Northern Grapes News

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Understanding the Ripening Chemistry of Cold-Hardy Wine Grapes to Predict Optimal Harvest Time

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The chemical composition of *Vitis vinifera* cultivars has been extensively researched, but little is known of the chemical composition of cold-hardy cultivars. We monitored fruit composition in 11 cultivars to determine how heat unit accumulations affected changes in fruit chemistry during the 2010 and 2011 growing seasons.

Tackling the intricate question of when to harvest can be difficult, and the chemical composition of grape berries has generally been accepted as the primary factor determining harvest time. Most growers and winemakers use soluble solids (mainly sugar) content or pH as harvest indicators and others may rely simply on taste. Growers want to capture the optimal balance between sugars, acids, and flavor that will contribute to sensory quality, stability, and alcohol potential of wine. The chemical composition of grapes continuously changes as the berry develops from fruit set to harvest. The grape ripening process after veraison includes a decrease in organic acids and an increase in sugars, berry weight, and pH. Developing a dynamic profile of the ripening process by tracking these changes will guide harvest decisions, leading to optimal grape maturity and improved wine quality.

Acids and sugars. Important indicators of grape maturity are titratable acidity (TA), pH, and soluble solids (°Brix), which measure the organic acid and sugar content. The most abundant organic acids in grapes are tartaric and malic acids. High amounts of malic acid can lead to undesirable effects on TA, pH, and wine sensory quality. Fortunately, malic acid concentrations decline after veraison, which contributes to the desired decline of TA. Tartaric acid is generally the most abundant organic acid and does not typically decrease after veraison. Glucose and fructose make up 99% of the total soluble solids and concentrations increase from veraison through maturity. Soluble solids are measured using a refractometer and expressed in °Brix and reflect the relative "sugar weight" of a juice sample (1.0 degree Brix is denoted as 1.0% sugar by weight). Measuring TA, pH and soluble solids is vital for determining optimal grape harvest times.

Research methods. Our objective was to identify and quantify organic acids and sugar composition of fruit from wine grape cultivars throughout fruit maturation. Grape berry samples of eleven wine grape cultivars (Table 1) were harvested every 8 to 10 days from early August to mid October during the 2010 and 2011 growing seasons at the University of Minnesota Horticultural Research Center in Chaska, MN. Samples of 40 berries at each harvest date were divided into 4 replicates of 10 berries that were weighed and juiced. Juice samples were measured for soluble solids, TA and pH. Analysis of variance and Least Significant Difference (LSD) were used as statistical analysis procedures to determine when harvest date no longer had a significant effect on grape maturity indicated by changes in °Brix, TA, and pH.

photo: David L. Hansen, University of Minnesota
Vignoble Le Mernois Vineyard and Winery

Results. As grape berries near maturity, the accumulation of soluble solids and degradation of organic acids begins to slow down and concentrations become nearly stable. When TA and °Brix plateau, the berry has reached the range of peak maturity. By expressing the harvest date in terms of accumulated heat units expressed as growing degree days (GDD), we are able to compare soluble solids, TA, and pH data from years that had quite different weather conditions. For example, 2010 was cool and wet compared to the hot

and dry growing season of 2011. When comparing the two years of data to GDD, they showed nearly identical trends, supporting the use of GDD to track these measurable components (Fig 1). In both 2010 and 2011, TA and °Brix leveled off at approximately 2555 GDD, which was on Sept. 8th in 2010, and Aug. 29th in 2011.

Observations. Concentrations of organic acids, sugars, and berry weight were measured to predict peak maturity. By applying this technique to the grape cultivars in this study, we were able to make several notable observations:

- Peak maturity range occurred later than the historical harvest time (in terms of GDD accumulation) in most locations.
- In this study, *Vitis vinifera* cultivars matured later with respect to soluble solids, °Brix and pH.
- TA for 'St. Pepin' and 'St. Croix' plateaued much earlier than their corresponding soluble solids.
- °Brix plateaued earlier than TA in most U of M cultivars, which was unlike all other cultivars.
- 'Marquette' reached peak maturity between 2550 – 2650 GDD.
- 'Frontenac' reached peak maturity between 2575 – 2725 GDD.
- 'Frontenac gris' reached peak maturity between 2530 – 2700 GDD.
- 'La Crescent' reached peak maturity between 2515 – 2630 GDD.

Take home message. By determining the concentration of sugars and acids during fruit ripening relative to growing degree days, we found that 2500 to 2725 GDD are needed to ripen cold climate wine grapes to peak maturity in east central Minnesota. Although this is true for Chaska, growing locations in the Northeast may not accumulate as many GDD and optimal maturity ranges may occur earlier. Change in the chemical composition of cold-hardy wine grape cultivars depends on many factors including growing location, cultivar, and amount of heat units accumulated over a season. These results will vary from site to site, but the same method used in this study can be applied and tracked in any vineyard. Knowing how many GDD have accumulated by harvest in prior years can help guide harvest decisions and allow growers to estimate the number of days to harvest.

Physiological maturity often differs from optimal harvest parameters. Wine styles or flavor may be more important than optimal maturity when determining harvest time. For example, 'St. Croix' is generally harvested according to flavor before the soluble solids reach their peak range, but grapes should hang longer if a sweeter wine is desired. Whatever harvest indicator is used, it is important to consider the many factors involved and the changes the grapes undergo. Complete knowledge in the timing and range of variation for these measurable components should be used as a tool when determining harvest time.

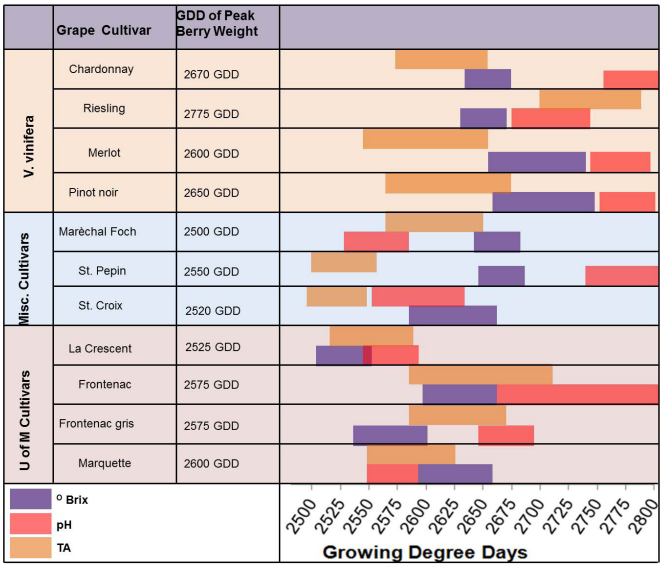

Table 1. Colored boxes indicate when there is no longer a significant change in °Brix, pH, and TA in respect to GDD highlighting the range of peak maturity for each trait in grapes grown in Chaska, MN. Peak weight is the maximum weight achieved during the harvest season.

