Understanding *Vitis Vinifera* cold hardiness after a decade of monitoring

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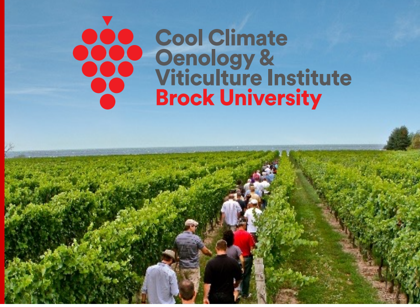
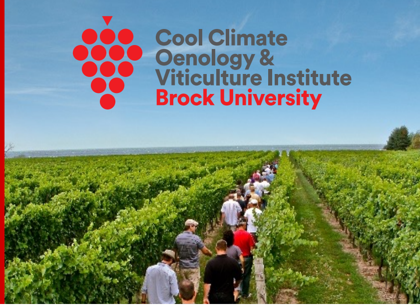
Acknowledgements



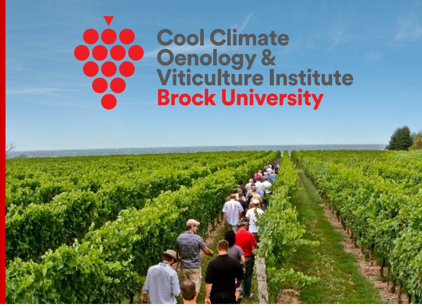
- Dr. Debbie Inglis, Dr. Kevin Ker and Ryan Brewster for development, support of VineAlert and data collection
- Dr. Andréanne Hébert-Haché (former PhD student)
- A. Gunn, S. Bilek, M. Jasinski and all the students and others who helped collect and analyze DTA data in our lab

Background



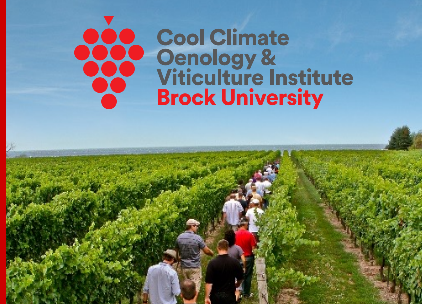
- **Freeze injury threatens grape and tender fruit production throughout North America and increasingly worldwide**
- **CCOVI/Brock University have been leaders in grapevine cold hardiness in Canada since 2010 with many research, outreach and service initiatives to assist the industry mitigate freeze injury and crop loss related to cold temperatures**

Mitigating freeze injury



- **Many cool climate regions can be susceptible to freeze injury**
- **Cold tolerance is often the limiting factor for growing grapes or a cultivar within a given region or site**

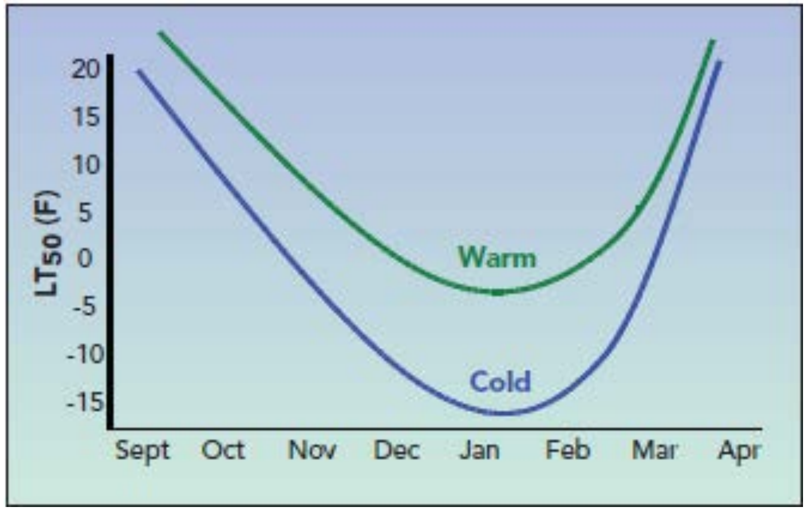
Cold hardiness



For effective mitigation strategies during dormancy, a grower needs to know how cold tolerant their vines are

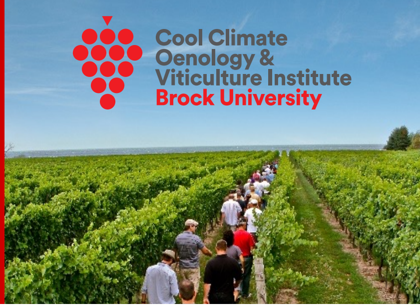
Why?

- **Cold tolerance changes throughout dormancy**
- **Very complex trait with many contributing factors**
- **Influenced by both the grapevine's genetics and environmental conditions**
- **Highly dynamic condition**



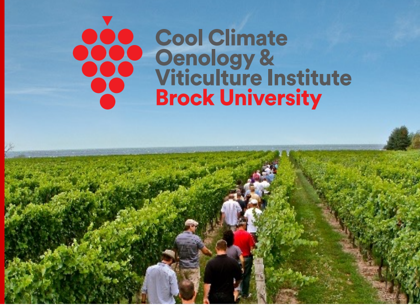
(MSU Extension Bulletin E2930, 2007)

Wide range of cultivars grown in cool climates



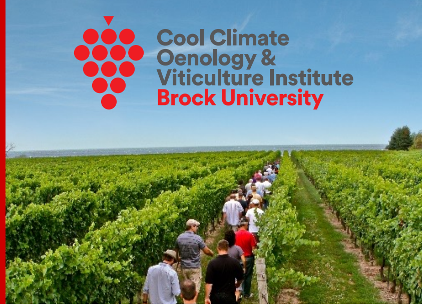
- **Many *Vitis* genotypes grown in cool climates**
- **Different cultivars, clones and rootstocks**
- ***Vinifera* and hybrids will have some unique responses**
- **Important to have some general sense of how they perform under different situations**
  - Growing season and fall conditions – impact on cold acclimation
  - Maximum hardiness
  - Resistance to deacclimation – warm periods during winter, erratic temperatures
  - Timing of bud break

What does this all mean?



- Environmental conditions during dormancy can have profound impacts on hardiness
- Cultivars will respond to conditions differently depending on their genetic background
- Maximum hardiness is important, but hardiness is dynamic
- As climate changes and we have more inconsistent weather during fall, winter and spring cultivar suitability will be more dynamic

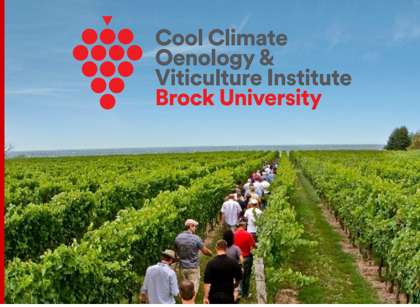
Freeze mitigation



- **In order to use proper freeze mitigation practices properly and efficiently it is critical that timely and reliable information on cold hardiness and vineyard temperatures are available for a range of cultivars grown**
  - Wind machines
  - Geotextiles
  - Vine Burial

- **Cold hardiness information is also critical for grapevine selection to ensure it survives local site conditions.**

VineAlert
http://www.ccovi.ca/vine-alert



- **Our cold hardiness database and alerting system during periods of risk**

Vine Alert: Overview

Grapevine management and monitoring system for cold hardiness and injury.

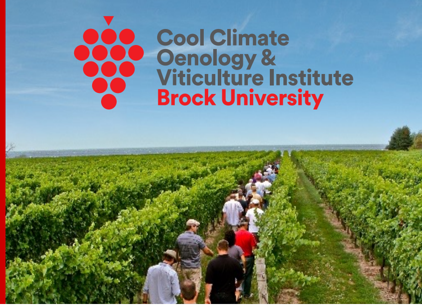
Overview | Recent | Bud Hardiness | Bud Survival | Alerts | Resources

Grapevine Bud Cold Hardiness Database

Overview

Welcome to the Ontario regional grapevine bud cold hardiness webpage. The information contained on this webpage is to provide grape growers with comparative levels of bud hardiness for cultivars at different locations throughout the dormant period. Monitoring bud cold hardiness throughout the dormant period is an invaluable tool to assist grape growers in managing winter injury. The data provided from this database will allow growers and researchers to see how cold-hardy grapevines are within a specific area. Cold hardiness is **not static** but varies throughout the dormant period and is determined through the grapevine's genetic potential and environmental conditions. Therefore, grapevine species and cultivars vary in terms of their cold hardiness. Bud sampling and testing will be done throughout the entire dormant season to monitor cold hardiness through the acclimation, maximum hardiness, and deacclimation periods. This ever-changing bud hardiness data can be helpful in determining when wind machine use or other freeze avoidance methods are warranted to protect the vines from winter injury.

VineAlert: Large hardiness data sets



- **>10 years of hardiness data**
- **Up to 8 cultivars over 3 appellations and 10 sub-appellations**
  - Replicated sites in every sampling region
- **Range of cultivars and diverse site locations**
- **Complimentary research of additional cultivars, clones, rootstocks and other experimental variables to study cold hardiness responses**
- **Probably getting close to a million buds frozen over all the CCOVI-related projects**
- **After 10+ years what are some things we have learned?**

Summary of the sites and corresponding cultivars along with the number of years the sites were evaluated, for a maximum of ten.

VQA region	VQA sub-appelation	Site	Cultivar	Years sampled
Niagara Peninsula	Beamsville Bench	BB1	Cabernet franc, Chardonnay	10
		BB2	Cabernet franc, Chardonnay, Riesling	10
	Creek Shores	CS1	Cabernet sauvignon, Chardonnay, Merlot, Pinot noir, Syrah	3 - 10
		CS2	Cabernet franc, Cabernet sauvignon, Chardonnay	4 - 10
		CS3	Cabernet franc	10
		CS4	Cabernet sauvignon, Riesling	4 - 10
	Four Mile Creek	FMC1	Cabernet franc, Chardonnay	10
		FMC2	Cabernet franc, Chardonnay	10
		FMC4	Cabernet sauvignon, Merlot, Pinot noir, Riesling	6
		FMC7	Sauvignon blanc	6
	Lincoln Lakeshore	LL1	Cabernet franc, Chardonnay	10
		LL2	Cabernet franc, Chardonnay, Merlot, Pinot noir	9 - 10
		LL3	Cabernet Sauvignon, Riesling, Sauvignon blanc	5
	Niagara Lakeshore	NL1	Cabernet franc, Chardonnay, Merlot	10
		NL2	Cabernet franc, Chardonnay	10
		NL3	Pinot noir	10
	Niagara River	NR1	Cabernet franc, Chardonnay, Riesling	10
		NR2	Cabernet franc, Chardonnay, Sauvignon blanc, Syrah	10
	St. David's Bench	SDB1	Cabernet franc, Chardonnay, Merlot, Pinot noir, Sauvignon blanc	9 - 10
		SDB2	Cabernet franc, Chardonnay	10
		SDB3	Syrah	10
	Short Hill's Bench	SHB1	Cabernet franc, Chardonnay, Merlot, Riesling, Sauvignon blanc	9 - 10
		SHB2	Cabernet franc, Chardonnay	10
	Twenty Miles Bench	TMB1	Cabernet franc, Chardonnay, Sauvignon blanc	10
		TMB2	Cabernet franc, Chardonnay	9
	Vinemount Ridge	VR1	Cabernet franc, Chardonnay	10
		VR2	Cabernet franc, Chardonnay, Riesling	10
Lake Erie North Shore		LENS1	Cabernet franc, Chardonnay, Merlot, Sauvignon blanc, Syrah	3 - 9
		LENS3	Cabernet franc, Chardonnay, Riesling	2 - 7
		LENS4	Cabernet franc, Chardonnay, Merlot, Riesling, Syrah	3 - 7
		LENS7	Cabernet sauvignon, Chardonnay, Gewurztraminer	2 - 6
Prince Edward County		PEC1	Cabernet franc, Chardonnay, Pinot noir	4
		PEC2	Cabernet franc, Chardonnay, Gamay, Pinot noir	2 - 8

