Wallingford, CT). *Treatments:* two planting densities (1.8m vs 2.4m in-row vine spacing) and four training systems (GDC, top wire cordon, vertically-divided 'Smart-Dyson' cordon, and Vertical Shoot Positioning [VSP]). *Cultivar:* St Croix. Years 1-3. Trial established in 2010.

b. 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:* Two of following: Marquette, Frontenac, and La Crescent. Years 1-3.

c. Iowa Trial **(Domoto and 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. Years 1-3.

d. Nebraska Trial **(Read)**. *Locations:* Checkline Vineyards, Creighton, Nebraska, and Univ. Nebraska (Lincoln). *Treatments:* HWC, GDC, VSP, Smart-Dyson, Scott-Henry. *Cultivars:* Frontenac and St. Croix.

ii. *Canopy and cropping level management* (Years 1-3, Domoto, Martinson, Harbut). 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.

Will modifying the light environment through canopy management practices such as leaf removal and shoot tipping improve fruit and winemaking characteristics? To evaluate the influence of canopy management practices on the fruit quality and wine making characteristics of cold climate grape cultivars, coordinated, multi-state trials will be conducted in conjunction with stakeholders in Years 1-3 to evaluate the performance of at least two cultivars per site (Marquette, Frontenac, Frontenac gris, La Crescent, Brianna, St. Croix). Vines will be trained to a common system (HWC or VSP) with the option to conduct the trial with both systems under all combinations of three levels of shoot thinning (none; basal shoots and single shoot per node only; basal shoots, single shoot per node and axillary shoots in the fruiting zone) and two levels of leaf removal (none; and removal on the east facing side in the fruiting zone). Treatments will be replicated and randomized in a 3 x 2 factorial arrangement with cultivar as main plot. In all trials, treatments will be assessed for grapevine productivity, impact on the canopy light environment (EPQA), and cost. Data will be analyzed by site and pooled for multi-site comparisons.

a. Iowa Trial **(Domoto and Nonnecke).** *Location:* Tassel Ridge Vineyards and Iowa State University; Marquette, Frontenac, Frontenac gris, La Crescent, Brianna, St. Croix.

b. Wisconsin **(Harbut).** *Locations:* Two trials in Door County, Wisconsin and Alma Wisconsin; St. Croix, La Crescent and Marquette.

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. Crop load adjustment **(Domoto and Nonnecke, Iowa, Years 1-4*).*** Three cropping levels will be established on Marquette (Penoach Winery and Nursery, Adel, IA)and La Crescent (Hickory Creek Vineyard, Adel, IA) based on projected yield to pruning weight ratios ranging from 4 to 10, in a randomized complete block design. Cluster counts at fruit set will be used to estimate individual vine yield, and the appropriate number of clusters will be removed to establish the target crop load estimates. Where possible, we will replicate this with high wire bilateral cordon (HWC) with appropriate shoot positioning.

b. Timing and severity of crop reduction **(Martinson, New York, Years 1-3).** We will evaluate the effect of the timing and severity of cluster thinning in two to three trials (Cultivars:

Marquette, Frontenac, Brianna) in selected commercial vineyards in northern New York. Rather than establish a range of crop load ratios, we will vary timing and severity to provide targets for crop adjustment. Six treatments will be applied: 1) no cluster thinning; 2) moderate (<25%, apical cluster only) prebloom thinning; 3) heavy pre-bloom (30-40%; 1- 1.5 clusters/shoot); 4) fruit set (moderate, apical cluster only); 5) fruit set (severe; 1-1.5 clusters/shoot); and 6) 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 (^{o}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.

c. Grower extension demonstration plots **(Years 3-4; Iungerman in New York, Harbut in Wisconsin, White and Domoto in Iowa, and Nail in Connecticut).** 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 (^{o}Brix, pH, TA), and arrange for separate wine lots to be made at a commercial winery for comparative tasting by the group at winter meetings. Project Advisory Council will be consulted in Year 2 to finalize sites and treatments. **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, Domoto, 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 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.

i. Soil sampling in research sites **(Years 1-3).** Each spring 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 grower and the University of Minnesota, where all results will be summarized and tabulated.