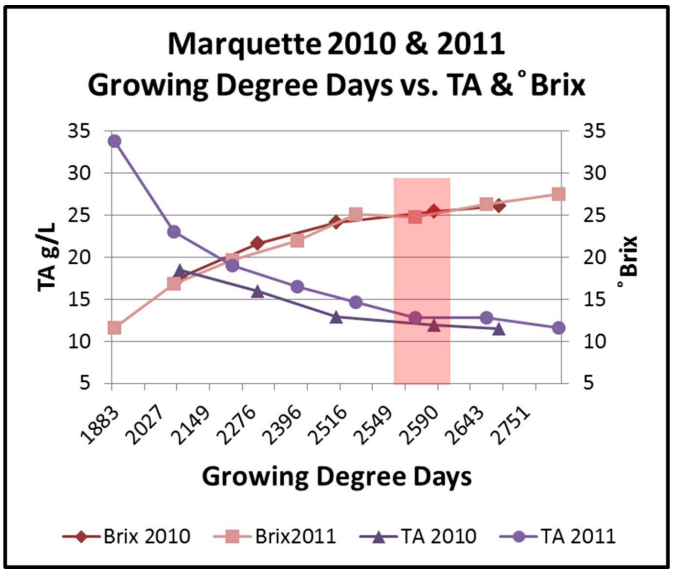

Figure 1. Changes in soluble solids (°Brix) and TA show the variation of sugar and organic acid concentrations throughout 'Marquette' grape ripening in Chaska, MN. Harvest dates were converted to GDD with a base temperature of 50 °F starting April 1. The red shaded area indicates the range of peak maturity.

Web Sites Offering Growing Degree Day Calculations

Minnesota and Wisconsin:

- http://climate.umn.edu/cropddgen/ (MN)
- http://www.soils.wisc.edu/asigServlets/asos/SelectDailyGridDD.jsp (MN & WI)

Dakotas:

- http://climate.sdstate.edu/awdn/archive/degreedays.asp (SD)
- http://ndawn.ndsu.nodak.edu/corngdd-form.html (ND)

Northeast:

- http://newa.cornell.edu/index.php?page=degree-days (NY)

Universal:

- http://www.weather.com/outdoors/agriculture/growing-degree-days/
- http://www.skybit.com/

Luke is a full time graduate student at the University of Minnesota pursuing a Master of Science degree in the Applied Plant Sciences Graduate Program. Luke's thesis project involves determining the contents of cold climate grapes for sugar and acids over the ripening period in late summer/ early fall.

Fruit Chemistry Across Many States

The Northern Grapes Project is tracking changes in wine grape chemistry at 11 NE-1020 plots throughout the states involved in the project. Berry samples from Marquette, Frontenac, La Crescent, St. Croix, and Frontenac gris will be sent to Iowa State Universiyy for analysis, and maturity indices will be related to climate indices from weather data collected at each site. This will provide us with information about how the varieties perform in different environments.

In the News: Michigan Wine Competition Results Announced

Emerging "super-hardy" varieties earn awards

Twenty-five wine experts gathered August 7 in East Lansing for the 35th annual Michigan Wine and Spirits Competition. Judges included wine experts from around the country, including Doug Frost, who is both a Master of Wine and Master Sommelier; three Master Sommeliers; and internationally known authors, winemakers and wine educators. Leading the group through the day was food and wine writer Christopher Cook, who judged at the competition for 12 years before becoming its superintendent in 2001. Cook is also a judge at wine competitions throughout the United States and abroad.

Emerging cold-hardy grape varieties were well represented in the competition. Medals were awarded to five wines made from "super-hardy" grapes, including gold medals for a 2011 Marquette from Burgdorf's Winery in Haslett, and 2011 "Sunshine," a blend of super-hardy white grape varieties, from Flying Otter Winery in Adrian. The grapes for Burgdorf's Marquette were grown at Michigan State University, one of a group of universities involved in a $2.5 million project that is studying a new group of extremely cold-hardy grape varieties that show potential for growing well in northern climates.

Source: Karel Bush, Michigan Grape and Wine Industry Council

eViticulture and the Northern Grapes Project

Eric Stafne, Mississippi State University and Lane Greer, Oklahoma State University

Most Google searches deliver the Wikipedia entry, a source of questionable accuracy, within the top three results. But while searching for 'growing grapes' yields over three million responses, even Wikipedia doesn't appear until the ninth page. Before that, numerous Extension pages appear, but all for individual states. (See Table in the supplement for some of these resources.) eViticulture, a website project of the eXtension Grape Community of Practice, was created to bring all these resources together, and provide a one-stop shop for online information on grape production. This website was created by viticulture specialists around the country and provides accurate, science-based information for commercial grape growers.

The front page of the eViticulture.org website. The page is updated regularly with new information. Northern Grapes Project links can be found in the 'Coordinating Projects' tab.

Why eViticulture? The initial focus of the site was on articles, but increasing attention has been on adding videos, webinars, photos, and more links to regional resources. The information is designed for the Web; it's easy to read, short and to the point. Further, it comes from trusted sources, and all the articles are peer-reviewed. Other current and future offerings include Ask an Expert (have your viticulture question answered by one of our Extension experts), videos, online courses, and the Vineyard Doctor, an interactive diagnostic tool for grape problems. Social media efforts by eViticulture include Facebook, Twitter, and YouTube – all of which can be accessed from eViticulture.org.

