Improving resiliency in grapevines to avoid freeze damage in a changing climate

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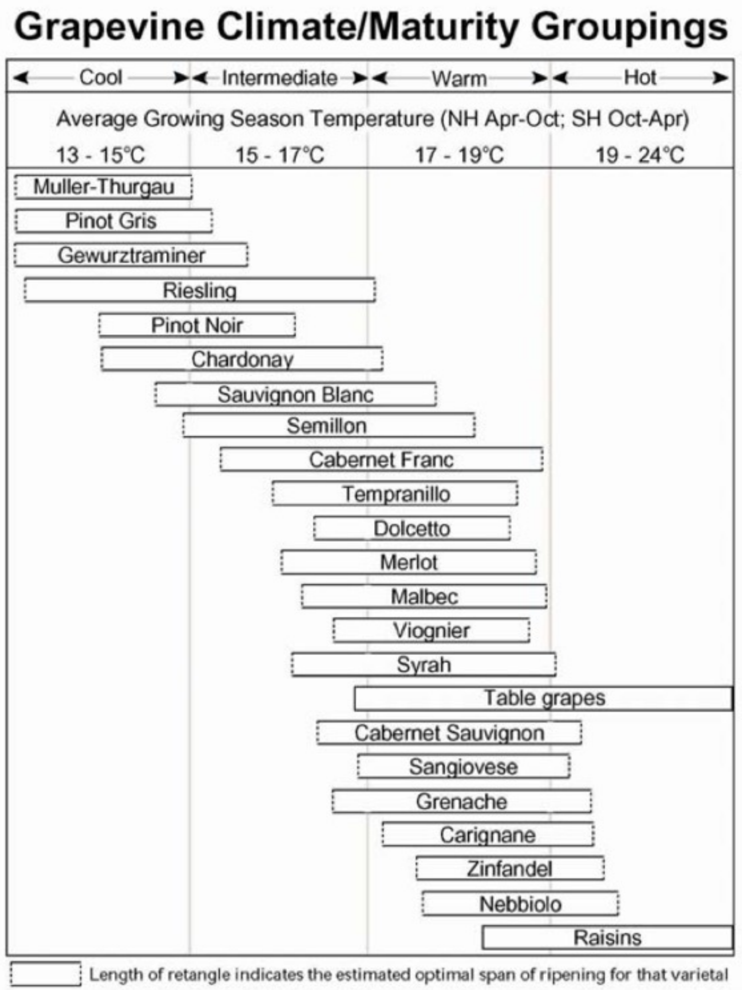
Cool climate viticulture and a changing climate

- Our cool climate regions are diverse
  - Growing seasons vary and can be short
  - Wide range of soils (type, fertility, drainage, depth can vary greatly)
  - Precipitation timing and events vary both regionally and seasonally
  - Limiting winter temperatures vary and can be extreme
  - Extremes can swing from one season to the next
    - Drought conditions, extreme cold, high rainfall, volatility
  - Some irrigation

- Climate change may move the goal posts with GDD, growing seasons and winter temperatures but weather volatility and extremes may increase