Implication of site on cold hardiness and freeze injury

SITE SELECTION

Considerations:

- **Proximity to a large body of water**
- **Planting on a landform that has air drainage**
- **Temperatures in spring, fall and winter can vary by site**
- **Soils can impact drainage and vine vigor**
  - Both can have an affect on growth, fruit/vine Maturation that can impact hardiness

Absolute minimum temperatures
- implications on cultivar selection and protection strategies

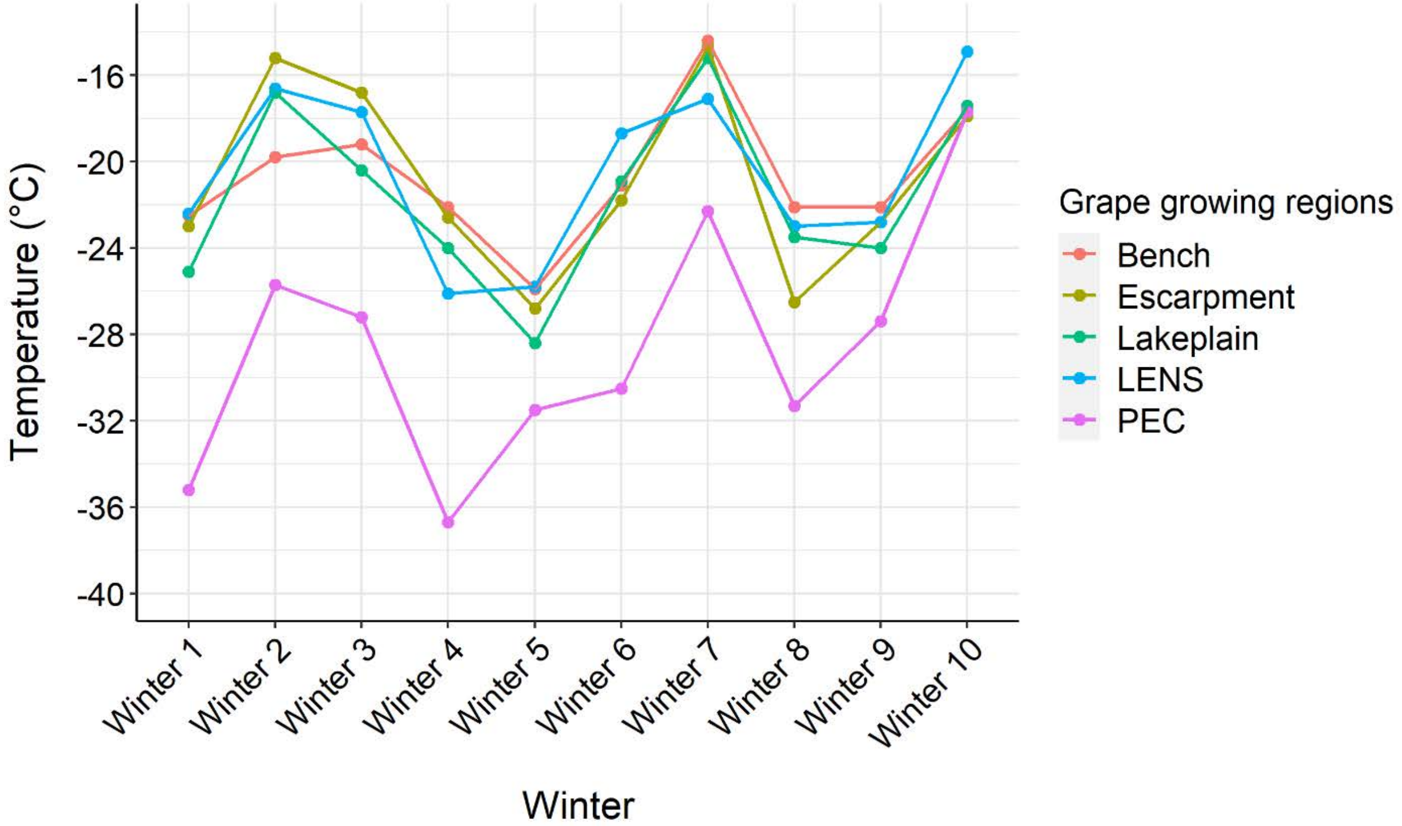


Figure 1. Absolute minimum temperature recorded on the ten winters of the study in the five regions under study: Bench, Escarpment and Lakeplain in the Niagara Peninsula, as well as Lake Erie North Shore (LENS) and Prince Edward County (PEC).

Differences in minimum temperatures over 10 winters in Niagara

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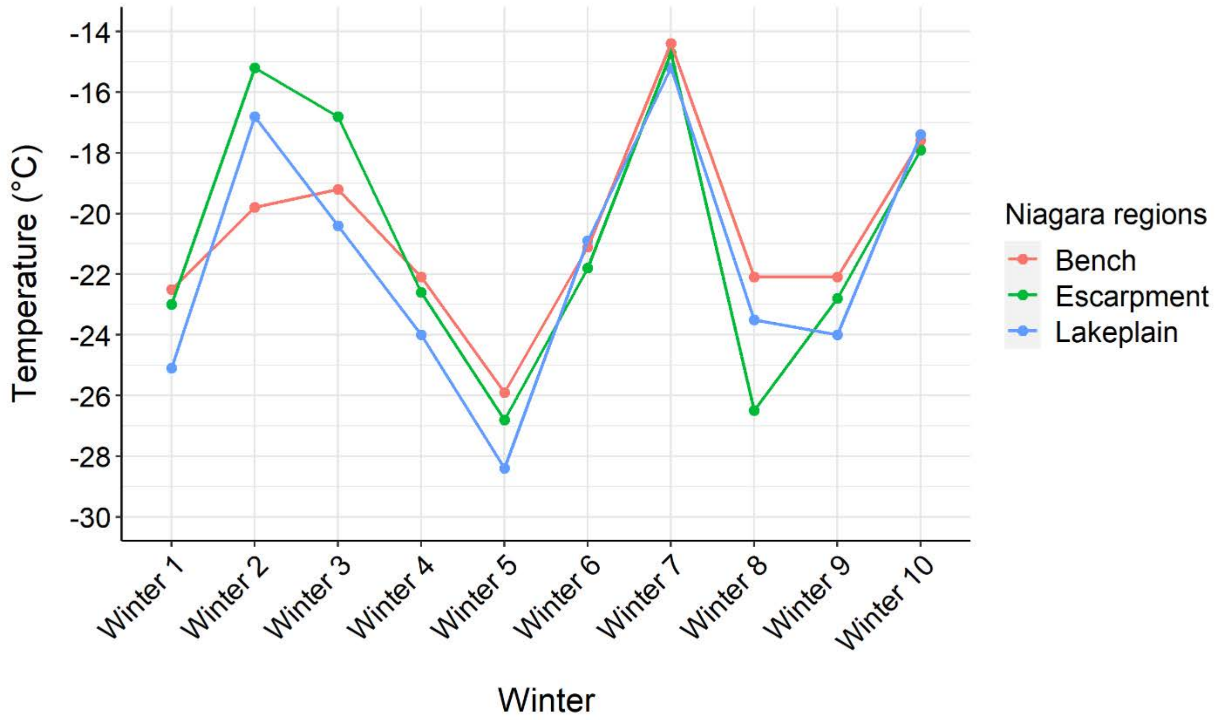

Figure 2. Alternative to figure 1, Figure 1. Absolute minimum temperature recorded on the ten winters of the study in the three Niagara Peninsula regions under study: Bench, Escarpment and Lakeplain.

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Cold hardiness differences across VQA designated areas
2012-13

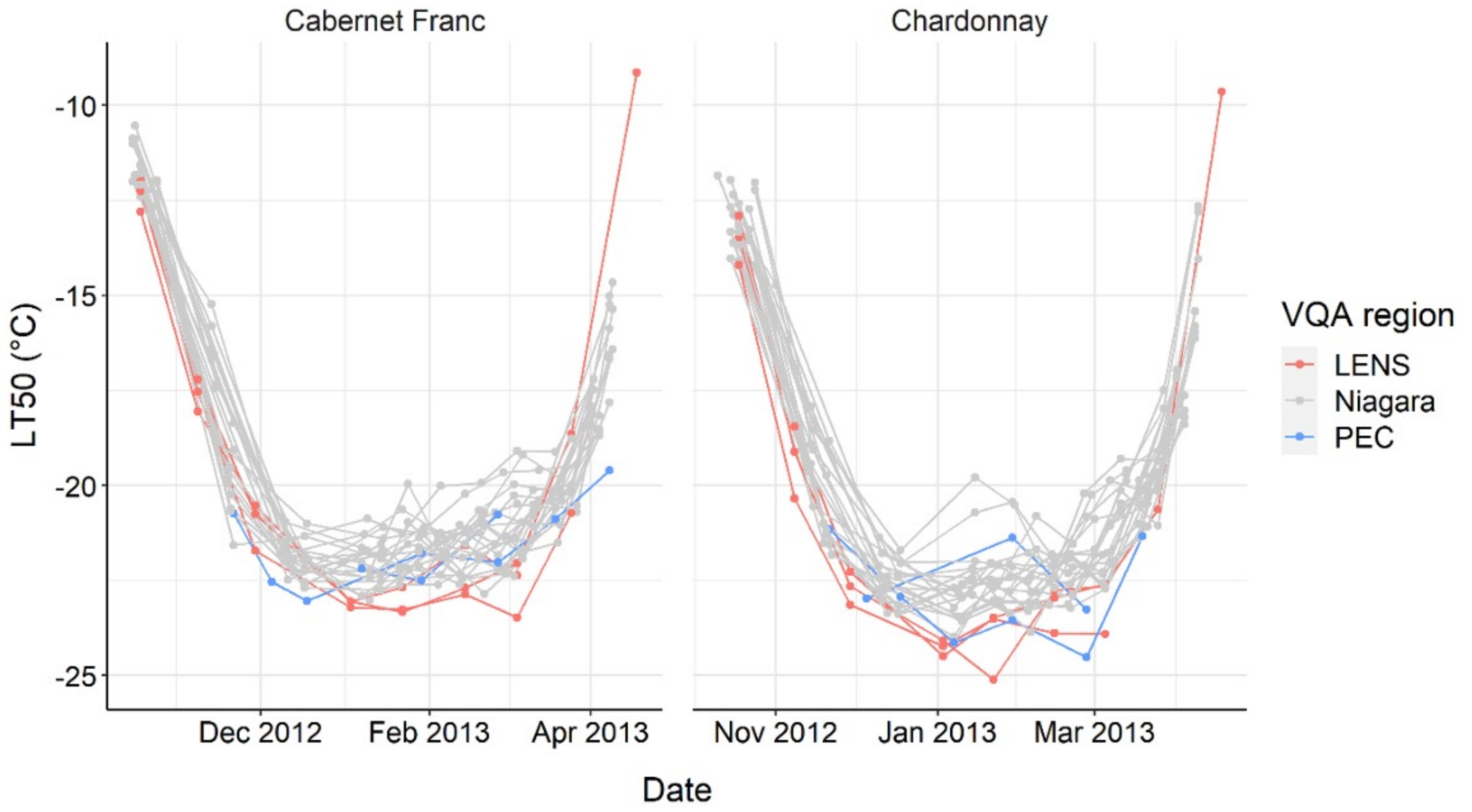
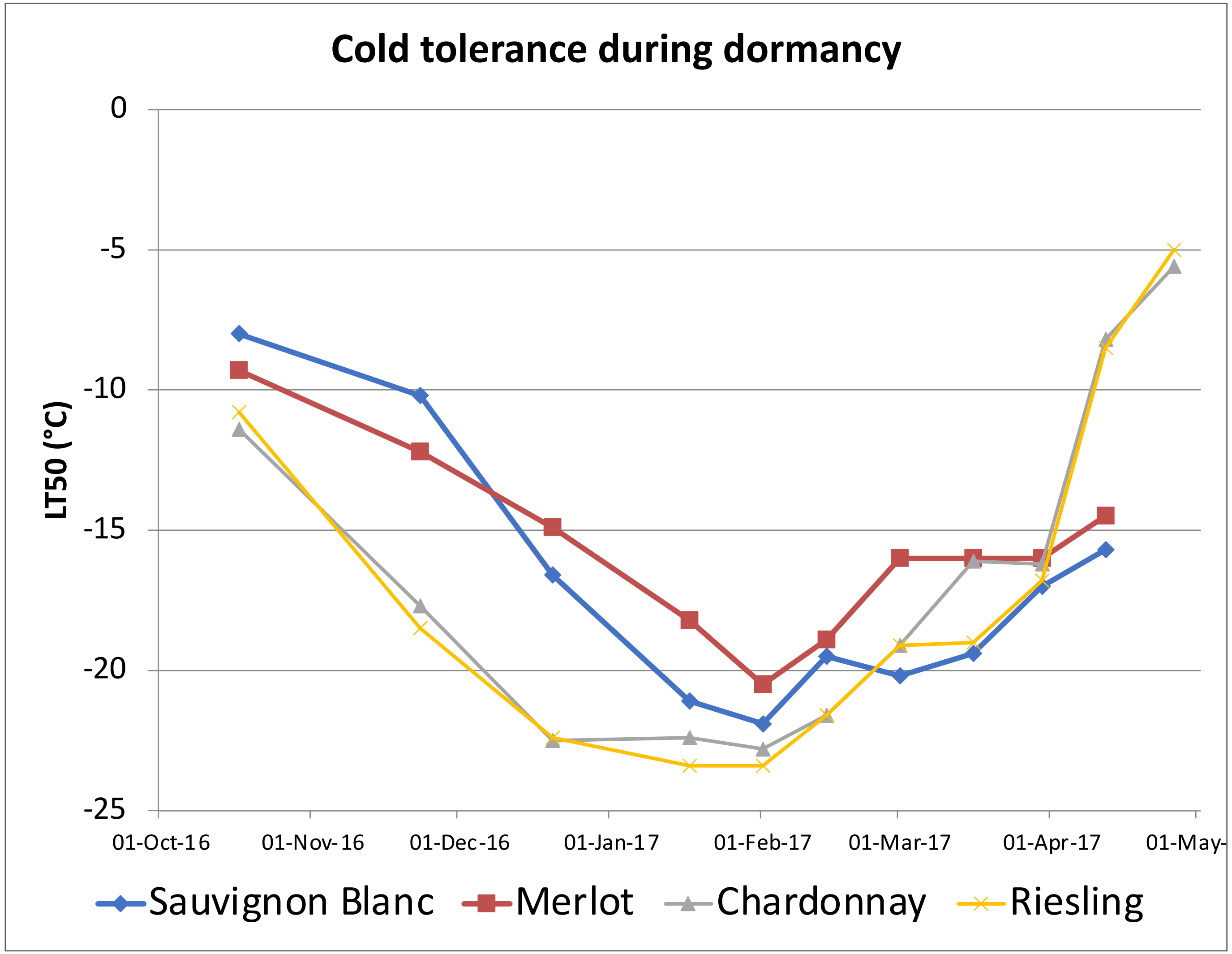