Ties to the Northern Grapes Project. Many of the specialists working in the Northern Grapes Project (NGP) are also members of the Grapes Community of Practice (GCoP), the group responsible for creating eViticulture. The GCoP consists of viticulture extension specialists from land-grant universities and was formed with funding from a USDA-NIFA-SCRI grant. Further ties to NGP include information dissemination. For instance, all NGP webinars are accessible through eViticulture. This fits in with the mission of the GCoP: to strive to meet the educational needs of the grape industry as a whole; including industry partners, extension employees, and consumers by providing science-based information and learning opportunities through eXtension.

The GCoP is currently comprised of a North America-based group of professionals with expertise in commercial grape production. To date, the GCoP has 89 members from 31 states and Canada, who interact through a variety of online methods to collaboratively create content on the eXtension site (www.extension.org/grapes). All content is collaboratively authored and reviewed by our community of professionals with expertise in viticulture and related disciplines. The new resource, eviticulture.org, created by the Grape Community of Practice (GCoP), is directed toward commercial viticulturists who need solid, tested, science-based information to improve their skills in the vineyard.

Eric Stafne is an assistant extension professor specializing in fruit crops at Mississippi State University. He previously spent 6 years at Oklahoma State University working with the growing grape and wine industry. Eric is the project director of the national eXtension Grape Community of Practice. His contribution to the Northern Grapes Project is to facilitate the delivery of extension materials and research results through eXtension.org/grapes and eViticulture.org websites.

Lane Greer is an Adjunct Faculty member at Oklahoma State University and is the Project Coordinator for the Grape Community of Practice and eViticulture.

In this issues of the *Northern Grapes News*, the *NGP Team Profile* series interviewed the three project team members from Michigan State University. With over 35 team members, and only 20 issues of the *Northern Grapes News* slated over the five years of the project, we have to cover more than one team member in some issues. The MSU team consists of Don Holecek and Dan McCole, both from the Department of Community, Agriculture, Recreation, and Resource Studies, and Paolo Sabbatini, from the Department of Horticulture.

NGP Team Profile: Don Holecek

photo: Jacqueline Holecek

Don Holecek is a Professor Emeritus in the Department of Community, Agriculture, Recreation, and Resource Studies at Michigan State University. He earned his BS and MS degrees from the University of Illinois and his PhD from the University of California-Berkeley. His research has spanned a wide range of topics including boating, camping, agriculture tourism (including wines), climate change, and other tourism related topics. His focus in the Northern Grapes Project is on consumers, with the goal of establishing their awareness and perceptions of and preferences for wines made from cold hardy grapes.

1. Tell us a little about how you ended up working in economics and in the Department of Community, Agriculture, Recreation, and Resource Studies (CARRS) at Michigan State.

My major as an undergraduate was forestry. I was stimulated by the combination of social and biological sciences in the forestry curriculum and some specialization in social science became my goal when I became a graduate student. The forestry professor, Dr. Holland, who impressed me the most was an economist and he became both my role model and graduate advisor. My M.S. degree studies at University of Illinois were interrupted by a tour of duty in Vietnam, but my "enforced sabbatical" there gave me the opportunity to finally select a core focus for my graduate studies. That focus was on resource economics with a strong minor in marketing. It was Prof. Holland who encouraged me to venture outside the Midwest for my Ph.D. program, and he facilitated my move to the University of California, Berkley, via arranging for me to receive an assistantship there. As I neared the end of my program at Berkley, it was Prof. Holland who once again surfaced to influence my career path. He passed along the message that the Department of Park and Recreation Resources at Michigan State University was trying to recruit an economist to fill a new faculty position. For me, an academic position was my "plan B" career choice. "Plan A" was a forestry economics research position with the U.S. Forest Service. At the time, a federal hiring freeze was in place so it was off to MSU and the beginning of my academic career. Following a merger of several departments, I am now a faculty member in the Department of CARRS.

2. You've worked with a lot of other tourism-related industries in Michigan during your career. What, other than wine, did you find the most interesting and why?

Over my career, I've applied my expertise in economics and marketing to a very wide variety of geographic areas- private and public sectors, local, regional, state, national, and global- and to a wide variety of topical areas- advertising, boating, camping, commercial and tribal casinos, ag-tourism, travel taxes, student and youth travel, underwater parks, wineries, and more. All of these were interesting. Under the outdoor recreation category, my underwater parks research in the Great Lakes was the most unique and arguably the most interesting. In the tourism area, the 20 plus years of longitudinal Michigan tourism forecasting, economic impact, and market tracking ranks high since it held my interest for so long. But, it is the variety of areas and topics that I've been able to study that have fueled a high level of interest even as a professor emeritus. I never seem to tire of learning something new and exercising my knowledge in problem solving.

3. How did you first become involved with winery tourism?

My primary focus shifted from public sector-provided outdoor recreation to commercial recreation and tourism when I became director of MSU's Tourism Center in 1985. As a result, my economic analysis shifted from being non-market driven to market-driven in focus. And, the topics that I studied were generally linked to tourism in some way (for example, climate change's impact on travel, ag-tourism, etc.). In about 2001, a colleague invited me to join him in seeking funding to expand understanding of Michigan's wine industry to include how it related to tourism. We were successful in securing funding.

4. How has the wine industry in Michigan changed since you first worked with it several years ago?
There have been many changes, and they have been dramatic. First, there are far more wineries and grape growers in Michigan now than 20 years ago. Growth has occurred in the traditional southwest and northwest areas along Lake Michigan, but the most interesting additions have occurred in the non-traditional wine producing regions. This change is in part due to the recent introduction of super cold hardy grape varieties, which are the focus of the Northern Grapes project. Second, the quality of Michigan's wines has increased several fold. We have learned how to grow better grapes and to use them to make better wines. Finally, the number of first class tasting rooms has increased more rapidly than even the number of wineries. Whether this resulted from increased consumer demand or from more entrepreneurial suppliers is uncertain. However, what is certain is the boost the tasting rooms are having on tourism activity. For example, a few years ago we had no wine trails and touring multiple tasting rooms wasn't on many peoples' radar screens. Now, wine trail trips are a popular topic at most social events that I attend.

5. What is your role in the Northern Grapes Project?
I am one of the Co-PIs who is focusing on the demand rather than the supply side of the overall SCRI project. Initially, I will be surveying wine tasting room visitors and later randomly selected households in our study region to gather data to assist in marketing cold hardy wines and in assessing their economic importance. What we learn in our survey will be used by Dan McCole in his project to enhance collaboration among and between wineries and tourism industry stakeholders. It will also be used by Bill Gartner in his economic impact project.