Climate requirements for grapes

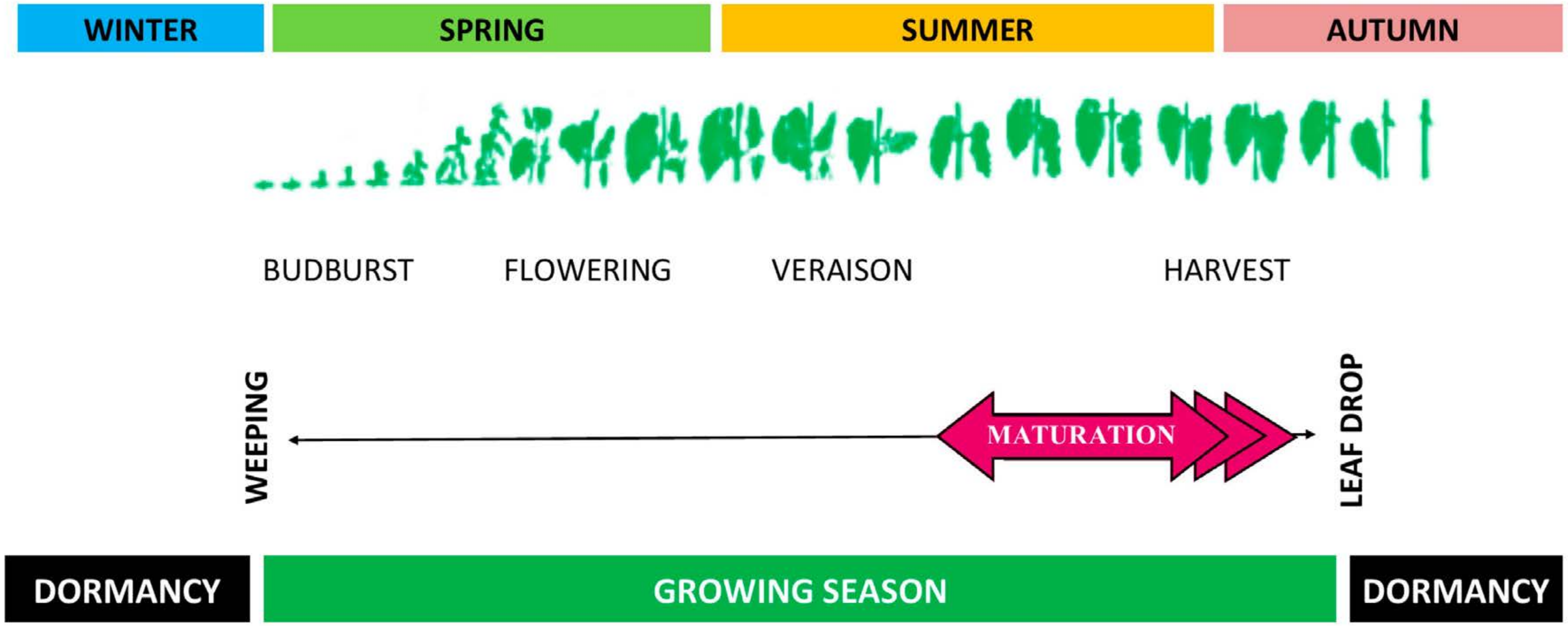
- Grape cultivars have specific climate requirements
- Min. winter temps, growing season temps and length
- Some cultivars more versatile than some other cultivars



igure 1. The climate-maturity groupings given in this figure are based on relationships between phenological requirements nd climate for high to premium quality wine production in the world's benchmark regions for each variety. The dashed line t the end of the bars indicates that some adjustments may occur as more data become available, but changes of more than +/- 0.2-0.6°C are highly unlikely. The figure and the research behind it are a work in progress (Jones, 2006).

What happens when climate changes?

- Changes in climate can impact wine grapes through changes in growth and development, fruit maturation and fruit composition
- We can taste these impacts in wine grapes because wines have yearly “vintage effects” from year-to-year variations that impact yield, quality and typicity.
- Vintage effects are variations from the ”average” growing season but what happens with consistent trends of warming or extreme weather (i.e. climate change)?