ii. Nutritional profiling of cold climate grape cultivars **(Years 1-3).** Eight commercial vineyards in Minnesota, Iowa, North Dakota, South Dakota and New York will be selected based on a variety of climatic conditions and soil types. Mature (>4 years old) Marquette, La Crescent, and Frontenac vineyards will be selected for the study. Petiole and leaf blade samples (30 leaves per replicate) will be collected at three times during each growing season: full bloom, pre-veraison, 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 **(Years 1-4).** Measurements of yield components, pruning weights, and fruit composition (grape sugar content, pH, TA, and yeast assimilable nitrogen) will be collected. In New York (Martinson) and Iowa (Domoto and 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. De-stemmed berries from five clusters will be frozen and sent to the University of Minnesota for measurement of grape sugar content (°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 vine growth and grape juice quality will be valid.

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

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 and *Botrytis* bunch rot has not been tested. These diseases can be treated successfully 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 and insect 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. The 2007 NE1020 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, Vignoles, and Traminette) in six replicate blocks managed under NE1020 protocols. At the West Madison Agricultural Research Station in Wisconsin (USDA hardiness zone 5a), we will establish a similar replicated planting 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. In Wisconsin, pests will be managed during Years 1-3 using standard cultural and chemical controls. However, during Years 4 and 5, the vineyard will not be treated for insects or diseases. Vineyards in both states are equipped with weather stations to monitor environmental conditions. Disease incidence, severity, and area under the disease progress curve, as well as insect incidence and injury, will be assessed using established methods (Berkett et al., 2005, 2007; Pearson, 1986; Weigle and Muza, 2010; Martinson et al., 1991). Key insects will include grape berry moth, eastern grape leafhopper, and phylloxera. Key diseases 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 and are the most effective and economical option for organic growers. Therefore, in the years of vineyard establishment in Wisconsin, we will use copper and sulfur as the backbone of the disease management program on three vines in each replicate of each cultivar. We will monitor vines at least weekly and rate the incidence and severity of leaf and fruit injury at least three times per season. In addition to information about cultivar sensitivity to copper and sulfur, this approach will allow us to compare disease control based on copper and sulfur fungicides acceptable in organic production (three vines per replicate) with a more conventional management program (remaining vines in each replicate). **Pitfalls and limitations:** 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.

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.

3a. Optimize deacidification methods for cold climate cultivars (Cook, Mansfield).

Issue: In wine, biological deacidification is typically achieved through malolactic fermentation (MLF) via lactic acid bacteria (LAB) such as *Oenococcus oeni,* which decarboxylate L-malate to produce the milder acid L-lactate. In wines with high concentrations of malate, 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. In wine styles where MLF will be detrimental to product quality, chemical deacidification methods are required. One promising method is double salt deacidification, which has been demonstrated to reduce malate (Munyon 1977; Steele 1978, 1979). Commonly employed in traditional cool climate wine production areas, double-salting has yet to be formally evaluated for new, cold climate wine grape cultivars. Combined physiobiological and chemical treatments will also be investigated.

i. Physiobiological Deacidification: In Years 2 and 3, one lot each of red cultivars Marquette and Frontenac will be vinified following standard winemaking protocols 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 be used for amelioration trials, and all fermentations will be performed in duplicate.

ii. Chemical deacidification: During Years 2 and 3, wines will be produced from La Crescent, Frontenac gris, and Frontenac using standardized production methods; Frontenac will be produced as a rosé, following white wine protocols. After pressing, juice lots for each cultivar will be divided into three equivalent aliquots, with one serving as a control, one a pre-fermentation treatment, and one a post-fermentation treatment. One juice lot will undergo double salt treatment prior to fermentation. After treatment, all three wine lots will be inoculated for fermentation following the standard protocol. At dryness, a second lot will undergo double salt treatment as a young wine. For both pre- and post-fermentation treatments, sample aliquots will be taken prior to addition, and at 30, 90, and 120 minutes, and 12, 24, and 48 hours after treatment. All samples will be analyzed via HPLC to determine the concentration of malic, tartaric, and citric acids. Difference testing and/or descriptive analysis will be performed on finished wines using appropriate sensory panels.

iii. Treatment optimization: In Year 4, optimization trials will be developed to evaluate multiple-variable deacidification methods combining the results of Years 2 and 3. Treatments will be replicated at the research wineries at the University of Minnesota and Cornell to assess efficacy across regions. Wines will assessed sensorially in formal sensory evaluation analysis, and will be made available to regional extension personnel for informal assessment by industry stakeholders.