6. In your opinion, what is the most exciting research-based information that will come out of the Northern Grapes Project?
As a graduate student, I was exposed to the value of systems thinking and to using systems theory in research. This SCRI project is the closest research project in which I've been involved that truly approaches my ideal of a systems approach to research and problem solving. I am keenly interested in being part of such a diverse group of scientists from an extensive geographic area who share a common interest in the demand and supply side issues involving cold hardy grapes and wines.

NGP Team Profile: Dan McCole

Dan McCole is an Assistant Professor in the Department of Community, Agriculture, Recreation, and Resource Studies at Michigan State University. He earned his BA from the University of Massachusetts, MBA from Michigan State University, and PhD from the University of Minnesota. As part of the Northern Grapes project, he will work to identify the best practices for collaboration in the wine industry. He will also support the effort to profile tasting room visitors and potential visitors.

1. Many of our readers might wonder why we need to have social scientists involved in the Northern Grapes Project. Can you explain how they'll be able to use the results of your research?
One of the great things about the Northern Grapes Project is its multi-disciplinary nature and its holistic approach to the success of cold-hardy grape cultivars. Learning more about how to best grow these grapes and how to better make quality wine from them is critical to their success, but those research areas only address the supply side of the industry. Wouldn't it be a shame if wineries produced exceptional wines from cold-hardy grapes, but nobody bought them? In order for growers and winemakers to be successful, they have to convince people to buy their wine. In emerging wine areas, most of the wine produced is sold in the tasting room. The social scientists in this study are trying to learn more about the people who visit wineries and why they visit. We're looking at the types of experiences people are seeking when they come to a winery, and how wineries can improve those experiences. We're gaining insights into people's wine consumption and purchase behaviors to better inform the many decisions growers and wineries make. We're learning about how wineries can best collaborate with each other and with the tourism industry to attract tasting room visitors and improve tourism destinations.

2. You indicated that you were the first person in your family to attend college. What made you decide to go to college and ultimately earn an MBA and then a PhD in Parks, Recreation and Leisure Studies?

From a very young age, I longed to explore the world. But growing up in a family of limited financial means, we never took a vacation, so my worldly adventures occurred in my head while reading the classic adventure novels and heading to the Saturday matinee double feature. As the end of my high school career approached, my future path was unclear. Since nobody in my family had been to college, I wasn't really sure how it worked. I knew two things about college: 1) it was very expensive; and 2) I didn't have much money. But I did know that the Army could help pay for college if I served first. My test scores qualified me for a military intelligence program that offered intensive training in a foreign language and an overseas assignment. The day I left for the Army was the first time I'd flown in a plane or traveled more than 200 miles from my home. Four years later, after seeing much of the U.S. and Europe, I headed off to college with my GI Bill money, a passion for travel and the discipline to hit the books. In college I studied international business and German literature. This allowed me to study abroad for a year and travel even more. After college and a couple years of work experience, I earned a master's degree in business and then spent another five years working for General Mills before making the decision to go into academia. As I looked into Ph.D. programs, I eventually realized that I could focus on my love of travel by combining my business experience and education with a Ph.D. that focused on the economics, psychology and sociology of how people spend their leisure time. Whenever I tell people I'm a professor of tourism, most seemed surprised that such a job exists, but they are also usually a little envious.

3. Much of your research focuses on and how recreation and tourism can help build sustainable communities. What impact do you feel the cold-hardy grapes will have on the areas in which these grapes are grown?

Many communities throughout the northern United States have experienced the boom and bust that often accompany extraction and manufacturing, and have been looking to initiatives that can bring economic stability without diminishing resources. Natural resources- and agricultural-based tourism offer strong potential for some of these communities if they can use their resources to offer a desirable experience that will attract visitors to spend money at local businesses, all while providing incentive to protect a community's natural resources. Winemaking is an especially great industry for rural areas because it offers what I like to call the trifecta of local economic activity: a good crop to be grown, a value added process to that crop that often takes place in the community, and the attraction of visitors with money to spend. The continued development of cold hardy grapes will allow more communities to develop a wine tourism experience that can either enhance existing destinations or even create new tourism areas.

4. In your opinion, what is the biggest challenge facing the vineyards and wineries that are growing the cold-hardy grape cultivars?

I think surviving the challenges of inexperience. I don't mean that to sound condescending, but the reality is that a large number of new wineries have opened in recent years and that trend is likely to continue. Not all of these new grape growers and winery owners (and their employees) have the benefits of wisdom that will come from years of experience with growing grapes, making wine and operating a tourism business. All of them will make mistakes in the next couple years that they won't make in 20 years. The key is minimizing the consequences of those mistakes while their businesses are at their least profitable stage. Hopefully the Northern Grapes Project will help with that.

5. How will you use what you are learning as a member of the Northern Grapes Project in future non-grape-related research?

My research on the project includes studying collaboration in the wine industry and will focus on what is called horizontal collaboration (collaboration among wineries) and vertical collaboration (collaboration between wineries and non-winery businesses along the supply chain such as tourism organizations). My findings related to horizontal collaboration will have implications for some of the other industries I work with such as the ski industry, which is analogous because there you also have competing tourism businesses that can, at times, benefit more through collaboration than competition, but often don't know the best time or way to do so. I also currently advise a graduate student who is studying collaboration in the farmer's market industry. The results of both of our projects should inform the other. Additionally, I do a lot of work in Michigan's tourism industry including the annual tourism forecast for the state. Just being involved in this project has helped me to better understand the role of wine in enhancing the attractiveness of a destination.

6. In your opinion, what is the most exciting research-based information that will come out of the Northern Grapes Project?

I'm not sure I can answer that. In my opinion, the most exciting thing about the Northern Grapes project is its commitment to multidisciplinary work that will address the full range of a winery's challenges from growing grapes, to making wine, to operating a successful tasting room, to partnering with other wineries and tourism organizations to improve a region. I think this project will go a long way in speeding up the learning curve and success rate of cold-hardy wineries.