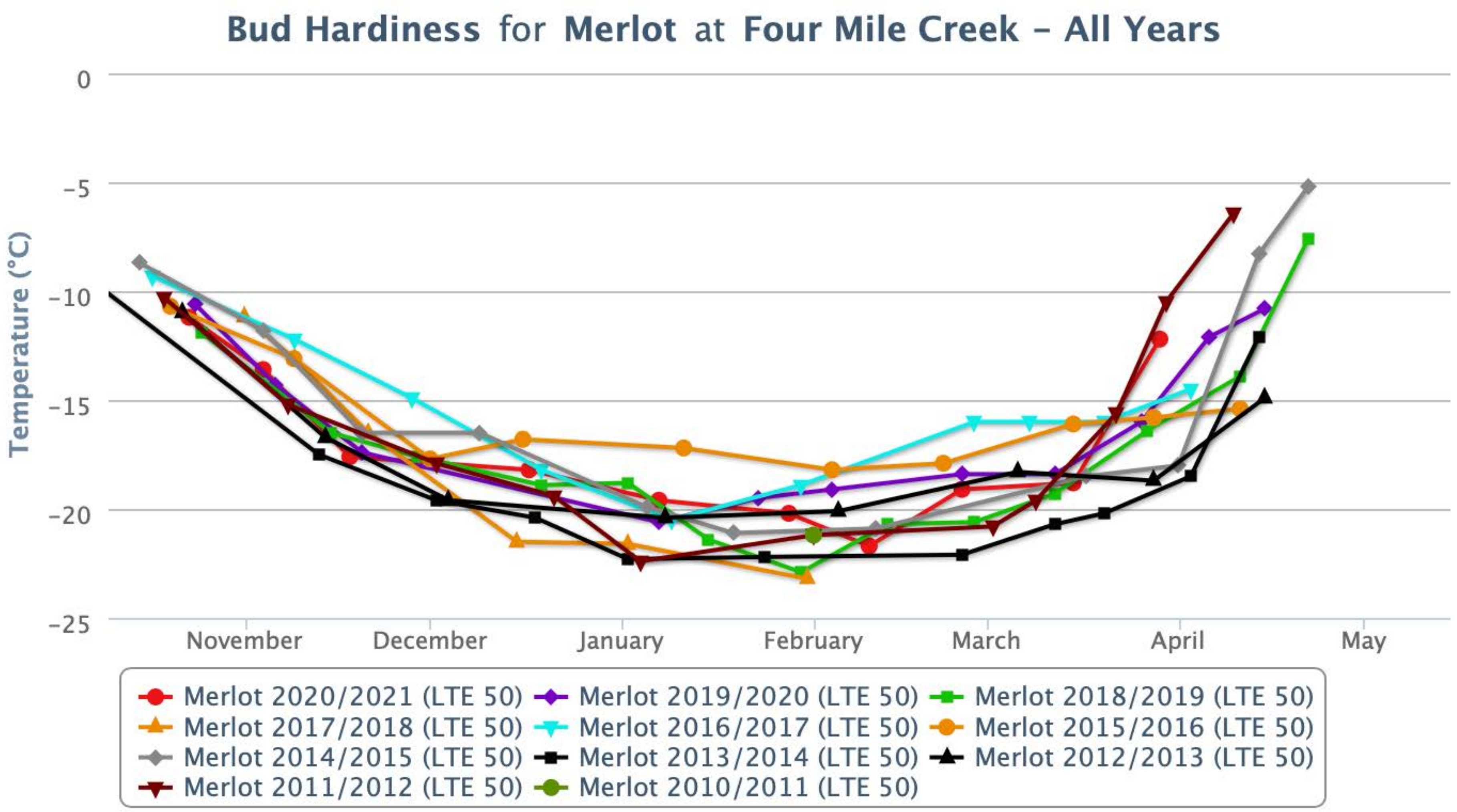
Figure 5. Cold hardiness differences during the winter 2012-2013 between sites of the three VQA regions: Lake Erie North Shore (LENS), Niagara Peninsula, and Prince Edward County (PEC). Each line of the same colour is from a different site within the region. LT50 represents the lethal temperatures to 50% of the primary buds.

Hébert-Haché, 2023

Cultivar differences here in Ontario



How climate can impact cold hardiness –Tender *V. vinifera*



Cultivar mid-winter hardiness differences

Measure	Cultivar	*n*	Minimum	Mean ± SD	Maximum
LT10	Merlot	156	-12.53	-18.03 ± 1.87 a	-22.46
	Syrah	64	-13.81	-18.48 ± 1.76 a	-22.00
	Sauvignon blanc	122	-12.08	-18.50 ± 2.10 a	-24.75
	Cabernet Sauvignon	66	-12.24	-18.63 ± 2.16 a	-22.15
	Cabernet franc	543	-16.12	-20.19 ± 1.37 b	-23.99
	Chardonnay	536	-13.07	-20.94 ± 1.33 c	-24.12
	Pinot noir	109	-15.07	-20.67 ± 1.92 c	-24.31
	Riesling	129	-13.79	-20.84 ± 1.58 c	-23.84
	***p*-value**			**<0.0001**	
LT50	Merlot	156	-16.03	-20.46 ± 1.57 a	-24.58
	Syrah	64	-17.72	-21.08 ± 1.28 b	-23.72
	Sauvignon blanc	122	-16.63	-21.40 ± 1.53 bc	-25.19
	Cabernet Sauvignon	66	-17.83	-21.59 ± 1.42 c	-23.62
	Cabernet franc	543	-19.06	-22.16 ± 1.08 d	-25.43
	Chardonnay	536	-16.46	-22.86 ± 0.99 e	-25.56
	Pinot noir	109	-18.11	-22.98 ± 1.42 e	-25.78
	Riesling	129	-18.96	-23.15 ± 1.19 e	-25.85
	***p*-value**			**<0.0001**	
LT90	Merlot	156	-18.00	-22.46 ± 1.46 a	-26.36
	Syrah	64	-20.63	-23.06 ± 1.07 b	-26.53
	Sauvignon blanc	122	-17.37	-23.29 ± 1.35 bc	-26.42
	Cabernet Sauvignon	66	-20.45	-23.74 ± 1.44 d	-28.00
	Cabernet franc	543	-20.60	-23.54 ± 1.03 cd	-27.40
	Chardonnay	536	-19.61	-24.19 ± 0.99 e	-26.91
	Pinot noir	109	-21.55	-24.38 ± 1.30 e	-27.65
	Riesling	129	-20.49	-24.80 ± 1.27 f	-28.79
	***p*-value**			**<0.0001**	

Hébert-Haché, 2023

Table 3. Descriptive statistics and comparison of the mean midwinter lethal temperatures of 10%, 50% and 90% of the buds, LT10, 50, 90, respectively, ± standard deviation (SD) between the cultivars within the Niagara Peninsula compared by two-way analysis of variance (ANOVA) model. Only combination of cultivar x vineyard x year with four or more sampling dates between 15 December and 1 March were selected.

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Mid-winter hardiness of different cultivars

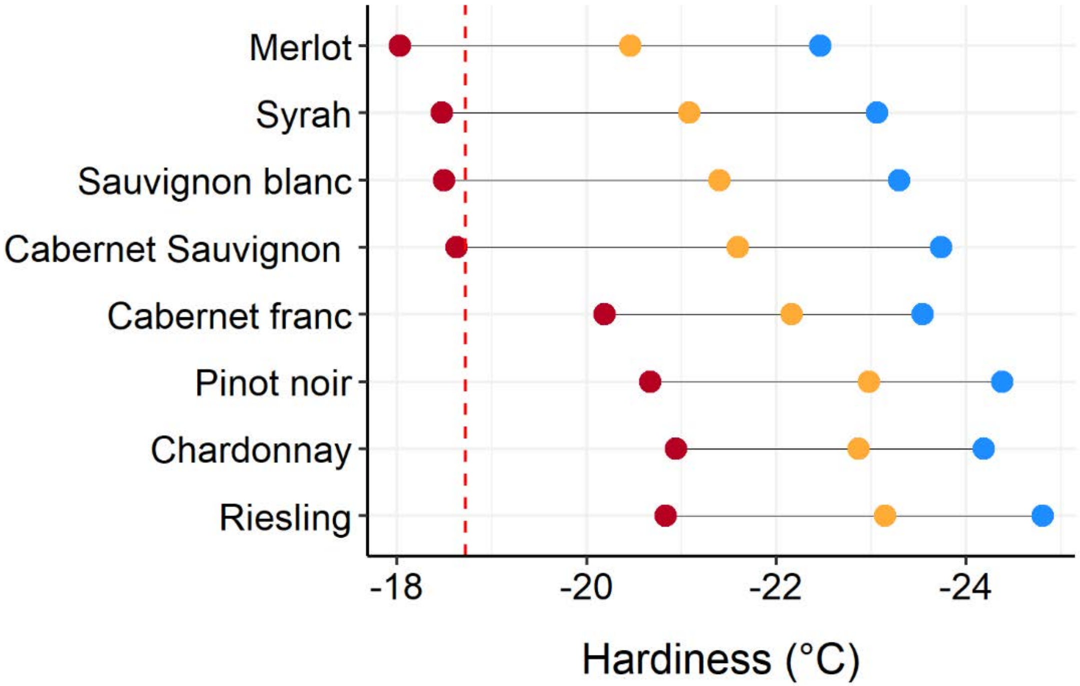


Figure 5. Mean midwinter hardiness as quantified by the lethal temperatures to 10%, 50%, and 90% of the buds (LT10, LT50, LT90). Within each cultivar, the three points represent the mean LT10 (red), LT50 (orange), and LT90 (blue). The red vertical line represents the January mean monthly minimum temperature (-18.7 °C) in the Niagara Peninsula for the winters 2010-11 to 2018-19.