3b. Minimizing herbaceous or 'hybrid' aroma (Mansfield).

Issue: Previous work conducted at Cornell has identified a set of volatiles, analyzed via gas chromatography-olfactometry/mass spectrometry (GCO/MS) potentially associated with vegetal or herbaceous aromas characteristic red wined produced from hybrids with *V. riparia* ancestry (Sacks, personal communication, 2010). Once positively identified, means of reducing these compounds through targeted viticultural or enological practices can be assessed.

Methods: In Year 2, a selection of *V. riparia* species from germplasm collections in New York and Minnesota and two *V. vinifera* grapes (as controls) will be used to produce separate wine lots with extended skin contact time. Wines will be screened with GCO and GC/MS to determine whether this treatment increases concentrations of key volatile compounds or if new, unique odorants are detectable. In Years 3 and 4, volatile compounds identified in this work will be used to spike neutral red *V. vinifera* wines, mimicking concentrations found in *V. riparia* wines. Sensory evaluation will be performed to assess similarity of spiked samples and wines produced from hybrids with *V. riparia* ancestry. Rank index analysis will be performed, followed by descriptive analysis or projective mapping to develop sensory profiles.

3c. Enhancing wine sensory profiles (Dharmadhikari, Koziel, Cook, 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 (Appendix A) 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 as been found to increase the concentration of flavor precursors (Marais and Rapp, 1988; Sachez-Palomo et al., 2005; Selli et al., 2006a, 2006b). However, skin contact treatments can also increase phenolic extraction from skin, contributing to 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. Preliminary work suggests that some *V. riparia* cultivars, particularly Frontenac, have moderate to high concentrations of pigmented polyphenolics, but low concentrations of those involved in astringency, structure, and mouthfeel. Optimal use of enological tannins has yet to be elucidated, and as they are costly, further work on this issue is needed. 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.

i. Yeast strain trials. Frontenac, Frontenac gris and Marquette grapes, sourced from Minnesota, Vermont, and New York, will be vinified 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 Years 3 and 4, aromatic white cultivars Edelweiss and La Crescent will be divided into twelve 100 lb 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. Enhancement of red wine structure and mouthfeel through addition of enological tannins. In Years 1-2, concentrations of key polyphenolics (pigments and compounds implicated in astringency, bitterness, and mouthfeel) will be assessed in Frontenac and Marquette grapes. In the Years 2-3, the effects of enological tannin additions on pigmentation and sensory qualities of red wines made from these cultivars will be assessed. Eighteen wine lots will be vinified, following standard wine protocols; one lot will be held as a control. Five further treatments, consisting of enological tannins additions made at various steps during processing, will be performed for each cultivar. Protein precipitation assays developed by Harbertson et al. (2002) and Adams et al. (2004) will be used to assess changes in polyphenolic compounds. Wines will be evaluated sensorially using preference and/or difference tests.

iv. Technology transfer: Wines produced for Obj. 3c will be presented in informal sensory evaluation sessions to regional winemakers during Years 2-4. Results from all trials, as well as feedback from stakeholders involved in sensory evaluations, will be developed as e-newletters for inclusion on the extension webpages of participating universities.

Limitations and pitfalls: De-acidification, aroma enhancement and tannin addition trials may work only in some cultivars or regions. Areas growing other aromatic cold climate cultivars may not realize the benefits of this study. The skin contact trials will be conducted at ambient temperatures and the effects of skin contact time at lower temperatures will not be evident from the results. To account for between year changes in fruit chemistry, we will be running the single-cultivar trials over two vintages to inform the optimization trials in Year 4 with multiple variables. Understanding that climactic conditions may cause there to be a year in which there is insufficient quantity of fruit, the importance of 2 seasons of trials is also validated. For this reason, Year 4 multivariable trials will take place at more than one site (Cornell and the University of Minnesota).