NGP Team Profile: Paolo Sabbatini

Paolo Sabbatini is an Assistant Professor of Viticulture in Department of Horticulture at Michigan State University. He earned his MS and PhD from the University of Ancona, Italy. He first visited MSU in 2002 as a PhD student to work with Dr. Jim Flore for a few months. He then returned to MSU in 2004 as a post-doctoral researcher, and was hired for his current position in 2007. Paolo is a member of the Vineyard Studies and Extension/Outreach teams in the Northern Grapes Project.

1. You grew up in Jesi, Italy, which is in the Marche region. How did you find your way to the U.S. and your position at MSU?

Honestly, I accepted this position at Michigan State University because it excited me. I did not need a job; I was fully employed at the University of Ancona in Italy. I knew that Michigan State University had an outstanding reputation as an agricultural-based university and that the Horticulture Department was held in high esteem across the U.S. I viewed Michigan State University as an ideal place for me to work on plant agriculture and plant biology. We have on campus a diverse group of colleagues and excellent facilities, which provide excellent opportunities for developing a strong research and extension program. My goal is to demonstrate that I can be effective and gain respect in an institution that is nationally and internationally renowned.

2. Your position at MSU was previously filled by Dr. Stan Howell for over 35 years. Were you intimidated when you first started, and if so, how have you managed that indimidation?

Yes. Immediately after I was appointed in 2007, I took a proactive attitude and studied what Dr. Howell had achieved in his career. I needed to understand the needs of our Michigan grape industry and develop a productive program of basic and applied research without repeating the same work done by Dr Howell and learn from his success and failures.

3. How did you develop your interest in viticulture?

I grew up in a small town in Italy, and as a child I spent most of my free time at my grandfather's vineyard, growing and harvesting fruit. After high school, horticulture appeared as a logical major, as I shared my father's passion for mathematics and physics (he was a mechanical engineer). Viticulture is the science of growing grapes, and I am interested to understand the complex interaction between environment and vine physiology. I got interested in grapes because it was part of my job responsibility in Italy but also because I grew up in an environment where grapes and wine part of my daily life. For this reason, I am trying my best to positively influence the economic future of Michigan's grape and wine producers. There are fundamental viticultural issues that require attention and solutions before we can realize targeted objectives in the vineyard; pivotal is to investigate metabolic changes throughout the growth of grape berries and their role in determining berry quality for wine production in a cool-cold climate region.

4. What is the main focus of your research outside of the Northern Grapes Project?

I am working with juice and wine grapes. Michigan's wine and grape juice producers face a complex array of challenges, from abiotic and biotic stress that reduce their production compared to other grape growing areas in U.S. For the juice industry, the challenge is one of production consistency in a region having considerable year-to-year variability in temperature, sunlight and water availability. Therefore, my research is on achieving maximum yields of quality fruit every year through precise crop estimation and crop adjustment models. In contrast with juice grape production, the shortage of high-end premium wine grapes and appellation-specific grapes is an important issue for Michigan wineries. I am evaluating several new wine grape varieties and clones to assess genotypic adaptation to climate for several geographic areas in Michigan. Some of these varieties may be critical to the expansion of commercial grape and wine production such as the super cold-hardy. We know than in cool and cold climates, several high-value vinifera varieties are often harvested before they achieve optimum maturity; fruit have reduced accumulation of sugar and aromatic compounds due to environmental stress. Understanding how photosynthesis, carbon assimilation and translocation are affected by environment and cultivation practices is the most important component of my research program.

5. Michigan's grape and wine industry is largely based on vinifera cultivars. How did you become involved with the Northern Grapes Project?

The expansion of our industry in areas not suitable for *V. vinifera* requires the evaluation of the cold hardy varieties and my contribution to the Northern Grapes Project is to propose this new genetic material in Michigan for growers that are interested in growing grapes outside our AVAs or in sites prone to very low winter temperatures.

6. In your opinion, what is the most exciting research-based information that will come out of the Northern Grapes Project?

That's a tough question. There are several researchers working on several aspects. My focus is viticulture and I am looking for the next exciting research-based information coming out from this project and I hope it will be related to a better understanding of basic physiological mechanisms related to achieving excellent "technological fruit maturity at harvest" – a good balance between sugar content and acidity of grapes, anthocyanin content, phenolic maturity, aromas and their interaction with viticultural practices. With information generated from our research, I hope that growers will be able to make informed choices guided by data-driven results to improve the quality of fruit produced in cold-climate regions.

Policies Affecting the Domestic Production of Grapes and Wine in the United States

Canhui Hong and Bill Gartner, University of Minnesota

As part of the Northern Grapes Project, we reviewed state policies related to winery operations. To date, we have investigated laws related to the operation of wineries in 20 states (Fig. 1). We found many differences relating to winery operations in each state.

Shipping Laws. Most of the states allow wineries to ship wine directly to consumers. In some states, such privilege is granted under the condition of an additional license, or based on other considerations, which is the most popular legislative practice (Fig. 1). In general, the annual fee for a direct shipment license is about $50, but is more costly in some states; for example, the annual direct shipment license fee in Louisiana is $1,500, compared to just a $50 annual fee for a winery permit. Among the 15 states which permit direct shipments, only four (IA, CO, WA, and NE) do not pose a cap on the amount which the winery can ship to consumers. Minnesota, Arizona and Wyoming allow only 18 liters of wine to be shipped directly to an individual in a calendar year, while most of the other states permit a maximum of either 108 or 216 liters per individual per year.

Use of Domestic Grapes. To encourage grape production and the development of a domestic wine industry, eight of the 20 states require a minimum percentage of domestic grapes (those grown within the state) be used in wine production (Table 1). Requirements range from 85% to 50%. The other 12 states don't require a minimum percentage of domestic grapes in wine, including Louisiana, which repealed the 51% minimum requirement in Acts 2006, No. 808. Most of the states with no minimum requirement are located near California, and may see the lack of a requirement as a way of boosting the state's wine industry.