Hébert-Haché, 2023

Maximum annual winter hardiness of 8 cultivars grown within the Niagara Peninsula

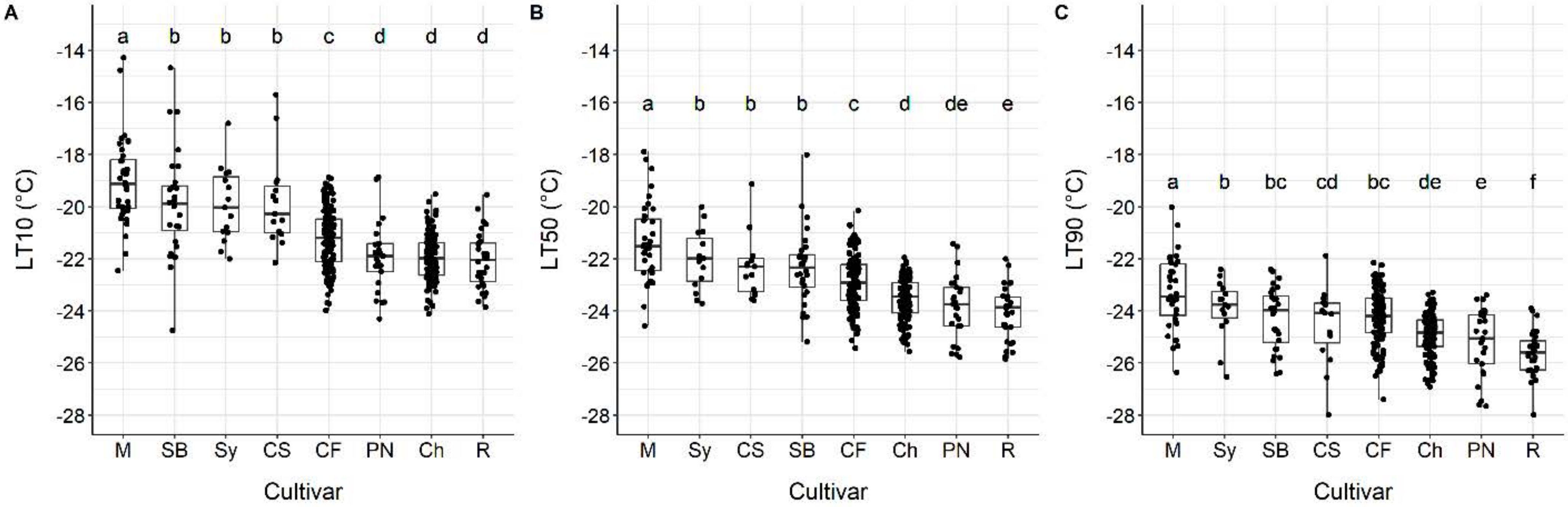
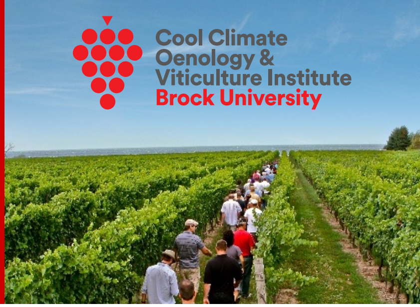


Figure 6. Maximum annual LT10 (A), LT50 (B), and LT90 (C) for the eight main cultivars (CF: Cabernet franc; CS: Cabernet Sauvignon, Ch: Chardonnay; M: Merlot; PN: Pinot noir; R: Riesling; SB: Sauvignon blanc; Sy: Syrah) within the Niagara Peninsula. The best hardiness from each cultivar x year x site were identified within the mid winter hardiness dataset, comprised of combinations of cultivar x year x site were with more than four datapoint within the maximum hardiness phase (15 December to 1 March). Comparison of the means is available in supplementary table 6.

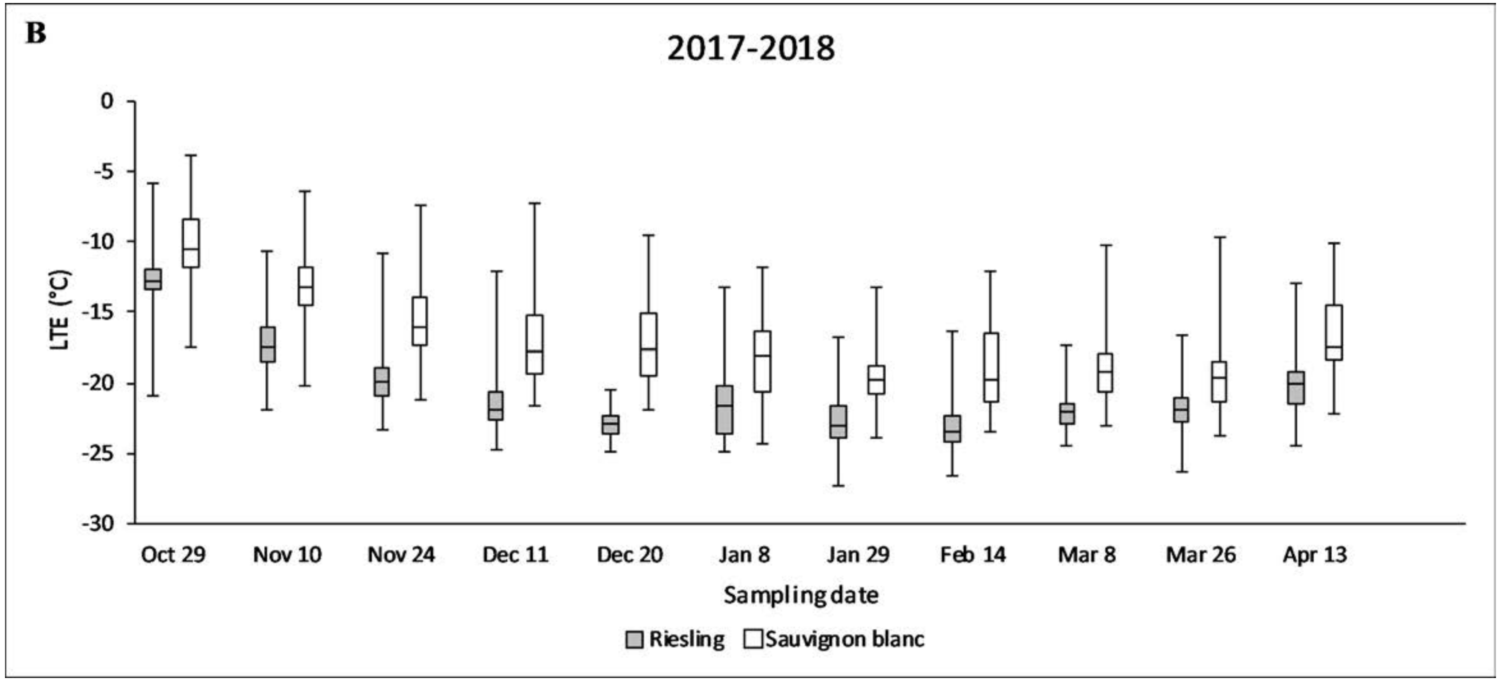
Hébert-Haché, 2023

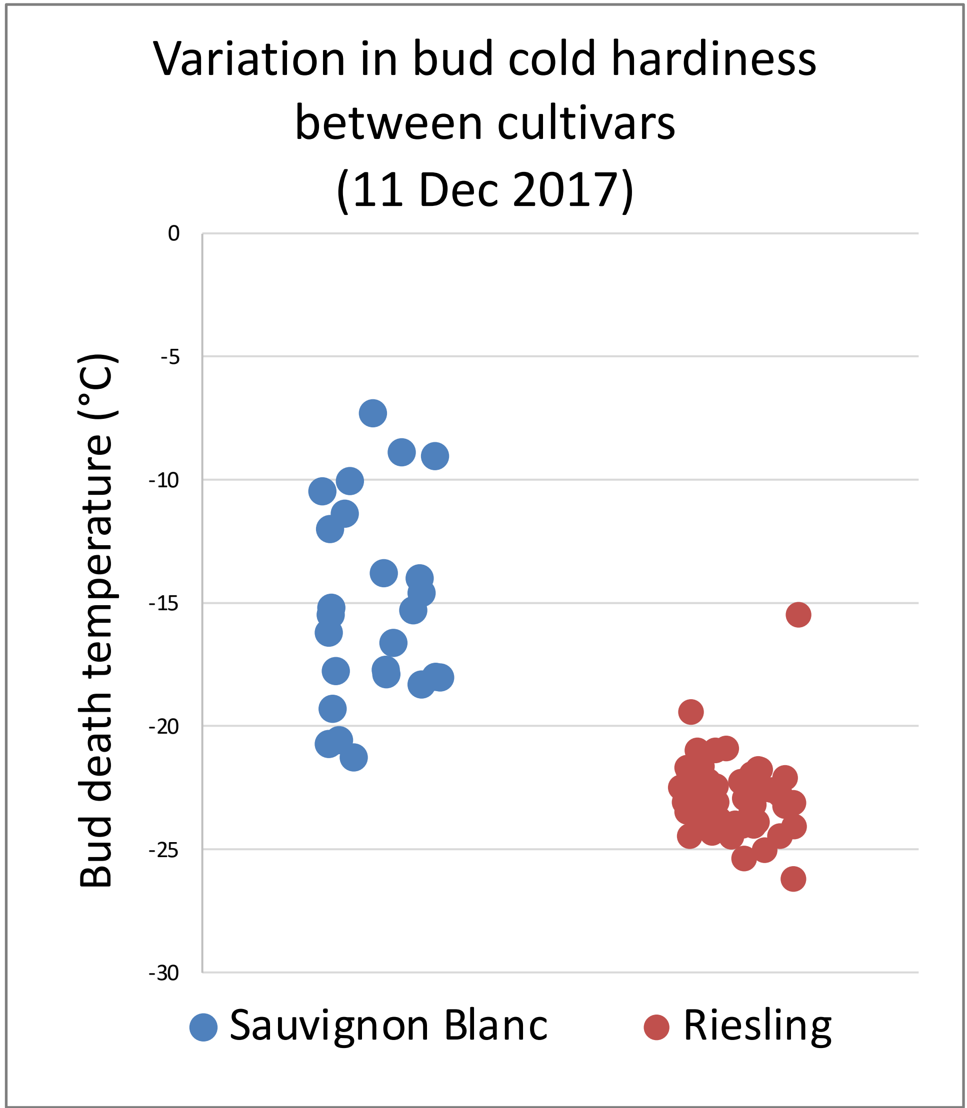
Cultivar comparison within a site

Hébert-Haché et al. (2021) Am J. Enol. Vitic.