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.
- 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 in 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.**

Who are the consumers of cold climate wines? **(Holecek)** Information about consumer behavior and preferences is essential for marketing and product development of cold climate wines. It will also provide 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. Three surveys of consumers will be conducted in the first 30 months of the project.

i. Pilot survey **(Year 1).** The purpose of the pilot survey is to test and refine the research instruments and procedures for consumer surveys. Tasting room operators in Michigan will be asked to recruit survey respondents on a semi-random basis. Consumers who agree to participate will be mailed a questionnaire to assess the following issues of interest: wine purchase and consumption behavior, wine tasting room experience and preferences, perceptions of the wines tasted and tasting room experience, comparisons to wines from other regions, trip profile, wines purchased on this trip and, socio-demographics. Then the survey will be mailed back to Michigan State University for coding and analysis.

ii. Multi-state survey **(Year 2).** Following completion of the pilot survey, consumer surveys will be conducted through Michigan State University in other cold hardy grape states where tasting room operators are willing to participate. The questionnaire will include a core set of questions that address the seven issues noted above. If there is interest, local stakeholders will be allowed to provide additional questions of local interest. The core set of questions will provide insight on similarities and differences across states.

iii. Household survey **(Year 3).** An on-line survey of randomly selected households in the study region and vicinity will be conducted. The household survey will provide information about the general population such as the percentage that 1) visits wine tasting rooms, 2) consume wine, and 3) is aware of the cold climate wine brand. **Pitfalls and limitations:** The challenge in all survey research is to obtain results that are representative of the population(s) of interest. A key challenge will be to secure a good cross-section of tasting room partners and their cooperation in obtaining a random sample of their visitors.

What tasting room marketing strategies produce customer satisfaction and loyalty? **(Gómez)** We will work 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) will be 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.

i. Pilot study **(Year 1).** We will develop and pilot test the survey instrument based on earlier work by Gómez (2010) and Gómez, McLaughlin and Wittink (2004) adapted to cold climate wine regions. The survey will ask tasting room visitors to rate their satisfaction with a number of attributes associated to their tasting room visit, purchase and re-purchase intentions, purchasing behaviors, the context of the visit (i.e., part of a wine tour), and the same demographic information collected in the Holecek survey above. Our measures of sales performance include whether or not the customer purchased wine, the amount purchased (bottles and dollars), and the intention to purchase in the future.

ii. Customer surveys **(Years 2 and 3).** The wineries will periodically collect customer data. These data will be used to build a system to monitor customer satisfaction and sales performance links. Data collection will be done in the tasting rooms by winery staff. This will build capacity among managers and tasting room staff in the collection, compilation, and analysis of customer data. In Year 2, we will work with wineries in two states (e.g., New York, Minnesota), and in Year 3 we will expand to other states participating in this proposal. We will conduct statistical analysis to identify the drivers of customer satisfaction and their links to sales performance.

iii. Workshops **(Years 4 and 5).** We will conduct a series of workshops to disseminate the establishment of customer information systems, based on what we learned in Years 1-3. We will offer backstop technical assistance to wineries interested in implementing the system. **Pitfalls and limitations:** The challenge in all survey research is to obtain results that are representative of the population(s) of interest. This study design and implementation strategy will mitigate some potential sources of bias (i.e., instrument and interview bias). Non-response bias tests will be employed. A key challenge will be to secure a good cross-section of tasting room partners and their cooperation in obtaining a random sample of their visitors.

Branding outreach to cold climate wine regions and wineries **(Gartner).** 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 Year 2, regional branding 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) will be used to frame the demand side of the branding strategy. The results will be compiled and provided with recommendations to the representatives of each state association. In Year 2, a second meeting will be held to discuss findings and develop a plan of action for implementation of the branding strategy. This meeting's report will be shared with contributing cold climate grape and wine associations. In Years 3 and 4, workshops for wineries will be held in participating states to review the findings from the first initiative, provide a seminar on the branding process, and help participants develop their own winery branding strategy. **Pitfalls and limitations:** The success will depend on implementation by the wineries and regional associations. Refinement of branding as consumer demographics change will be required over time.

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 and Gustafson).