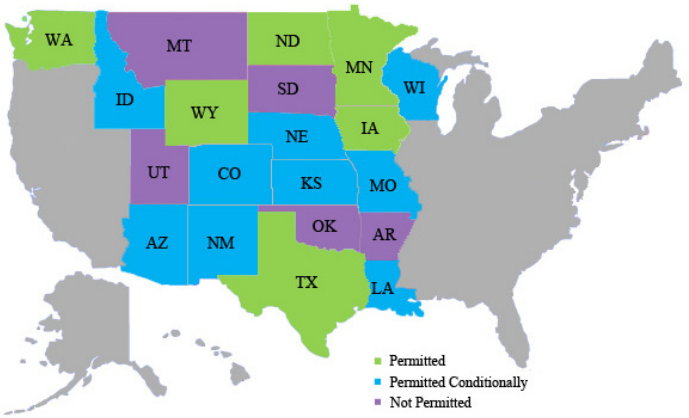

Figure 1. *The map indicates the 20 states included in the initial study and the shipping laws in each. States in green allow direct shipment to consumers on an unconditional basis, states in blue allow direct shipment on a conditional basis, and states in purple do not allow direct shipments.*

Table 1. *Eight of the 20 states included in the initial survey require that a percentage of grapes used in winemaking were grown within the state.*

State	Percentage
Arkansas	75%
Kansas	60%
Minnesota	51%
Missouri	85%
Nebraska	75%
New Mexico	50%
North Dakota	51%
South Dakota	51%

Tax Laws. Taxation on wine plays an important role in the daily operations of wineries, and five states which use fiscal policy to help develop domestic wineries and vineyards are shown in Table 2. The tax credit policy in Arkansas is designed to encourage the use of domestic materials, while policies from the other four states are more likely to help the development of new or small wineries. The benefit from such policies can be substantial in some states; for example, the tax on wine is only $0.06 instead of $0.95 for farm wineries in Nebraska, without further limitations. Since the winery can enjoy a tax credit equal to $0.69 out of $0.75 total tax, such policy in Arkansas would certainly provide the wineries a great incentive to use domestic materials in their yearly production.

The policy project continues with the goal of assessing wine and grape related policies in all 50 states to be completed by the end of the year. It is the goal of this project to not only examine state wine and grape policies but to eventually assess their effect on business operations. Stay tuned for more policy news.

Canhui Hong is a Ph.D. student in the Department of Applied Economics at University of Minnesota. He earned a Master's degree in Economics from Peking University in China. As a member of wine law project, Canhui will investigate the state policies and regulations related to winery operation in different states and conduct analysis on how these policies and regulations affect the viability of the cold climate grape and wine industries

Bill Gartner is a Professor in the Department of Applied Economics at the University of Minnesota. His research interests are branding, image, economic impact, and tourism development. He has worked extensively in Asia, Europe, Latin America, and Africa. He has conducted economic impact and baseline monitoring studies for the grape and wine industry in Minnesota and is the Principal Investigator on Economic Impact and Baseline Monitoring, Policy Review, and Branding studies for the Northern Grapes Project.

Table 2. *Five states use fiscal policy to help develop wineries and vineyards. The states, including the statue number and policy, are shown below.*

Arkansas	Statue 3-5-1605: Subsidy in an amount of $0.07 per pound for Arkansas-produced grapes, berries, fruits, and vegetables purchased and used in the production of wine by wineries in Arkansas. The aggregate amount of subsidy that any one winery may receive shall not exceed an amount of the equivalent of $0.69 on each $0.75 of tax levied upon each gallon of wine sold in Arkansas by the winery produced from Arkansas-grown fruits and vegetables upon which the tax is paid.
Missouri	Statue 135.700: Tax credit in an amount equal to 25% of the purchase price of all new equipment and materials used directly in the production of wine in Missouri during the calendar year. A producer may only apply for and receive the credit for 5 tax periods.
Nebraska	Statue 53-160: Gallonage tax is only $0.06 for wine produced by farm wineries ($0.95 per gallon for other wine).
New Mexico	Statue 7-17-5: For wine produced by a small winegrower and sold in New Mexico, tax is $0.10 per liter on the first 8,000 liters sold and $0.20 per liter on all liters sold over 8,000 liters but less than 950,000 thousand liters.
Utah	Statue 32B-2-304: For spirituous liquor manufactured by a manufacturer producing less than 30,000 proof gallons of spirituous liquor in a calendar year, the mark up would be 47% above the landed case cost to the department (not less than 86% for other wine).

Yeast Selection Trials for Cold-Hardy Grapes

Katie Cook, University of Minnesota

One of the questions winemakers in northern climates ask most often is what yeast strains are recommended for fermenting various cold-hardy grape cultivars. While I understand why this question is asked - most catalogs selling yeast don't list 'Marquette' or 'Frontenac' as recommended cultivars for a particular strain - it is also difficult to give a recommendation based on grape cultivar alone. Variables such as growing conditions of the grapes, winemaking conditions in the cellar, and stylistic goals are all important factors in determining what yeast should be used for making a certain wine. Vintage variation (especially in northern climates) can mean that a certain outcome with a commercial yeast strain one year doesn't necessarily mean that we will have the same outcome the following year. Yeast can't enhance the spicy character of Marquette, for example, if the aroma compound(s) responsible for that character aren't in the grapes when they are harvested. Complicating matters is the fact that we are just beginning to learn what aromatic compounds might be involved in varietal aroma for these grapes!

Table 1. *The table below shows the yeast and grape cultivar combinations that will be used in small-scale trials this year, along with the goal of each.*

Yeast	Grape cultivar	Goal
Vin 13 NT 116	Frontenac gris	Understand whether thiols play an important role in varietal aroma
Vitilevure Elixir Cross Evolution	La Crescent	Release terpenes to intensify primary aromas
D254 BRG	Marquette	Enhance spicy characters
Rhone 4600 ICV Opale	Frontenac	Enhance fruity character

Development of new yeasts. Before a new commercial yeast strain is released, it undergoes extensive fermentation trials, from lab-scale to commercial scale and with various grape cultivars, to understand its impact on the wine. These trials require a great deal of costly research in order to be certain that the yeast activity will be fully understood once it is released. Unfortunately, the costs of this research guarantees that more obscure grape cultivars are not typically used in these trials. You are about as likely to see yeast recommendations for Picpoul or Vermentino as you are Marquette or Frontenac gris. Fortunately, with the assistance of the Northern Grapes Project, researchers in the Midwest and Eastern US will be able to perform small-scale yeast trials this year for our cold-hardy grape cultivars (Table 1).

