



## **Innovation and adaptation in the Ontario grape and wine industry: An integrated, transdisciplinary response to climate change\***

Kerrie Pickering <sup>\*\*ab</sup>, Gary J. Pickering <sup>cde</sup>, Debbie Inglis <sup>cd</sup>, Tony Shaw <sup>b</sup>, Ryan Plummer <sup>afg</sup>

<sup>a</sup> Environmental Sustainability Research Centre, Brock University, St. Catharines, Ontario, Canada L2S 3A1

<sup>b</sup> Department of Geography, Brock University, St. Catharines, Ontario, Canada L2S 3A1

<sup>c</sup> Cool Climate Oenology and Viticulture Institute, Brock University, St. Catharines, Ontario, Canada L2S 3A1

<sup>d</sup> Department of Biological Sciences, Brock University, St. Catharines, Ontario, Canada L2S 3A1

<sup>e</sup> Department of Psychology, Brock University, St. Catharines, Ontario, Canada L2S 3A1

<sup>f</sup> Department of Tourism and Environment, Brock University, St. Catharines, Ontario, Canada L2S 3A1.

<sup>g</sup> Senior Research Fellow, Stockholm Resilience Centre, Stockholm University, SE - 106 91 Stockholm Sweden

\* A Working Paper based on: *Pickering, K., Pickering, G.J., Inglis, D., Shaw, T., and Plummer, R. (2012). Innovation and adaptation in the Ontario grape and wine industry: An integrated, transdisciplinary response to climate change. (Refereed) Proceedings of the International Conference on Innovation and Trends in Wine Management, Dijon, June 22, 2012. Groupe ESC Dijon Bourgogne, Institut Du Management Du Vin. Digital PDF file, paper 31:1-9. Published with permission of Institut Du Management Du Vin.*

\*\* Corresponding author. Email: [kpickering@brocku.ca](mailto:kpickering@brocku.ca)

### **Abstract**

With scientific consensus supporting a 4°C increase in global mean temperature over the next century and increased frequency of severe weather events, adaptation to climate change is critical. Given the dynamic and complex nature of climate change, a transdisciplinary approach toward adaptation can create an environment that supports knowledge sharing and innovation, improving existing strategies and creating new ones. The Ontario wine industry provides a case study to illustrate the benefits of this approach. We describe the formation and work of the Ontario Grape and Wine Research Network within this context, and present some preliminary results to highlight the opportunities for innovation that will drive the successful adaptation of the Ontario grape and wine industry.

**Keywords:** climate change; climate adaptation; transdisciplinary; grape; wine; innovation

### **Acknowledgements**

Thank you to all our partners in The Ontario Grape and Wine Research Network. The support of the Ontario Research Fund for Research Excellence Funding (Round 5), Ontario Grape and Wine Research Inc., the Wine Council of Ontario, the Grape Growers of Ontario, and the Winery and Growers Alliance of Ontario is gratefully acknowledged.

## 1.0. Introduction and Context

The evidence supporting anthropogenic climate change is overwhelming (Rosenzweig et al., 2007, Füssel, 2009, Rockström, 2009, Adger and Barnett, 2009, Smith et al., 2009). While mitigation efforts continue to be important, the International Panel on Climate Change (IPCC, 2007) stresses the urgent need to focus on adaptation efforts, as communities begin to experience impacts. Taking into account present temperature increases, emission rates, and improved climatic modeling, a 4°C rise in global mean temperatures over the next century is forecast (Adger and Barnett, 2009, Smith et al., 2009). At 4°C, feedback loops within systems will create greater uncertainty in predicting impacts, and it is highly possible many biogeographical thresholds will be crossed causing transformative changes that may threaten the planet's ecological life support systems (Adger and Barnett, 2009, Smith et al., 2009, Füssel, 2009, Rockström et al., 2009). Adaptation to climate change is a necessity to reduce future human suffering (IPCC, 2007). While some adaptations are planned and others occur spontaneously, each is the outcome of a system's adaptive capacity, defined as the ability of a system to adjust to a stressor outside its normal coping range (Smit and Wandel, 2006). Adaptive capacity is a social process heavily influenced by social and institutional structures, and the ability of individuals and groups to work collaboratively (Armitage and Plummer, 2010, Matthews and Sydneysmith, 2012).