Issue: Because wineries rely on wine sales directly to consumers via tasting rooms, many winery owners have realized that a wine *region* is more likely to draw visitors than a single winery. Consequently, wineries in more established wine regions may collaborate for regional promotion through wine trails and special events, such as festivals. Moreover, there is potential for wineries to develop partnerships with non-wine organizations in the tourism industry and other rural attractions. The newer cold climate wine regions have not yet developed the knowledge-base to promote regional tourism. **Our goal is 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 wine trail development? (**Years 1-2, Gustafson**) A situation assessment will be conducted in Year 1 by a University of Minnesota undergraduate student with supervisory assistance from the University of Michigan Tourism Center. It will note wine trail marketing techniques that appear to demonstrate increased sales for the cooperating wineries. An owner/manager survey will focus on their experiences with wine trail marketing techniques to assess how various marketing techniques associated with wine trails have impacted attendance and sales. In Year 2**,** a web-based survey will be developed and implemented to wineries from all of the cold climate states participating in the project. **Pitfalls and limitations:** Because wine trails are relatively recent additions to the marketing mix of cold climate wineries, data related to costs, revenues, and economic impacts of wine trails have not been collected by many of the existing wine trail organizations. Informality in the organizations themselves may limit available data.

What are the best practices in wine tourism partnerships? **(Years 1-3, McCole)** The current best practices for wine tourism partnerships will be identified through a situational assessment (Year 1), case studies, explorative interviews and surveys (Year 2) with wine tourism stakeholders in both mature and emerging wine regions. The consumer surveys in Obj. 4a (Holecek) will be used to gather this information. The best practices will involve the following components: identification of potential partners, essential elements of partnership success, relationships and roles, benefits of and barriers to partnership, development and maintenance of partnerships, and the role of government and associations in promoting/hindering partnerships. **Pitfalls and limitations:** Wineries may be resistant to developing partnerships with competitors or with non-traditional partners. Because many are new and small businesses, it may be difficult for them to dedicate time to partnership development. Data related to the costs, revenues, and economic impacts of wine trails may not have not been collected by many of the existing wine trail organizations.

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).

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 a needed benchmark. Synthesis of existing studies is difficult because of differences in data collection and analysis, prohibiting cross state comparison. The purpose of this objective is to study the current economic impact of the cold climate grape and wine industry, develop benchmarks for assessing future growth, and to conduct a thorough analysis of existing state regulations to assist state associations in strategic planning to promote industry growth.

What is the current economic impact of the cold climate wine industry? This study will involve all cold climate states that choose to participate. State associations that contribute to this study will supply a list of grape growers and wineries in their state. A web based instrument will be developed after a thorough review of existing studies and examination by the advisory panel. State associations will be asked to solicit their membership to complete the questionnaire. Results will profile the industry at large as well as providing separate state reports for use by state associations.

How do state policies and regulations affect the viability of the cold climate grape and wine industries? Although there is an international database of country wine policies (http://www.fivs-abridge.com/index.htm), there is no corresponding database of state laws and regulations. In 2002

Wine America conducted a study of state winery laws and developed "model winery legislation" guidance (WineAmerica 2002). Our objective is to conduct a thorough analysis of existing state wine regulations by updating Wine America's 2002 report. We will do a thorough analysis of winery policies in all 50 states in Year 1 which will lead to the creation of a free, public database of state winery regulations in Year 2. This study will not be restricted to the cold climate states because policies operational in other wine-producing states should be examined. Policies examined in this study will then be added to the existing database or be used to create a separate database. In Year 3 there will be a review of the policies by winery operators in the cold climate states to determine how they affect their operations and whether the policies are considered supportive or restrictive. The policies to be examined will be selected from the first part of this study and will be discussed with the Project Advisory Council before proceeding to individual winery operators. **Pitfalls and limitations.** This data may not be of interest for states which have already completed a similar study already. It may be difficult to assess the direct effects of recent policies in some emerging cold climate states as many of the wineries are new and the long term effect of policies may be unclear.