Yeast trials. While we may already have some ideas of how certain yeasts behave with cold-hardy varieties, we have yet to perform a study that includes statistical analysis of sensory data in replicated wine trials. This will allow us to evaluate whether a certain aroma or flavor can be attributed to a difference in yeast, grape cultivar or to the growing conditions. Although we do not fully understand the key aromatic compounds involved in the varietal aroma of cold hardy wines, we are able to build on knowledge gained from studies of wine aroma and yeast metabolism to make educated yeast and cultivar matches. After several years of trials, we will be able to give confident recommendations for yeast strains to winemakers desiring a certain style of wine from their cold-hardy grapes.

Grape aroma vs. wine aroma. Wine primary aroma compounds, which are also described as the varietal aroma of grapes, are the key aroma compounds that are used to distinguish wines made from one grape cultivar over another. In the grape berry, they are present in both volatile and non-volatile forms. The term 'volatile' simply refers to the fact that these compounds can be found in the headspace above the wine in a glass. In other words, this is what you smell when you stick your nose in a wine glass. Some volatile or 'free' aromas that are present in the grape berry are also present in the wines. When this occurs, drinking a wine made from that cultivar may remind you of how the grapes tasted when you picked them ripe off the vine.

However, grape berries are also full of bound aroma compounds that can't be tasted when you eat a grape, but are transformed into their free form by the action of yeasts, bacteria, and enzymes over the course of vinification. These bound compounds are often present in much higher quantities than the free volatile compounds, and are also considered an important component of the varietal aroma of wine. This is one of the reasons why the aroma and flavor of a wine is much more complex than the juice from which it was made.

Yeast can play a key role in liberating these bound aromatic compounds so that they can contribute to the overall bouquet of a finished wine[1]. Thus, using a compatible yeast can help enhance the varietal aroma of the wine. Some of the

most important primary aromas that scientists have identified in grapes, and which yeast play a role in releasing during winemaking, are thiols and monoterpenes.

Thiols. Volatile thiols are one of the most potent groups of compounds found in wine. Some can impart a negative aroma, while others contribute positively to a wine's bouquet. They are almost non-existent in grape juice, and tend to only develop during fermentation. In Sauvignon Blanc, they are responsible for the box tree, passion fruit, grapefruit, and guava aromas that give the wine its varietal character. However, they have also been identified in wines made from other grape varieties such as Colombard, Merlot, Riesling, Semillon, and Cabernet Sauvignon. In grape juice, researchers have been able to identify the thiols in their bound form, also called an aroma precursor. Because of this, they have been able to understand the biochemical processes that yeast use to break apart the glycoside bonds with the thiols. Although all yeasts are capable of cleaving these bonds, certain strains of yeast have been shown to be better at it than others. Just as human metabolism varies according to a person's genetics, so does yeast's. Those that can efficiently release thiols are typically marketed as yeast that will enhance the varietal aroma of Sauvignon Blanc. This year we will be conducting trials with two strains of yeast that are known thiol-releasers to see how they affect the overall aroma wines made from Frontenac gris. We suspect that perhaps some of the tropical fruit aromas found in wines made from this cultivar could be due to thiols.

One to five gallon research wine lots, including yeast trials, ferment in carboys at the University of Minnesota's research winery at the Horticultural Research Center.

photo: Anna Katharine Mansfield, Cornell University

Monoterpenes. The second class of primary aroma compounds released by yeast is monoterpenes. Often simply referred to as terpenes, they are potent aromatic compounds found throughout the plant world. In grapes, they are found in large quantities in aromatic varieties like Gewurztraminer, Muscat and Riesling. Monoterpenes such as geraniol and linalool are often used as a fragrance in everything from soaps to air fresheners due to their rose or rose-like aromas. Other terpenes (cintronellol and nerol) can smell like citrus or lemongrass. Unlike thiols, monoterpenes often exist in a free, or volatile, form that can be detected in the grapes themselves. Nonetheless, a significant portion of monoterpenes found in grapes exist in a non-volatile, bound form. Yeast, bacteria, and enzymes in the grapes themselves are all capable of cleaving glycoside bonds and enhancing the varietal aroma of a wine. Knowing that La Crescent's heady floral aromas are similar to a Muscat or Gewurztraminer, one can suspect that monoterpenes play a role in its varietal aroma. Using a commercial yeast strain that is a good terpene releaser can help intensify the primary aromas found in the grape. For our trials with La Crescent this year, we are using two yeast strains intended for aromatic white wine production, but are especially interested in yeast that will help with terpene expression. Vitilevure Elixir and Cross Evolution are two yeasts that we hope will show off the varietal attributes of La Crescent.

Enhancing spicy aromas. Spicy aromas exist in many different grape cultivars; however, the chemical basis of these aromas isn't completely understood. Although the compound responsible for black pepper aromas in Syrah and other cultivars has recently been discovered, researchers are still trying to identify if there is a biological method (such as using a specific yeast) of expressing it in wines[2]. Nonetheless, through sensory analysis of wines fermented with different yeast strains, we know that some are better able to enhance spicy characters than others. We aren't certain what aromatic compound(s) is (are) involved in that spicy character, but we know that it exists. We know that sometimes Marquette wines can have a spicy character, even though we don't know what causes it. Thus, we will be trialing two yeasts that are known to enhance spice in two different cultivars. The strain D254 has been used in Rhone varietals, whereas the strain BRG has been used successfully in Burgundian varietals to enhance spicy characters. We are hoping that both can be used with success to enhance the varietal aroma of Marquette.

Yeast-derived aroma and flavors. While we are looking for certain yeasts that may help to express the varietal aroma of cold-climate grapes, yeast also produce a number of aromatic compounds as a by-product of fermentation that will affect overall wine bouquet. Of course, the most important job of yeast is the production of alcohol from sugar. The presence of ethanol is essential to enhance the other sensory attributes of a wine. However, excessive ethanol can mask the aroma and flavors in a wine and give the wine an overall impression of "hotness" that is undesirable. While there are many important yeast by-products that contribute to the overall aroma and flavor of wines (fusel alcohols, glycerol, sulfides, volatile phenols, succinic acid, acetic acid…), perhaps the most important aromatic compound to consider when selecting a commercial yeast strain is its ability to synthesize esters. The esters produced by yeast will contribute to the fruity and floral aroma of a wine. These compounds can have aromas ranging from pear drops to flowers, honey, and bananas. Often they are used in the food industry to give artificial fruit flavors to candies.