- **The uniformity of bud hardiness can greatly vary between cultivars**
- **Contributes to the susceptibility of Sauvignon blanc to cold temperatures**





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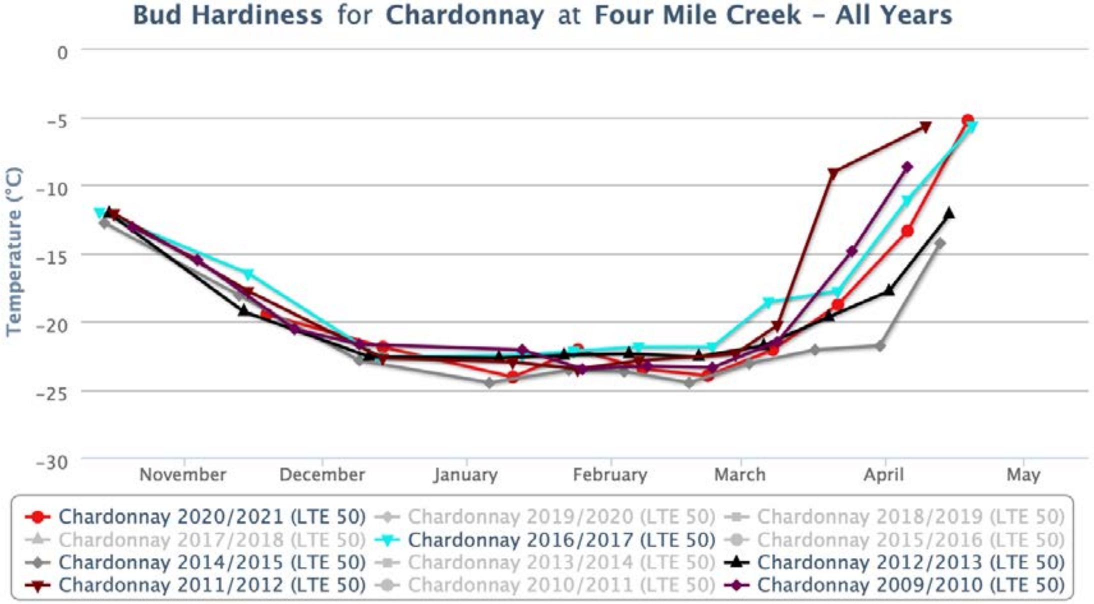
Rates of cold acclimation and deacclimation

- **Both genotype and environment can impact both acclimation and deacclimation**
- **Cultural practices and growing season have been shown to impact acclimation**

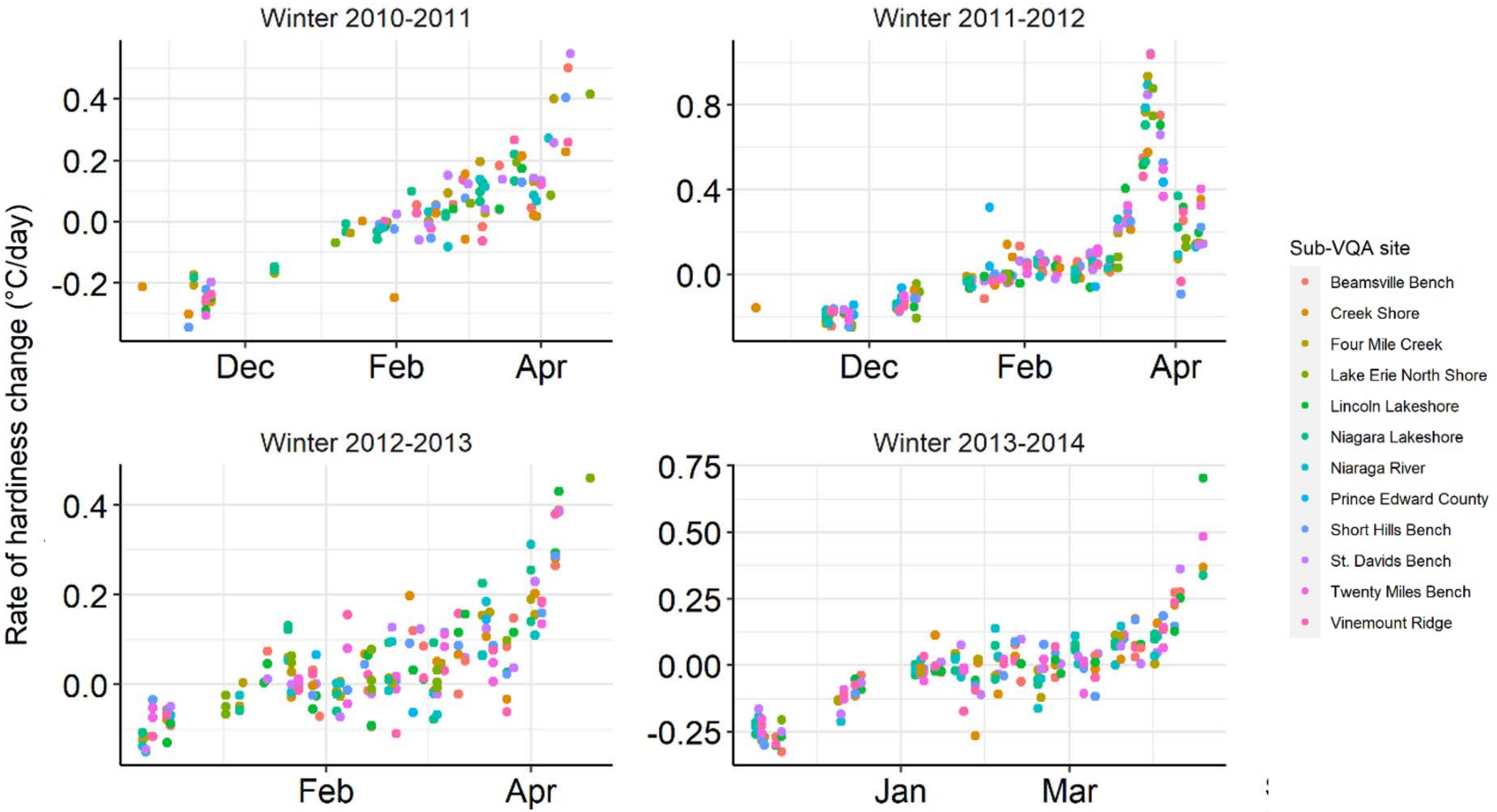


Let's examine how different years can impact one of the core varieties grown in Ontario

Rates of hardiness change/day for Chardonnay

Dormant periods 2010-14

Hébert-Haché, 2023



Rates of hardiness change/day for Chardonnay over different winters. Each color is assigned to a different VQA appellation/sub-appellation. Rates of hardiness change was calculated for every sampling date, by subtracting the mean hardiness on one day to the mean hardiness on the previous day and dividing it by the number of days between sampling dates.

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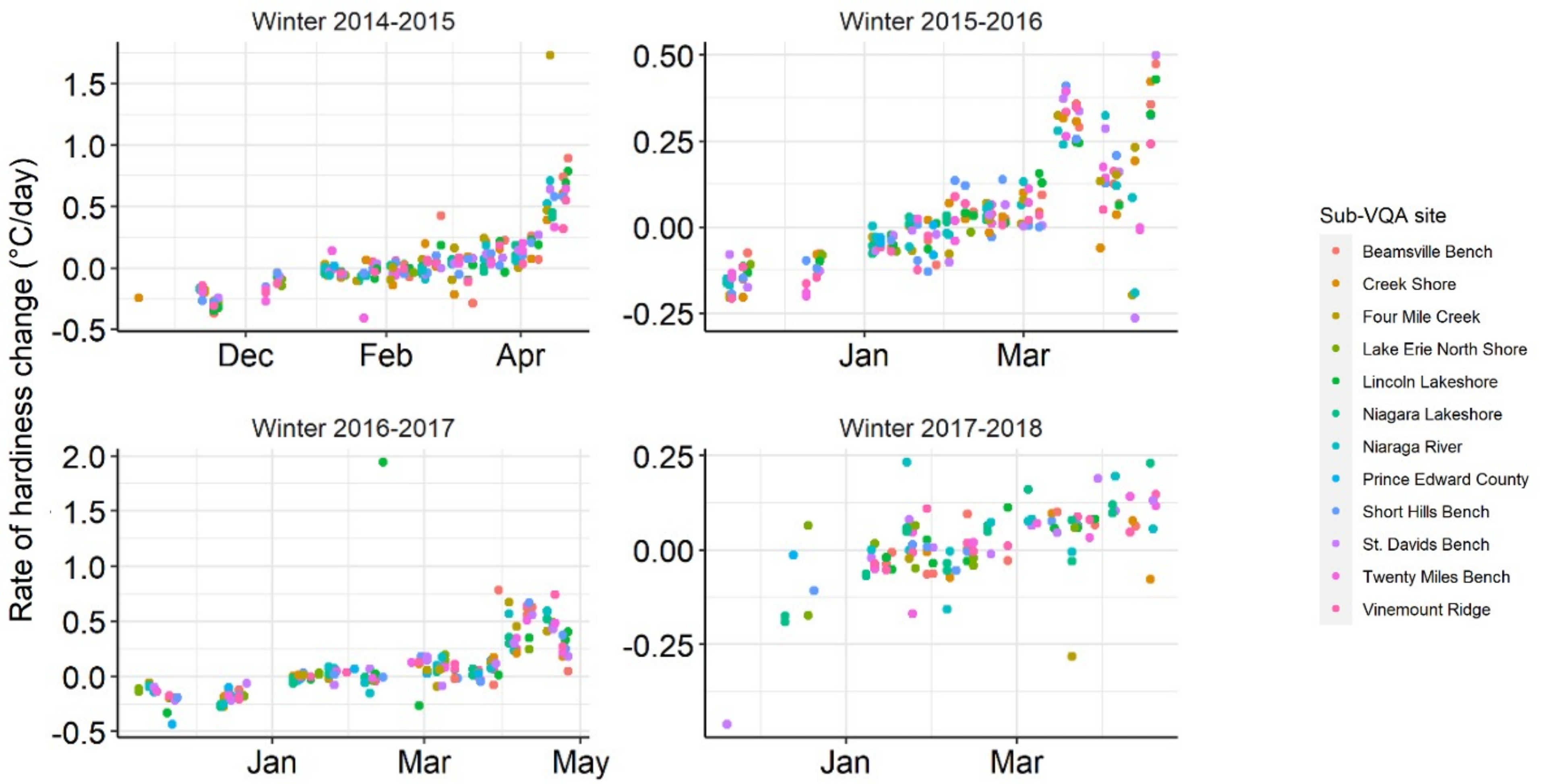
Rates of hardiness change/day for Chardonnay

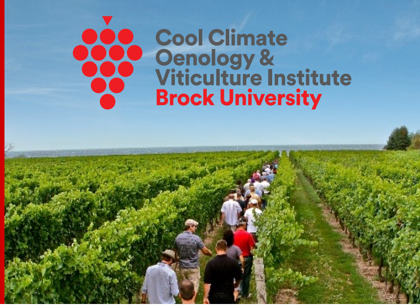
Dormant periods 2014-18

Hébert-Haché, 2023



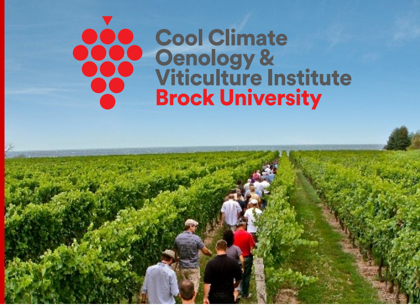
Rates of hardiness change/day for Chardonnay over different winters. Each color is assigned to a different VQA appellation/sub-appellation. Rates of hardiness change was calculated for every sampling date, by subtracting the mean hardiness on one day to the mean hardiness on the previous day and dividing it by the number of days between sampling dates.