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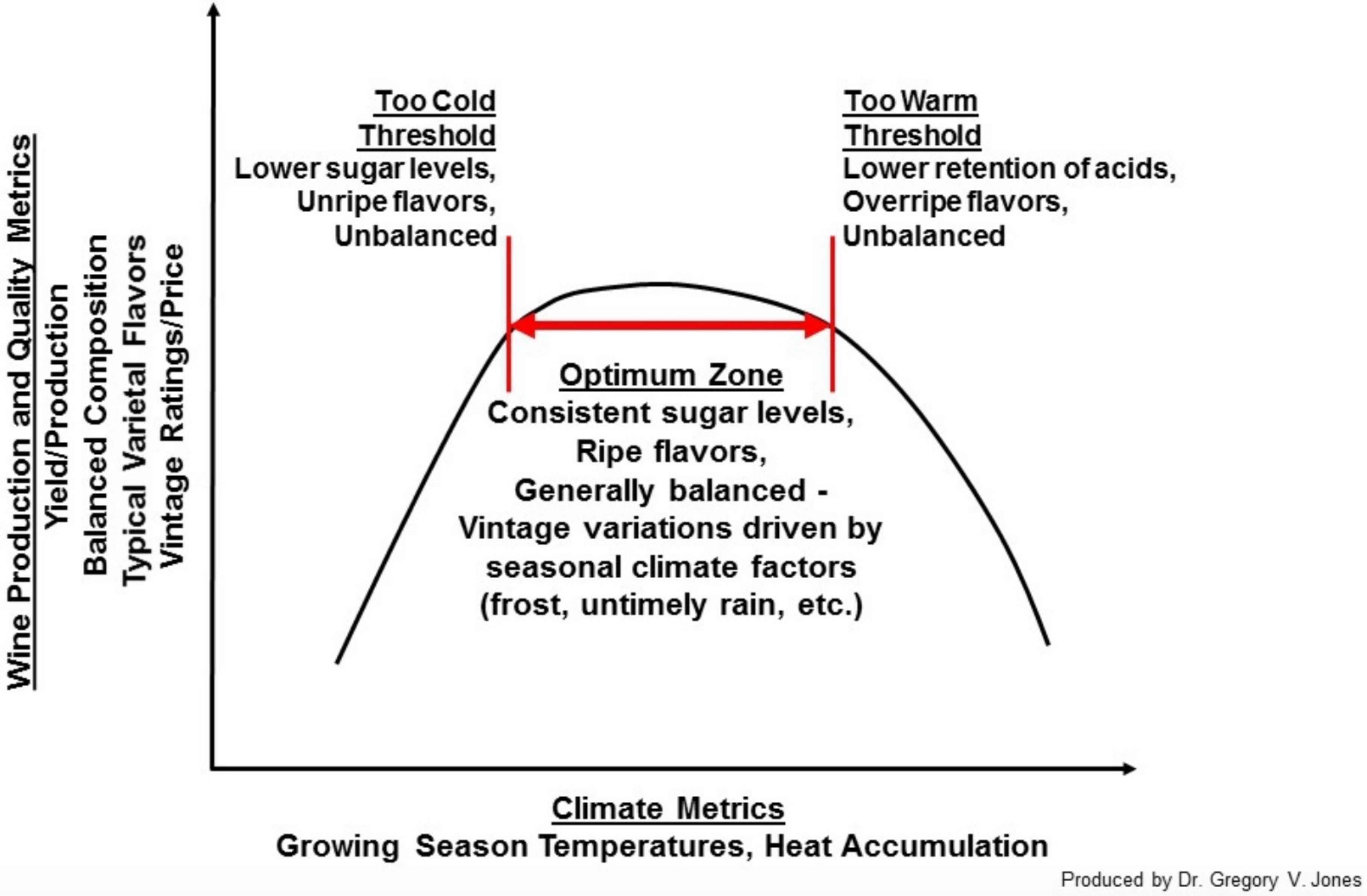
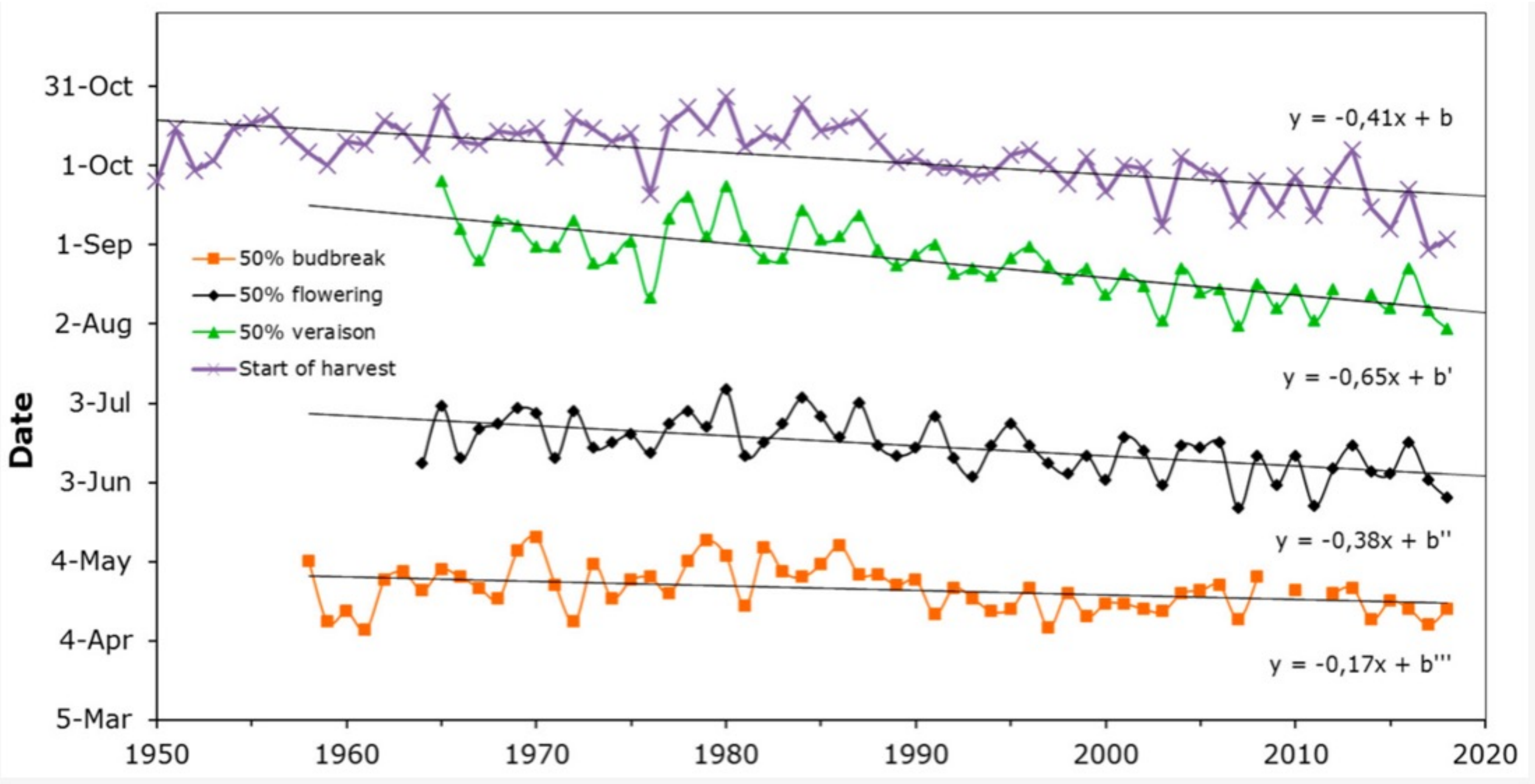