Climate change adaptation is a diverse and complex issue spanning the physical, social, and humanity sciences. It demands an integrative and comprehensive perspective extending beyond conventional (science) disciplines (Ludwig, 2001). "Transdisciplinarity is a specific form of interdisciplinarity in which boundaries between and beyond disciplines are transcended and knowledge and perspectives from different scientific disciplines as well as non-scientific sources are integrated" (Flinterman et al, 2001 in Choi and Pak, 2006 pp. 355). This approach creates a new pedagogical space beyond where knowledge can be analyzed and synthesized evolving into new perspectives for holistic and innovative solutions (Choi and Pak, 2006, Deppisch and Hasibovic, 2011, Koizumi, 2001). Adger et al. (2007) identified barriers to adaptation, including obstructions and gaps in knowledge. Members of the transdisciplinary team reduce these barriers by valuing and sharing knowledge, skills and responsibilities across traditional disciplinary boundaries as they work collaboratively on projects (Dyer, 2003). A diversity of perspectives and worldviews serve to define the complexity of a problem, which assists in developing knowledge and practices that support the common good (Pohl and Hirsch Handorn, 2007). Through the transdisciplinary process scientific knowledge is linked to the knowledge, needs and interests of relevant stakeholders, improving existing practices while creating innovative new ones (Hoffmann-Riem et al., 2008). The value of a transdisciplinary approach has been recognized in complex issues within child psychology, biodiversity, education, economics and climate (Hoffmann-Riem et al., 2008). By incorporating many forms of knowledge and working collectively, the transdisciplinary approach supports and provides an opportunity for adaptation and innovation, and represents a promising model for how the grape and wine industry can comprehensively respond to climate change.

## 2.0. Ontario Wine Industry

The cultivation of wine grapes in Ontario is made possible by the moderating effect of two Great Lakes (Ontario and Erie) and local geomorphology. This combination of physical features creates the four Ontario appellations: the Niagara Peninsula, Lake Erie North Shore, Pelee

Island, and Prince Edward County. While the industry produces many cool climate table wines from *Vitis vinifera*, it is internationally renowned for the production of Icewine, which constitutes 50% of the wine it exports (Wine Council of Ontario, 2012). In 2010 there were over 15,000 acres of vineyards and more than 130 wineries in Ontario, together producing 15.6 million litres of wine (Grape Growers of Ontario, 2010) creating an annual revenue of over \$1 billion. By 2020 it is predicted the industry will expand to a value of \$1.5 billion and employ 13,500 Ontarians. The wineries have a strong influence on local tourism, with over 1 million people visiting them each year (Wine Council of Ontario, 2012). Ontario's wine industry faces many climate challenges, including unpredictable extreme weather events such as early freezes, mid-winter freeze thaw cycles, and extreme cold temperatures. The extreme fluctuations in winter temperatures have led to poor grape vine survival and performance for some varieties, and the introduction/survival of pests that have damaged vineyards and tainted wines. In 2003 and 2005, low harvest yields and wine volume were largely due to extreme cold temperatures in the preceding winter (Cry et al., 2008). Grape growers in Ontario have few tools to mitigate winter damage of *V. vinifera*, other than the use of wind machines or helicopters during frost or freeze events.

The success and future growth of the grape/wine industry in Ontario depends on the ability to consistently ripen and harvest grapes that will produce the quality and quantity of premium (VQA) wines required to satisfy its domestic and international markets. To be able to do so requires us to know how to manage current and future weather events, understand and optimize cold hardiness in vines, and ultimately to develop cold tolerant varieties. At the same time we need to develop processes that optimize and diversify the use of cool climate grapes for new wine products that can compete on the international market.

### **3.0. Transdisciplinary Program**

To meet these current and future needs of the industry, we have formed a collaborative grouping of individuals and institutions with the relevant expertise - The Ontario Grape and Wine Research Network (OGWRN) – and instigated an innovative, transdisciplinary research program on climate change adaptation. The program has been given significant impetus with recent funding from the provincial government. The specific objectives are to (i) provide the wine industry with the requisite knowledge for adopting the best adaptive strategies, (ii) contribute to the creation of more value-added products, (iii) help maintain Ontario's competitive advantage, and (iv) help conserve the growing environments necessary for the production of high quality wines.