Acclimation and deacclimation

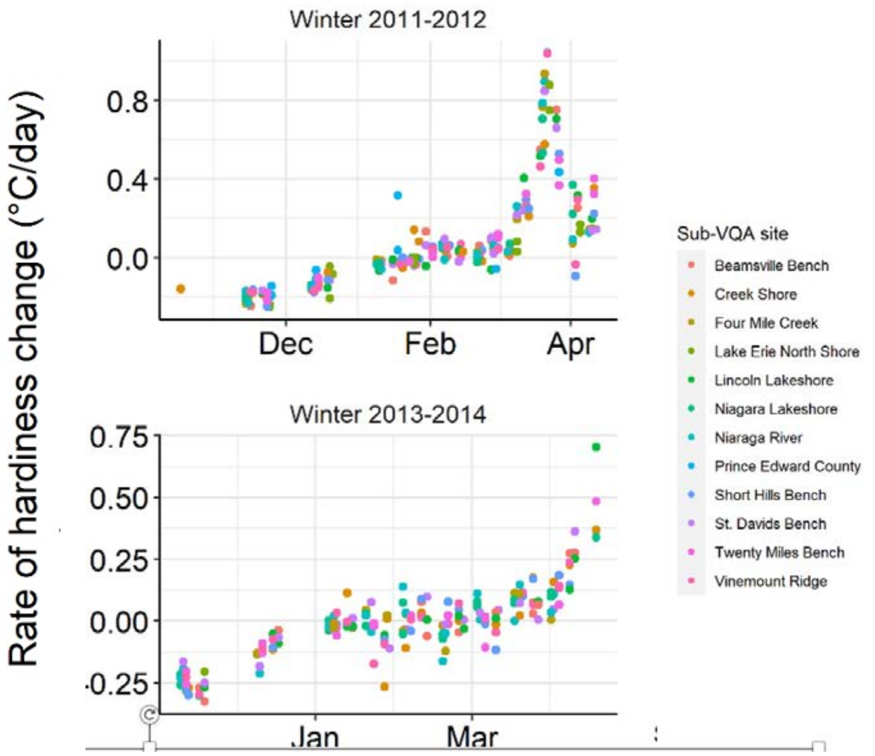


- **Cultivar, site and season can impact rates of acclimation and deacclimation**
- **Acclimation rates are highly impacted by growing season factors**
  - Weather
  - Crop levels and fruit maturation
  - Overall vine health (i.e. previous winter damage)
- **Genetics play the biggest role with maximum hardiness**
  - Temperature can impact this
  - Crop level and maturity can also limit the tolerance of the vine
- **Deacclimation is highly driven by temperature and winter conditions**
  - Genotype can impact rates
  - Site differences can play a larger role in some years

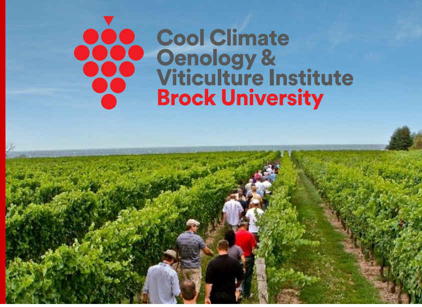
Implications



- **Cold winters with frozen ground will keep vines more cold hardy and maintain dormancy**
- **What about warm winters with great periods of volatility?**
  - Vines may not maintain hardiness
  - Increase risk of freeze injury later in winter
  - Greater consequences if combined with issues such as:
    - Heat or drought stress
    - Excessive rain during maturation
    - Virus/plant health status



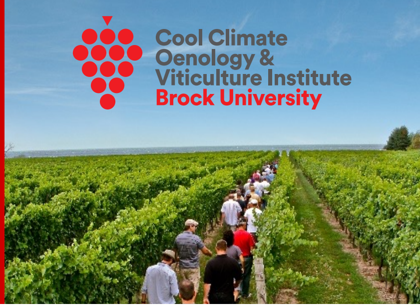
Extraordinary benefits of 10+ years of cold hardiness monitoring



- **The benefits of cold hardiness evaluation over 10+ years are plentiful**
  - Development of freeze mitigation strategies such as VineAlert to protect the crop and save the entire grape and wine sector enormous loses
- **Understanding of how grapevines respond to different growing seasons, winters, cultural practices, etc.**
- **Freeze injury and how and when it occurs**
- **Freeze mitigation practices and implications (i.e. wind machines, geotextiles, vine burial)**

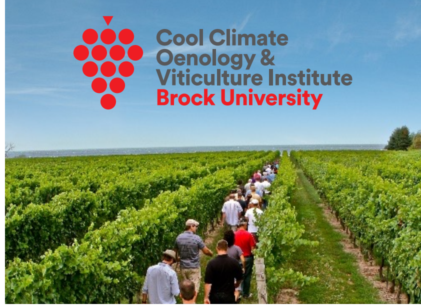
How did VineAlert help Ontario?

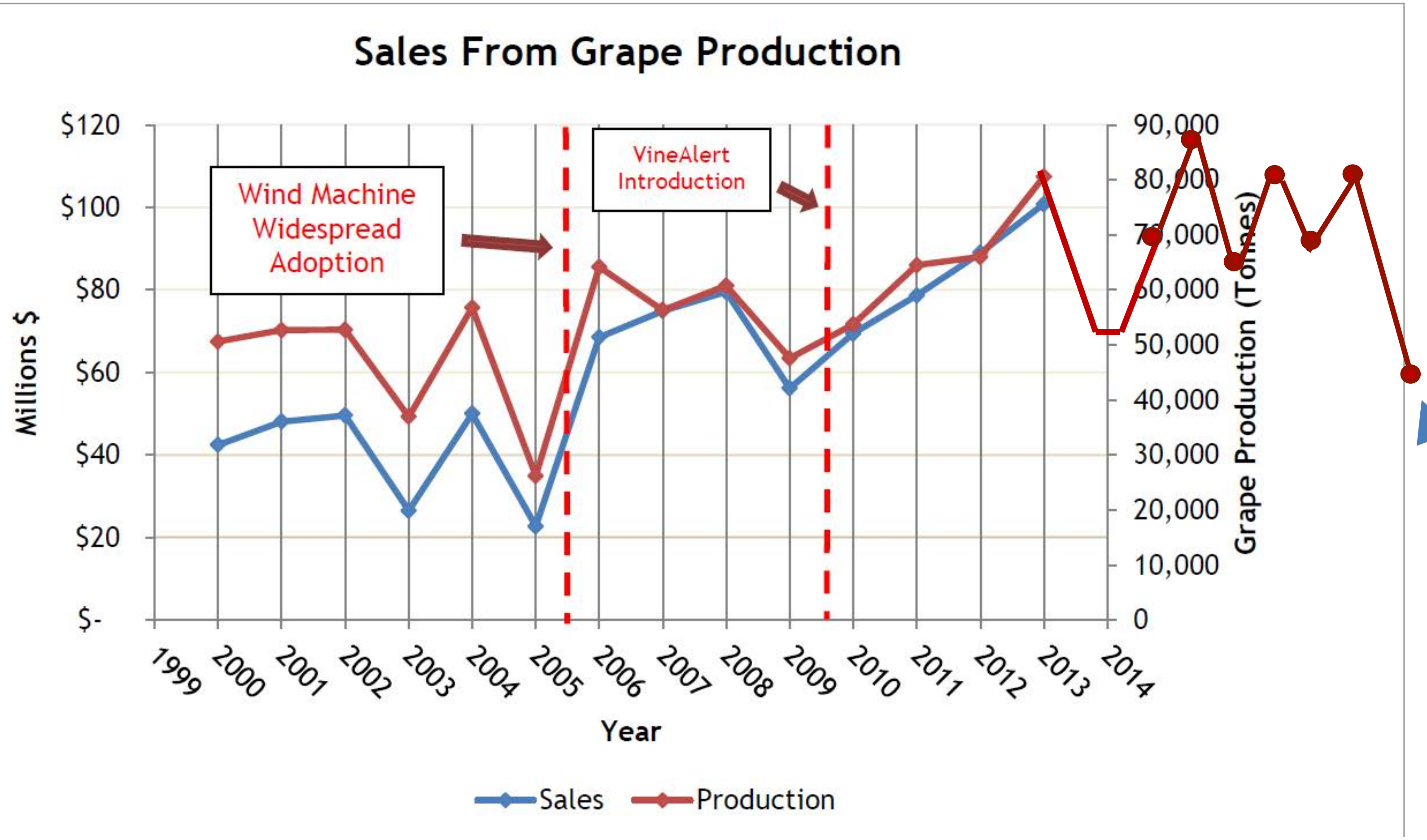
Economic analysis of VineAlert, Goodman School of Business, 2014



Saved crops in many winters at different times of the dormancy	$13.8 Million in first year and $11.7 Million in subsequent years
Reduced wind machine usage	Close to $2 Million/year in savings
Saved growers from renewing or replacing vines	$29.1 Million over 5 years in savings • Improved farmer/neighbour relations • Helped educate community and government about freeze risks and protection

Grape Tonnage and Sales in Ontario (1999-2022)
(Economic analysis of VineAlert, Goodman School of Business, 2014 and Grape Growers of Ontario Annual reports (2000-2023)





VineAlert program did not run this year

Freeze injury and how and when it occurs

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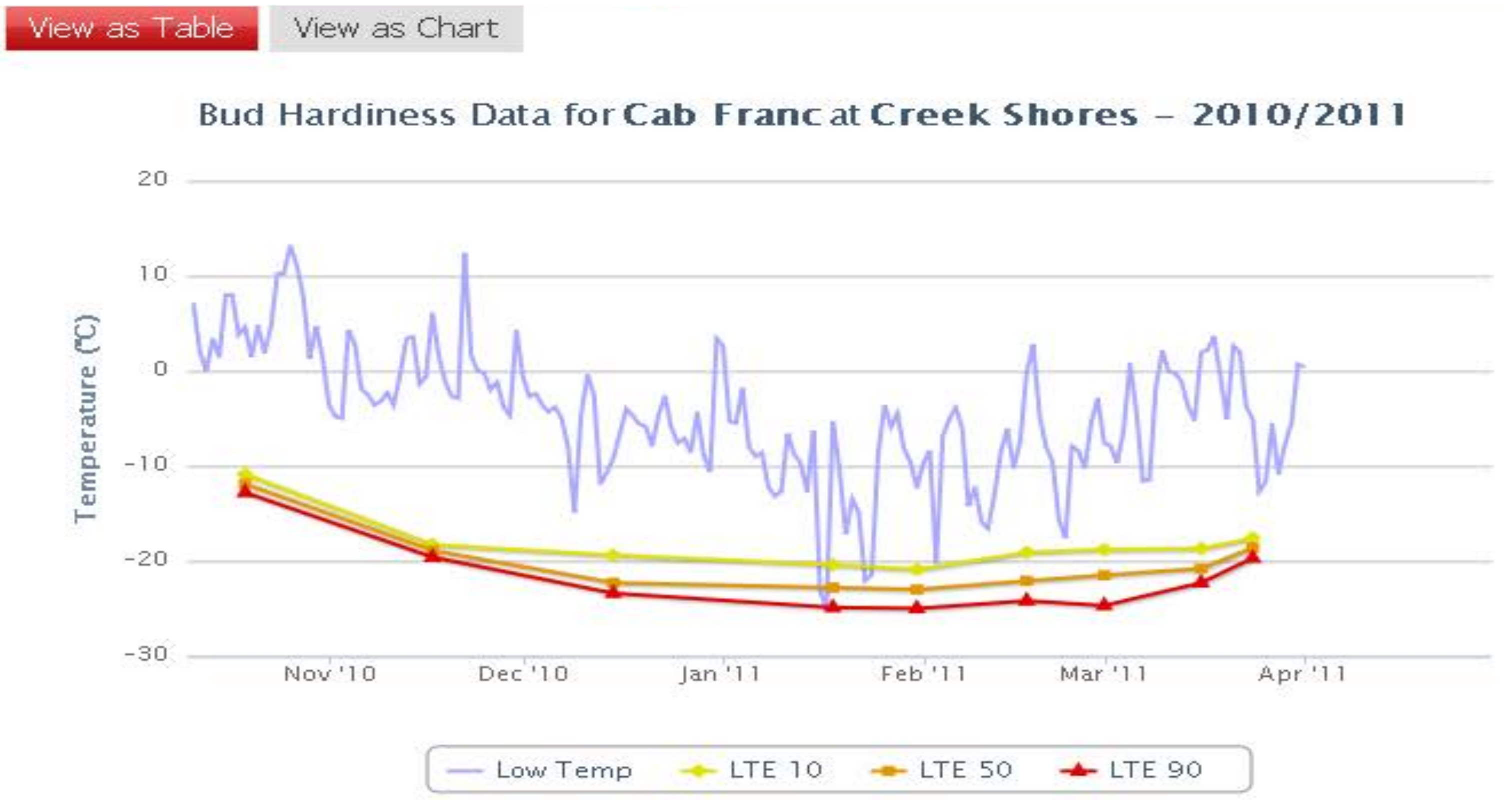
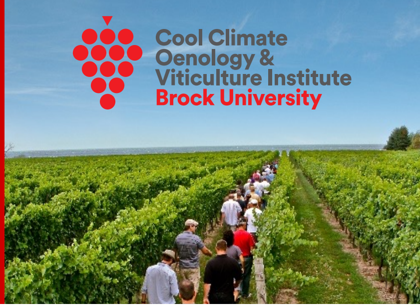


NOTE: Due to the geographic diversity of this region, winter low temperatures can differ considerably at different locations within the same appellation. The weather data displayed is courtesy of Weather Innovations Incorporated - Weather Station in St. Catharines Third Ave - Located on the north side of 3rd

Understanding of how grapevines respond to different growing seasons, winters, cultural practices, etc.