Esters and young wine aroma. While ester producing yeast strains aren't typically associated with enhancing the varietal aroma of a wine, their production can be influenced by grape variety. For example, in Pinot Noir wines, the characteristic fruity aromas of plum, cherry, strawberry, raspberry, blackcurrant and blackberry were shown to be influenced by esters. These esters are synthesized by the yeast, but from aroma precursors found in the grape berry[3]. Nonetheless, these compounds are some of the first to disappear during wine aging. The fruity and banana aromas that you smell in the winery during fermentation are typically associated with esters which disappear quickly in finished wine. Mixed yeast cultures containing non-Saccharomyces yeast can also have a positive impact on the production of esters in wine. If winemakers wish to guard these aromas in a wine, they should be sure to ferment the wine cold and limit oxygen uptake. Ester-producing yeast strains should typically be used only if the wines are meant to be bottled and consumed while they are still young. In years where poor growing conditions (rot or botrytis) make it difficult to get fruity aromas from the grapes themselves, esters from yeasts may help make up for lack of varietal character. There is also some market demand for wines with this fruity aromatic profile. We will be using two high-ester producing yeasts in trials with Frontenac this year: Rhone 4600 and ICV Opale.

Selecting a yeast. Think of yeast as one tool in your toolkit to help direct a wine to what you want it to be. The first step a winemaker needs to take when deciding what yeast to use is to determine the stylistic goal he or she has in mind for a wine. Is it going to be fresh and fruity with some residual sugar, or will the wine undergo a significant aging period in new oak and be made into a dry wine? Perhaps you are making wines in both those styles. You probably wouldn't want to use the same yeast for both of those wines. A wine that is meant to be fresh, young, and fruity should probably be fermented with yeast that will add some fruity esters to the wine. However, if you put that wine into a barrel, those ester aromas will quickly disappear due to their high volatility. You are better off trying to get the most fruit flavor out of the grapes themselves by using yeast that enhances varietal character.

Vineyard environment. Sometimes the stylistic goal the winemaker has in mind may not even be possible depending on growing conditions of the grapes. In a warm year, if the Brix is greater than 25, yeast that only tolerate 14% alcohol should not be used (assuming you want a dry wine). We battle with high acidity in all our wines, but growers in the most extreme growing regions of the north may have to face the fact that their grapes may have too much acid to ever turn them into a palatable dry wine. This may also be true in short growing seasons where it is difficult to get the acid numbers down prior to harvest. Sometimes trying to force a wine to be something that it is not is a sure way to end up with a mediocre wine. It is important to remain realistic and understand that no matter how hard you try, you probably will never be able to make a "big" Bordeaux-style wine from Marquette or Frontenac.

Winemaking environment. Winemaking conditions are also important. While *Saccharomyces* yeast tolerate the harsh conditions in grape juice and wine, each strain has their own special range of ideal conditions for growth. The yeast cell wall is made up of fatty acids in a lipid bilayer. Think of it as a layer of oil. Just as some fats react differently to extreme temperature changes, so does this lipid bilayer surrounding the yeast cell. Really cold temperatures can make it stiff and hard to move, while really hot temperatures make it thin and runny. The yeast cell wall is also sensitive to alcohol and osmotic pressure. The cell wall needs to transport nutrients into the cell and export waste products out of the cell, and both can make it difficult for the yeast to do so. The sugar concentration of the juice or must can make it difficult for the cell to get rid of waste, as it's pushing against the osmotic pressure of the solution against its cell wall. A buildup of waste inside the cell will lead to cell death. Also, each strain of yeast varies in how efficiently it uses nutrients. Although all winemakers should be checking the YAN levels of their juice or must, this becomes even more important when using a yeast strain that has higher nutrient needs.

In the end, selection of a commercial yeast strain can have a significant impact on your finished wine. Yeast can play an important role in ensuring that a fermentation finishes clean and dry with a predictable outcome to a wine, which is crucial to successfully marketing cold-hardy cultivars.

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Katie Cook is the Enology Project Leader for the University of Minnesota. Her appointment is split 60/40 between research and outreach activities in the state. Her main research is focused on enological evaluation of potential new grape cultivars developed through the U of M's grape breeding program. As part of the Northern Grapes Project, Katie will be involved in replicated regional optimization trials of cold-hardy varieties, focusing on biological deacidification methods as well as yeast selection.

The Northern Grapes Project is on Facebook!

We'll be posting updates about workshops, field days, webinars, newsletters, and more!

Upcoming Events

What: University of Wisconsin Table and Wine Grape Field Day
When: August 23, 2012, 10:00am-3:00pm
Where: West Madison Agricultural Research Station, 8502 Mineral Point Road, Verona, WI 53593
*registration required, open link for details

What: Northwest Michigan Horticultural Research Center Open House
When: August 23, 2012
Where: Northwest Michigan Horticulture Research Center, 6686 S. Center Hwy., Traverse City, MI

What: University of Wisconsin Wine Grape Crop Load and Canopy Management
When: Friday September 7th, 1:00-4:00pm
Where: Danzinger Vineyard, S2015 Grapeview Lane Alma, WI 54610
email Rebecca Harbut (harbut@wisc.edu) for further information

What: University of Minnesota Grape Breeding and Enology Open House
When: Sept. 8, 2012, 10am - 1pm
Where: University of Minnesota Horticultural Research Center, 600 Arboretum Drive (Minnesota Hwy 5) near Victoria, MN

What: University of Wisconsin Wine Grape Field Day
When: September 13, 1:00-4:00pm
Where: Peninsular Agricultural Research Station, 4312 State Highway 42, Sturgeon Bay, WI
email Rebecca Harbut (harbut@wisc.edu) for further information

What: Northern Grapes Symposium (in conjunction with Vit 2013)
When: February 6, 2013
Where: Rochester Convention Center, Rochester, NY

photo: Keith Striegler

NGP Director Tim Martinson and Keith Striegler, Outreach coordinator for the National Clean Plant Network visited Northern Grapes Project sites and nurseries in Wisconsin, Minnesota, and Iowa from June 11-June 14. Here in Iowa State's NE-1020 block are Tim Martinson, Paul Domoto, Murli Dharmadhikari, Somchai Rice, Michael White, Leah Riesselman, Gail Nonnecke, Jamie Harrington, Jason Vallone, and Jacek Koziel

Cornell University

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