#### *3.1. The players and management*

In order to meet the challenging objectives mandated by this program, the membership of the Network consists of individuals and institutions with the varied skill-sets and resources needed for success. There are 3 tertiary research institutions, including the lead university (Brock University), and 1 private research centre. There are 13 private partners, including the federal government department Environment Canada, 2 industry stakeholder groups (Grape Growers of Ontario and Ontario Grape and Wine Research Inc), 1 provincial government regulatory agency (Vintners Quality Alliance), and 9 private businesses consisting of wineries, vineyards, and greenhouses (Fig. 1).

In total, the research team consists of 19 individual researchers, representing the diverse disciplines required of the program, including climatologists, viticulturists, oenologists, sensory scientists, flavor and organic chemists, molecular biologists, microbiologists, grapevine pathologists, computer programmers, integrated pest management specialists and adaptation scientists. The management system for this large and diverse program is overseen by the OGWRN Board of Directors, which comprises of representatives from each of the partner institutions and industry stakeholder groups. An Administrative Director and Scientific Director report to the Board, and each of the major research projects within the program is coordinated by a Team Leader, who is responsible for the research deliverables and reporting requirements. The key industry stakeholders, represented by the Grape Growers of Ontario and Ontario Grape and Wine Research Inc, are involved in each step of the research process, from designing the research program through to the dissemination and commercialization stages. A Memorandum of Understanding exists between the institutional members of the OGWRN that outlines processes to deal with commercialization and intellectual property opportunities as the program advances.

### 3.2. *The research*

The program is divided into two main themes; *Viticulture and Climate* and *Oenology and Climate*. Figure 2 illustrates the individual research projects that collectively focus on developing adaptation strategies to the impacts of climate change and how the success of these depends on building and mobilize adaptive capacity.

The *Viticulture and Climate* theme has three linked foci concerned with successful adaptation to the challenges faced by current and projected climate conditions in the province. First, predictive climate models will be developed from historical data to help determine the potential impacts of climate change for Ontario *V. vinifera* production and its wine regions over the next 30 years. This will lead to the development of an expert climate prediction system ('VineAlert') that will enable growers to optimize vineyard management practices and grape varieties for projected changes in the sub-regional climates of our wine appellations. The study includes assessing and mobilizing the adaptive capacity of the industry to optimize operationalization of adaptive strategies. The second project focuses on optimizing grapevine winter hardiness to allow vines to better adapt to extremes in temperature fluctuations over the dormant season. It takes a multi-disciplinary approach that considers cultural practices, disease pressure and other key impact variables. The final project employs a genetic approach to identify the molecular markers that confer winter hardiness to grapevines. This will provide the tools needed for selective breeding of winter hardiness traits into premium *vinifera* vines, and will ensure a permanent solution against damage from low temperature winter injury, with significant commercialization opportunities for cool- and cold-grape regions throughout the world.

The *Oenology and Climate* theme complements the previous work by focusing on the optimization of wine flavor and styles for existing grapes in established Ontario appellations. In the first project, we will develop effective remediation tools for methoxypyrazines; potent wine flavor compounds that are closely linked to climate conditions, viticultural practices, and the quality of Ontario wine. These tools have enormous potential for commercialization in wine regions throughout the world. To date, few Ontario wineries produce sparkling wines, yet the high natural acidity of our grapes provides the ideal base for this high-value style. Enhancing a viable sparkling wine segment represents some 'insurance' for the industry when table wine

grapes fail to reach full maturity; a scenario that may become more common with increased climate variability. This research addresses some of the technical limitations to fuller adoption of this style in Ontario. Another challenge for the industry is to consistently ripen many premium *vinifera* varieties. Our final project investigates further ripening grapes off-vine, and creating unique, high-value appassimento-like wine styles. These new processing technologies and wine products will be realized within the time-frame of this program, but the expertise, technology and infrastructure that are developed also create future opportunities for exploitation from new Ontario wine regions/varieties that climate change will make viable.

#### **4.0. Preliminary Results**

The program has been underway for just under one year and some illustrative, preliminary results are presented here from three disciplines.