Merlot vines: 1 cluster/shoot and earlier harvest

Merlot vines: 2 clusters/shoot and delayed harvest

Freeze mitigation practices and implications (i.e. wind machines, geotextiles, vine burial)

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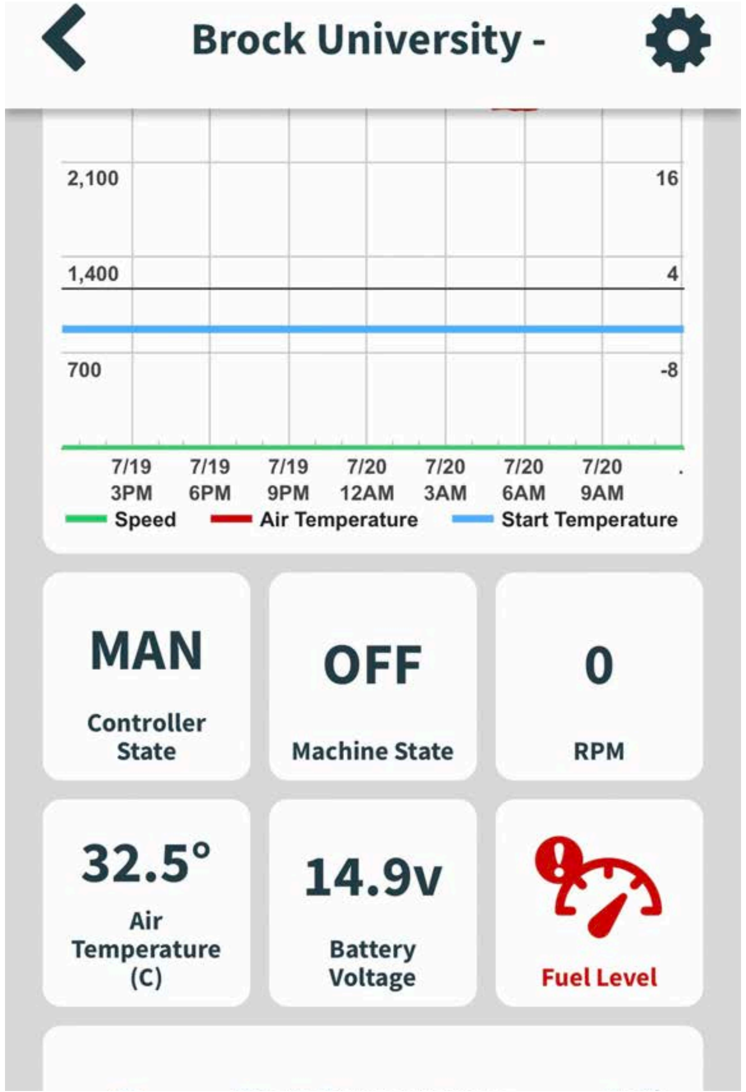
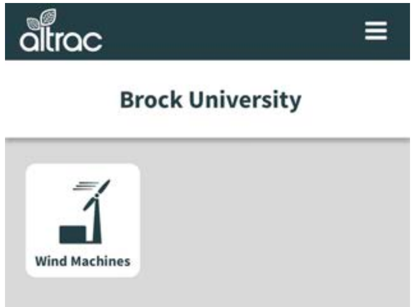
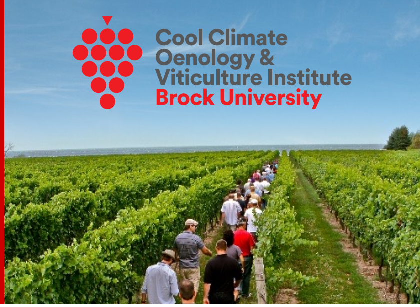
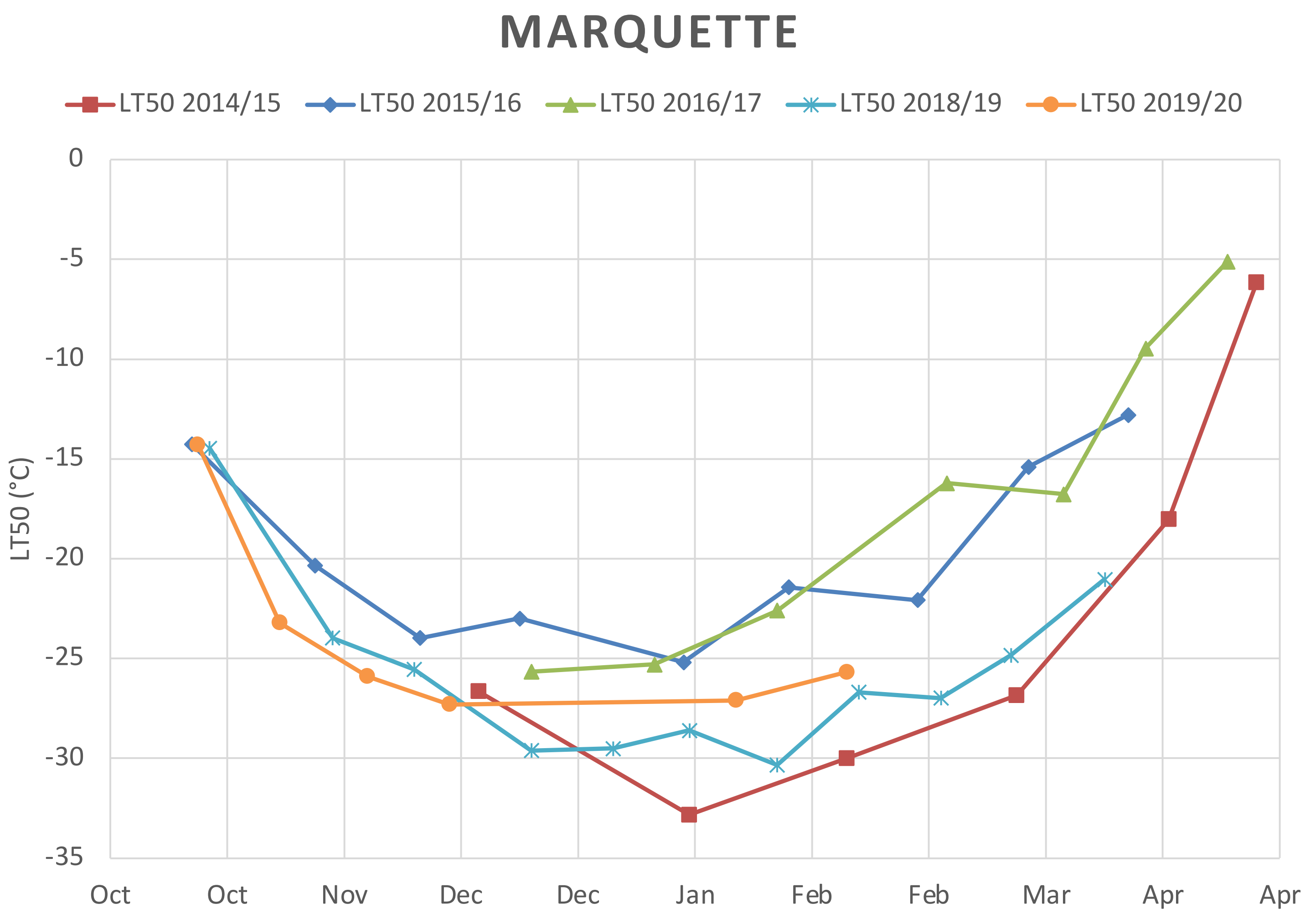