Objective 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 (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 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 CCVQA **(Years 1-2).** A voluntary Cold Climate Vintners Quality Alliance (CCVQA) 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. Once the CCVQA 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.

ii. Implementation of the CCVQA (Years 3-4). In Year 3 and 4 trial runs and benchmarking will be tested. Finished wines will be evaluated against established standards. Wines exceeding standards will be packaged with a quality designation and promoted in market place to build brand identity and reputation. 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. After establishment, the CCVQA program will be funded by entry fees and a levy imposed on the sale of CCVQA wines. **Pitfalls and limitations.** Participation in the CCVQA 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 partner with state and local winery associations from 12 states and the Project Advisory Council (PAC) 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 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 $97,500 in matching funds to support lodging and travel costs for speakers and conference promotion.

b) *Northern Grapes* Enterprise Workshops (Years 2-5)

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 Cook and/or 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 from November through April. Early presentations (Years 1-2) will focus on basic topics in grape production, winemaking, and marketing/business management. As information is generated by the project (Years 3-5), each webinar will feature results from project studies. All will be recorded and archived on the GCoP website bimonthly. These presentations and interactions will provide input for the users manual.

d) *Northern Grapes* Newsletter: We will develop and distribute an electronic project newsletter four to six times per year highlighting project activities and news, targeted to our partner organizations and their members. This newsletter, with brief updates on different aspects of the project and preliminary results, will 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): Cultivar-specific growing and winemaking practices will be produced for the GCoP, accompanied where appropriate by comprehensive research summaries. A working edition will be developed and reviewed by Year 3 and posted to eXtension as a trial to provide basis for comments, and a Sustainable Edition posted in Year 5 will be a summary of the Northern Grapes project and provide a basis for future updates by GrapeCoP members.

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 how they vary by climate
- 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 recently-established eXtension GCoP (www.extension.org/grapes) funded by a NIFA-USDA SCRI grant. Leaders Eric Stafne and Lane Greer (Oklahoma State) will conduct a training workshop in Year 1 for project team members to facilitate development and posting of modules, recorded webinars, and other web-based material generated by the project. PD Tim Martinson, or designate, will attend the annual GCoP conferences. The eXtension Grape CoP will serve as a home for the Northern Grapes newsletters, webinars, schedules of workshops, webinars and symposia, and the User's Manual publications described above. Materials will include 8-10 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 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, Dr. Paul Lasley will conduct surveys across all project states in Years 1 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.

	Activity	Project Year 1	2	3	4	5
Northern Grapes Symposia : Project symposia jointly organized with project team and industry winter meetings (estimated attendance in parenthesis) in the Midwest and Northeast:						
	Minnesota Grape Growers Association (600); $50K match	x	x	x	x	x
	Iowa Grape Growers Association (300); $15K match			x	x	
	Viticulture 2013, NY Wine and Grape Foundation (600) $12K match		x			
	Michigan Wine Industry Council $5500 match			x		
	Nebr. Grape Growers and Winemaker Forum (300)$15K match			x	x	
	Additional New England/Northeast conferences (Location TBD)			x	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, c; 2a,b,c): ND, SD, NE, MN, WI, IA, IL, MI, NY (two locations), VT, MA, CT)	x	x	x	x	x
Winemaker workshops	Two day-long shortcourses: Presented by Cook and Dharmadhikari (Upper Midwest), and Mansfield and Gerling (Northeast) (Obj. 3)					
	1. Basic Wine Production from Cold Climate Cultivars	x	x	x	x	
	2. Specialty Wine Production: Production of dessert, fortified, and sparkling wines from cold climate wine grapes			x	x	x
Marketing/ Management	Branding Workshops Obj. 4a (Gartner)		x	x	x	
	Customer information systems/customer loyalty (4a) (Gomez)				x	x
	Winery marketing workshops (Holecek, Gustafson, McCole)			x	x	x
Northern Grape Webinars – Electronic seminars delivered to computer desktops (110 capacity) Monthly November through April (6 annually) throughout project; archived at eXtension.						
	Basics of Grape Prod., Winemaking, and Retail management;	x	x			
	Years 3-5 Project-focussed one-hour seminars. Presentations 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						
	4-6 issues per year; news format; contributions from Co-PIs	x	x	x	x	x
Northern Grapes Owner's Manual Publications - Cultivar-specific growing and winemaking practices produced and posted to eXtension GCoP.						
	Working edition drafted	x	x			
	Working edition internally reviewed by PDs and PAC			x		
	Working edition posted, reviewed, and revised				x	
	Sustainable Edition posted					x