##### *4.1. Adaptive capacity*

While the development of new innovations to manage and exploit the impacts of climate change are of significant importance to the sustainability of Ontario's wine industry, equally important is the capacity to mobilize resources to incorporate and support these new products and strategies. By determining the adaptive capacity of the industry, the strengths and challenges for adaptation will be identified creating an opportunity to strategically build capacity and enhance the potential for adaptation. To help achieve this, a questionnaire has been developed from the adaptive capacity literature and adapted to the wine industry (Table 1). Grape growers, wine makers and supporting institutions including the Grape Growers of Ontario, Wine Council of Ontario and Vintners Quality Assurance will complete the questionnaire, and once the responses have been collected, collated and analyzed, they will be disseminated to participants and key organizations.

##### *4.2. VineAlert: early warning system for grape growers*

Determination of the winter tolerances of grape buds and real-time temperature tracking in Ontario vineyards have enabled us to develop a prototype of the VineAlert system that allows growers to use the Internet to track vineyard temperature profiles during a grapevine's vulnerable periods (Figure 3).

Included in the information provided are the cold tolerances of the buds for the specific grape(s) of interest. For instance, in Figure 3, the cold event in the middle of January (indicated with an arrow) represents a time point when bud mortality may occur. Such real-time data allows growers to intervene where necessary to protect their vines. A common intervention during such cold events is the use of wind machines, which increase the air temperature around the vine.

##### *4.3. Appassimento-style wines*

It is difficult in Ontario's current climate to achieve consistent ripening of many premium grape varieties for table wine. We will optimize off-vine ripening and the development of appassimento-style wines to add significant value to existing varieties and diversify Ontario's wine portfolio. We are investigating multiple drying technologies and varieties; Table 2 shows

the capacity of 4 techniques to dry the grapes and concentrate the subsequent sugars and flavors.

The wines from this first vintage were chemically and microbially sound, and possessed excellent flavor, often described as full bodied, well-balanced, with dark fruit and berry aromas.

## **5.0. Conclusion**

Transdisciplinary approaches affords the opportunity for more inventive, deeper, and meaningful responses to climate change than what might be achieved through single or even multi-disciplinary perspectives. In practice this has resulted in a diversity of scientists, industry, policy makers and stakeholders moving beyond their disciplines and coming together under the complex issue of climate change to share knowledge and collectively devise new and innovative solutions. Preliminary results indicate significant buy-in from the key stakeholders, and the promise of timely and innovative research deliverables for the industry.

## References

- Adger, N. and Barnett, J. 2009. Reasons for concern about adaptation to climate change. *Environment and Planning*, Vol. 40 pp. 2800-2805.
- Adger, W. Agrawala, S. Mirza, M. Conde, C. O'Brien, K. Pulhin, J. Pulwarty, R. Smit, B. and Takahashi, K. 2007. Assessment of adaptation practices, options, constraints and capacity. Pages 717-743 in Parry, M. Canziani, O. Palutikof, J. van der Linden, P. and Hanson, C. (editors). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.
- Armitage, D. and Plummer, R. 2010. Adaptation, learning and transformation in theory and practice: A state of the art literature review and strategy for application in the Niagara region. Final Report. Prepared for Adaptation and Impacts Research Section- Environment Canada. Toronto, Ontario. 47pp.
- Choi, B. Pak, A. 2006. Multidisciplinarity, interdisciplinarity and transdisciplinary in health research, services, education and policy: 1. Definitions, objectives and evidence of effectiveness. *Clinical Investigative Medicine*. 29:6:351-364
- Cyr, D, Kusy, M. and Shaw A. 2008. The potential use of weather derivatives in the viticulture industry, *Economia & Diritto Agroalimentare* Vol. 13 No.3 pp. 67-82.
- Deppisch, S. Hasibovic, S. 2011. Social-ecological resilience thinking as a bridging concept in transdisciplinary research on climate-change adaptation. *Natural Hazards*.
- Dyer, J. 2003. Multidisciplinary, interdisciplinary, and transdisciplinary educational models and nursing education. *Nursing Education Perspectives*, July-August 2003.
- Engke, N. 2011. Adaptive capacity and its assessment. *Global Environmental Change*. Vol. 21 pp. 647-656.
- Füssel, H. 2009. An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. *Climatic Change*. Vol. 97 pp. 469-482.
- Grape Growers of Ontario. 2010. Ontario's grape and wine industry. URL: <http://www.grapegrowersofontario.com/ontarios-grape-and-wine-industry>, April 4, 2012.
- Hoffman-Reim H. Biber-Klemm, S. Grossenbacher-Mansuy ref works p1-33
- IPCC, 2007. *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge University Press, UK, and New York, NY, USA.
- Koizumi, H. 2001. Trans-disciplinarity. *Neuroendocrinology Letters*. 22:219-221