Cultivars for Ontario
V. vinifera vs hybrid cultivars, alternative varieties





Merlot Kanthus

Clones

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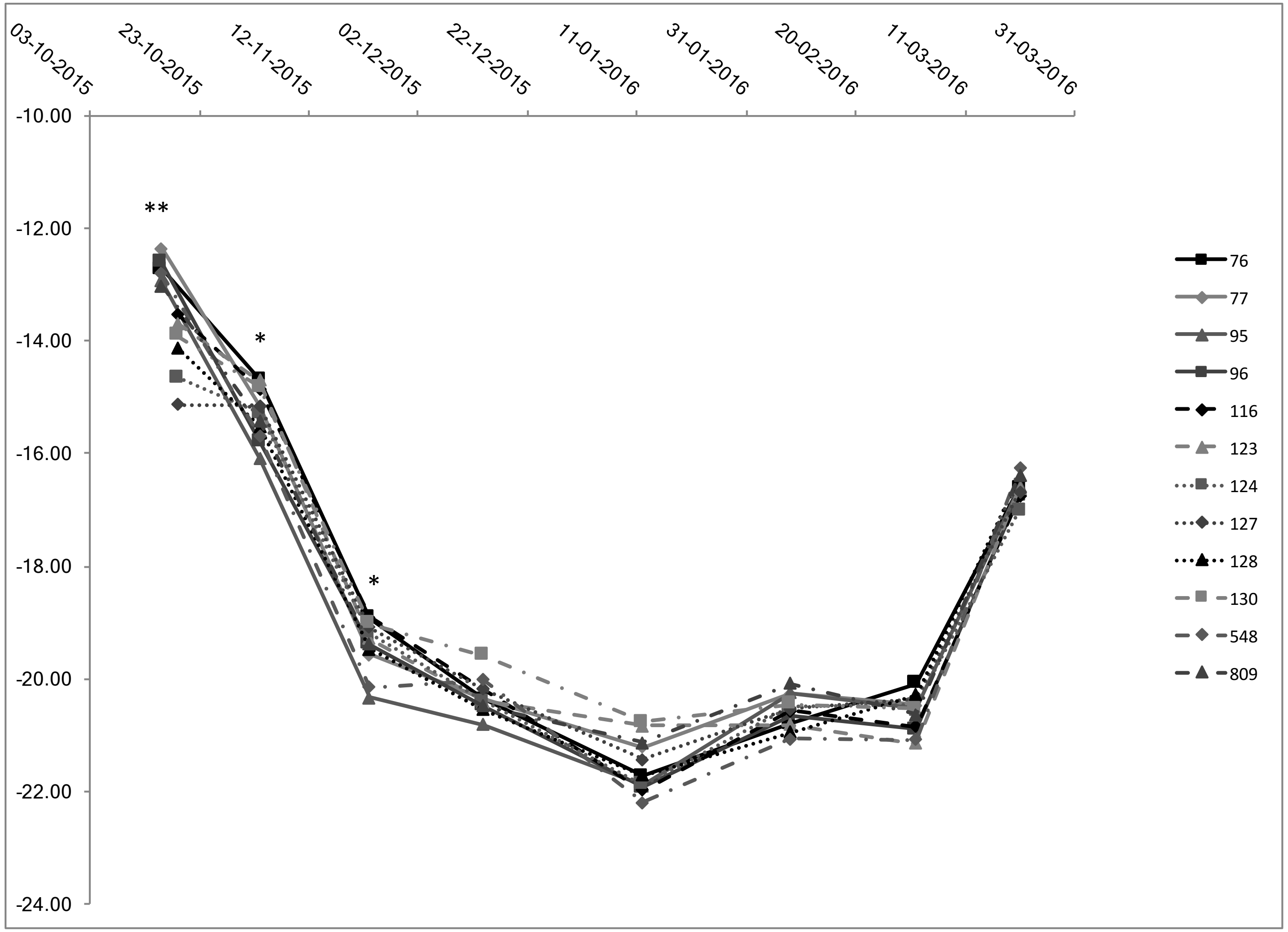
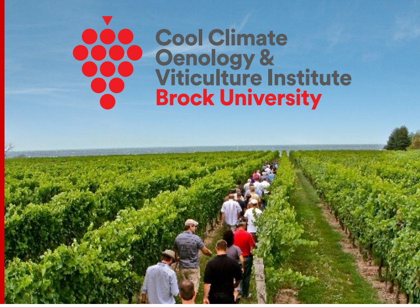
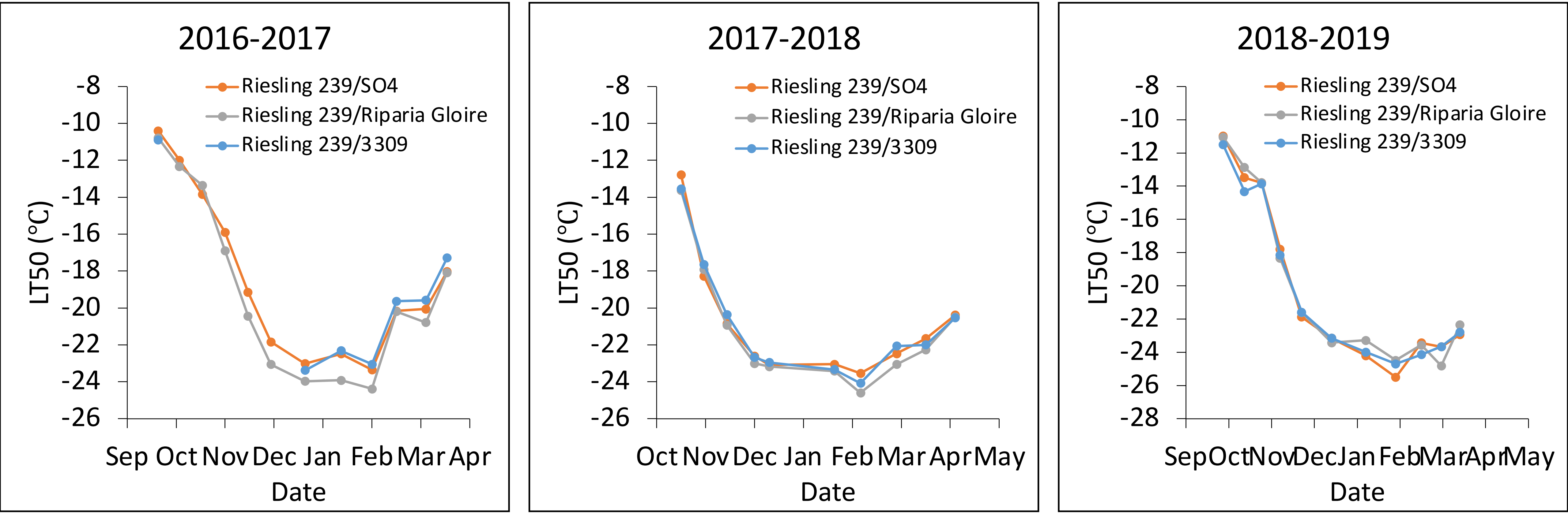


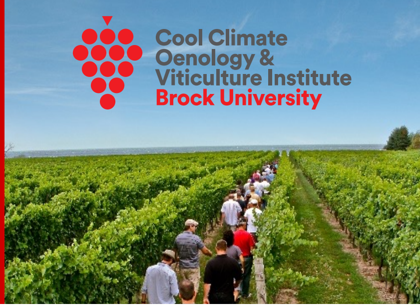
Bud hardiness of 12 Chardonnay clones during dormancy. St. David's Bench. 2015-16.



Rootstocks



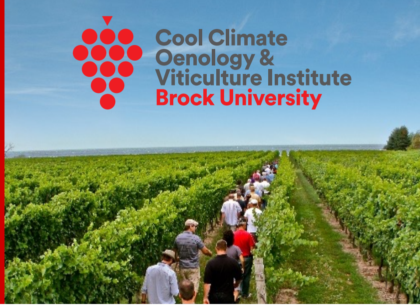
Hébert-Haché A., Inglis. D., Kemp, B. and Willwerth, J. (2021). Clone and rootstock interactions influence the cold hardiness of *Vitis vinifera* cvs. Riesling and Sauvignon blanc. Am. J. Enol. Vitic. 72: 126-136



Building resiliency in cool climate viticulture

- **Not one simple solution to deal with complex challenges that climate change brings**
- **Plant material and matching clean vines with the proper clone x cultivar x rootstock is critical**
  - Not every site will have the same fit
- **Tools in the tool box**
  - Different freeze mitigation and management strategies in general
  - Plant growth regulators such as Abscisic acid analogs

The past 13 years of cold hardiness monitoring and research will help pave the way to the future



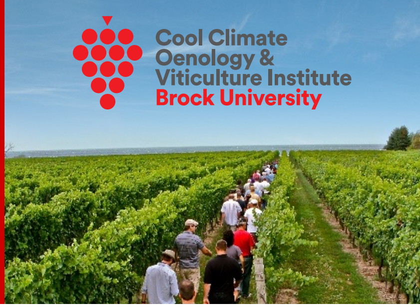
- We have learned so much about a complex trait and how different genotypes respond to different environmental conditions
- It has advanced our understanding of cold hardiness and develop better practices to mitigate freeze injury
- It has advanced our fundamental understanding of hardiness
- Cultivar, clone x rootstock evaluation have been established based on freeze injury and hardiness difference and these will continue and expand
- New cold hardiness promoters have been identified and may help reduce early deacclimation
- SCAP funding – "Selection of superior grapevine material using traditional field evaluations and genomic/metabolic signatures for cold resilience"

The future at CCOVI and Brock….

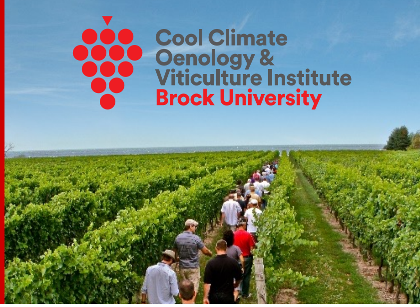
Clean Agriculture for Sustainable Production (CASP) Field Infrastructure

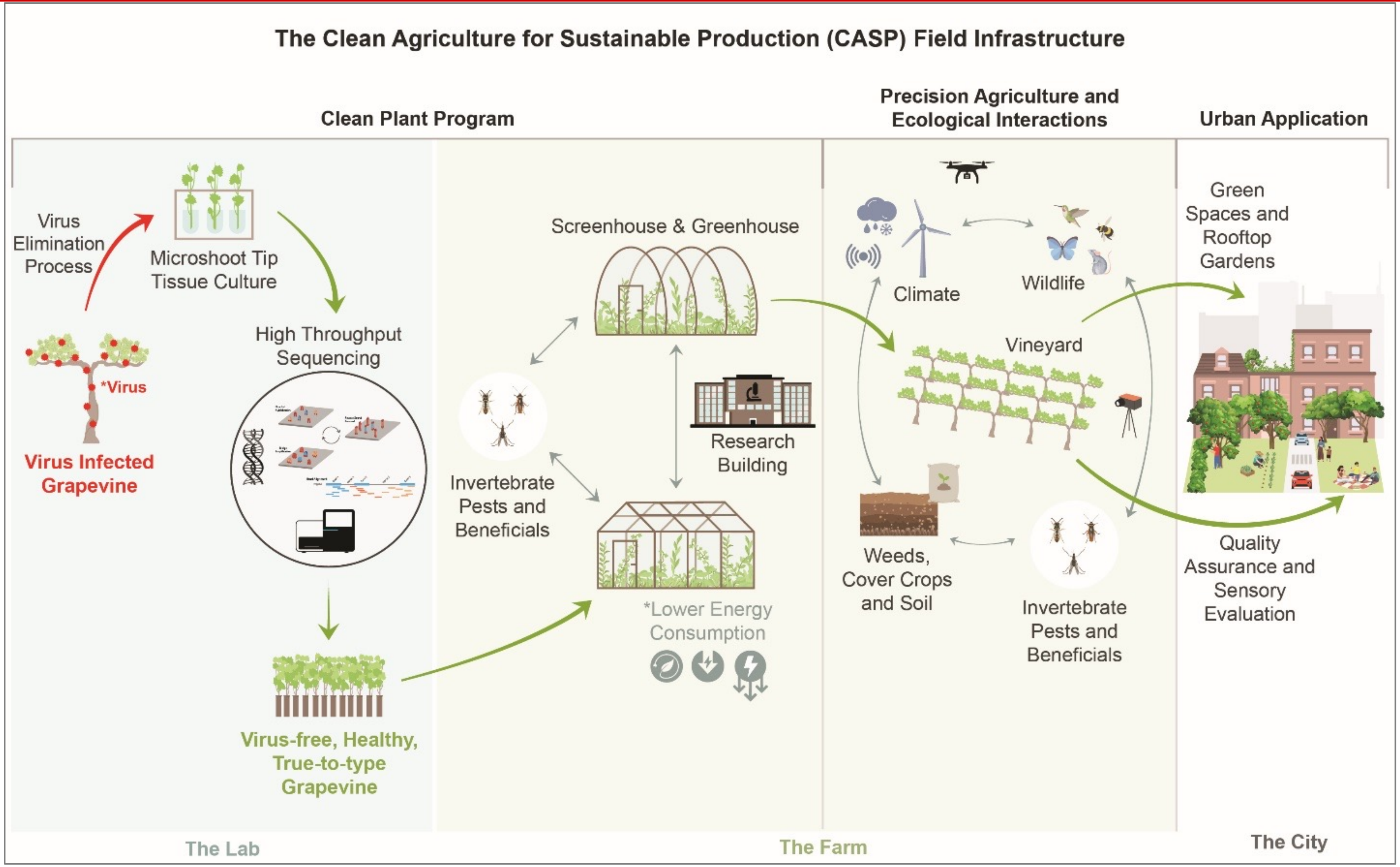
Cool Climate Oenology & Viticulture Institute
Brock University

$8.91M investment from Canada Foundation for Innovation (CFI), Ontario Research Fund (ORF) and Brock University

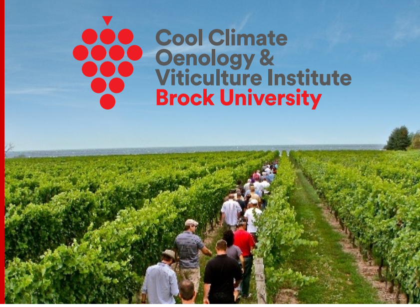


CASP Field Infrastructure at Brock University supporting clean plant program, precision agriculture, ecological interactions, and urban applications





And thanks to our funding and industry partners



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Grape Growers of Ontario

Ontario Grape & Wine Research Incorporated

WIN
Weather INnovations Incorporated

KCMS

NSERC
CRSNG

Canadian Grapevine Certification Network
CGCN-RCCV
Réseau Canadien de Certification de la Vigne

Ontario
Research Fund

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

BCS
Brewster Consulting Services Inc

Trius
Winery

Château des Charmes

Schenck
Farms & Greenhouses

Ziraldo

Canadian Agricultural Partnership

Cave Spring
Vineyard

Huebel Grapes Estates
Custom Farming · Custom Harvesting · GPS Planting

Arterra
Wines Canada