- Ludwig, D. 2001. The era of management is over. *Ecosystems*. 4:758-764
- Matthews, R. Sydneysmith, R. 2010. Adaptive capacity as a dynamic institutional process: Conceptual perspectives and their application. In Armitage, D. Plummer, R. eds. 2010 *Adaptive Capacity and Environmental Governance*. Springer Heidelberg Germany.
- Nelson, D. Adger, N. Brown, B. 2007. Adaptation to environmental change: Contributions of a resilience framework. *Annual Review of Environmental Resources*. Vol. 32 pp. 395-419.
- Pohl, C. and Hirsch Hadron, G. 2007. Principles for designing transdisciplinary research, proposed by the Swiss Academies of Arts and Sciences, *oekom, Müünchen*, 124.
- Rockström, J. Steffen, W. Noone, K. Persson, Å. Chapin III, F. Lambin, E. Lenton, T. Scheffer, M. Folke, C. and Schellnhuber, H. 2009. "Planetary boundaries: exploring the safe operating space for humanity", *Ecology and Society*, Vol. 14 No. 2, pp. 32.
- Rosenzweig, C. Casassa, G. Karoly, D. Imeson, A. Liu, C. Menzel, A. Rawlins, S. Root, T. Seguin, B. and Tryjanowski, P. 2007. Assessment of observed changes and responses in natural and managed systems. in Parry, M. Canziani, O. Palutikof, J. van der Linden, P. and Hanson, C. (editors) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, 79-131.
- Smit, B. and J. Wandel. 2006. *Adaptation, adaptive capacity and vulnerability. Global Environmental Change*, Vol. 16 pp. 282-292.
- Smith, J. Schneider, S. Oppenheimer, M. Yohe, G. Hare, W. Mastrandrea, M. Patwardhan, A. Burton, I. Corfee-Morlot, J. Magadza, C. Fussel, H. Barrie, A. Pittock, A. Rahman, , A. Suarez A. and van Ypersele. J. 2009. Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "Reasons for Concern". *Proceedings of the National Academy of Science of the United States of America*, Vol. 106 No.11, pp.4133-4137.
- Wine Council of Ontario. 2012. Industry Facts.  
URL:<http://www.winecouncilofontario.ca/Resources-Media/Industry-Facts>

## Tables & Figures

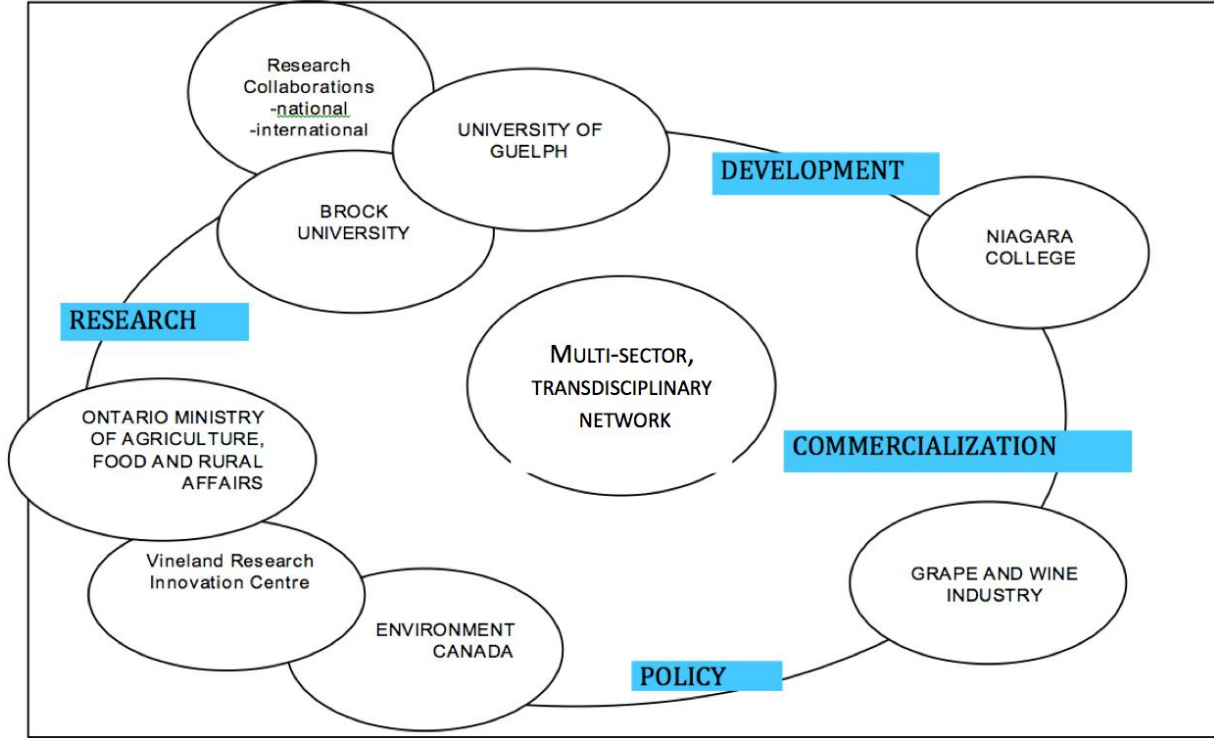
**Table 1.** Sample of adaptive capacity questionnaire for Ontario grape and wine industry.

<b>Determinant</b>	<b>Key Consideration</b>	<b>Example of Indicator</b>
Financial	Access to economic resources instruments	Do you have access to credit & (crop) insurance when you need them?
Institutional	Leadership	Overall how effective is leadership from the supporting Institutions?
Technology	Access to new technologies	When was the last time you used the internet?
Political	Political connections	How intensive is the cooperation between wine industry organizations & the authorities (e.g. spatial planning, environmental & economic agencies)?
Perception	Perception of risk	Do you believe that the climate is changing to an extent that it will substantially affect your vineyard/winery?
Diversity	Degree of diversity in income	Do you have many options available if you choose not to be a grape grower/wine maker?
Knowledge	How knowledge is transferred & shared among groups	What are the three most important sources of information about what the wine industry is doing?
Social Capital	Collective action & cooperation	If there was a water supply problem how likely is it people will cooperate to try to solve the problem?

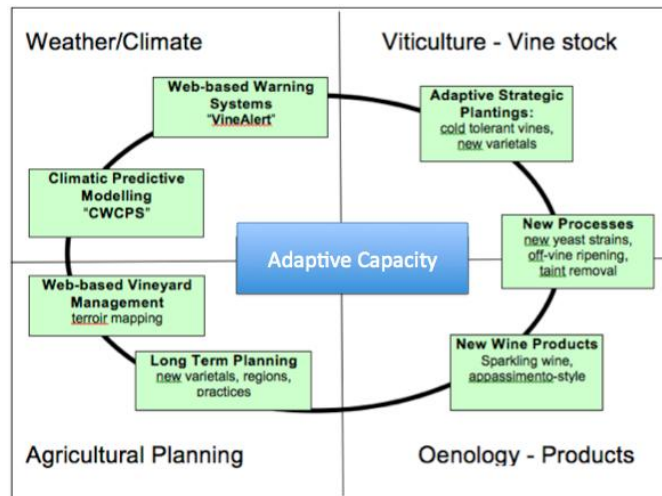
**Table 2.** Initial and final values for berry measurements of Cabernet franc berries from four different drying conditions.

<b>Parameter</b>	<b>Berries - Initial</b>	<b>Berries - Final</b>	<b>Drying Condition</b>
Soluble solids (°Brix)	24.78	32.40	tobacco kiln
		28.30	on the vine
		29.10	drying facility
		27.80	greenhouse
Net berry weight (g)	1.43	1.14	tobacco kiln
		1.33	on the vine
		1.39	drying facility
		1.36	greenhouse
Percent berry weight in juice (%)	70	58	tobacco kiln
		68	on the vine
		68	drying facility
		76	greenhouse

**Figure 1.** The Ontario Grape and Wine Research Network working on climate change adaptation for the Ontario grape and wine industry.



**Figure 2.** Overview of the major research projects within Ontario’s wine industry adaptation program.



**Figure 3.** Chardonnay bud hardiness and low temperature profiles for an Ontario vineyard in 2011/2012. Top line represents temperature in vineyard (daily low) and the 3 bottom lines represent cold tolerances of the grape buds.