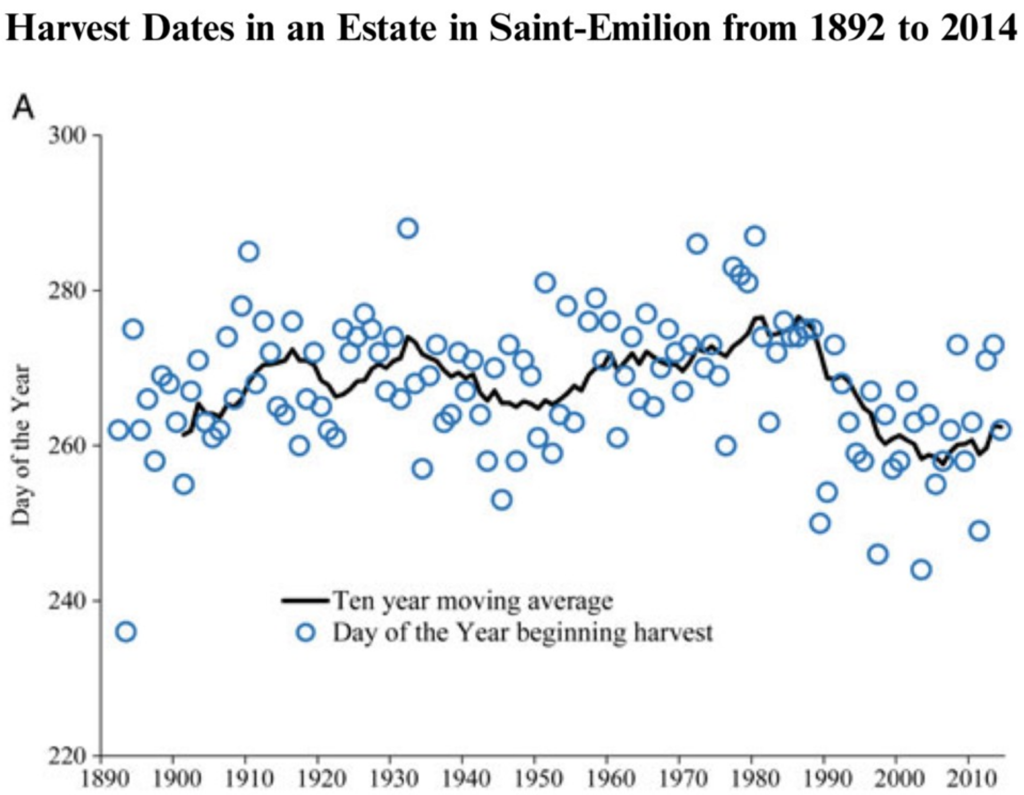
Wine Production and Quality Metrics
Yield/Production
Balanced Composition
Typical Varietal Flavors
Vintage Ratings/Price
Too Cold Threshold
Lower sugar levels,
Unripe flavors,
Unbalanced
Too Warm Threshold
Lower retention of acids,
Overripe flavors,
Unbalanced
Optimum Zone
Consistent sugar levels,
Ripe flavors,
Generally balanced -
Vintage variations driven by
seasonal climate factors
(frost, untimely rain, etc.)
Climate Metrics
Growing Season Temperatures, Heat Accumulation
Produced by Dr. Gregory V. Jones

Long-term evolution of vine phenology for Riesling in Alsace. Data source: budbreak, flowering and veraison adapted from Duchêne and Schneider (2005); harvest dates from Conseil Interprofessionnel des Vins d'Alsace (CIVA) (van Leeuwen et al. 2019)



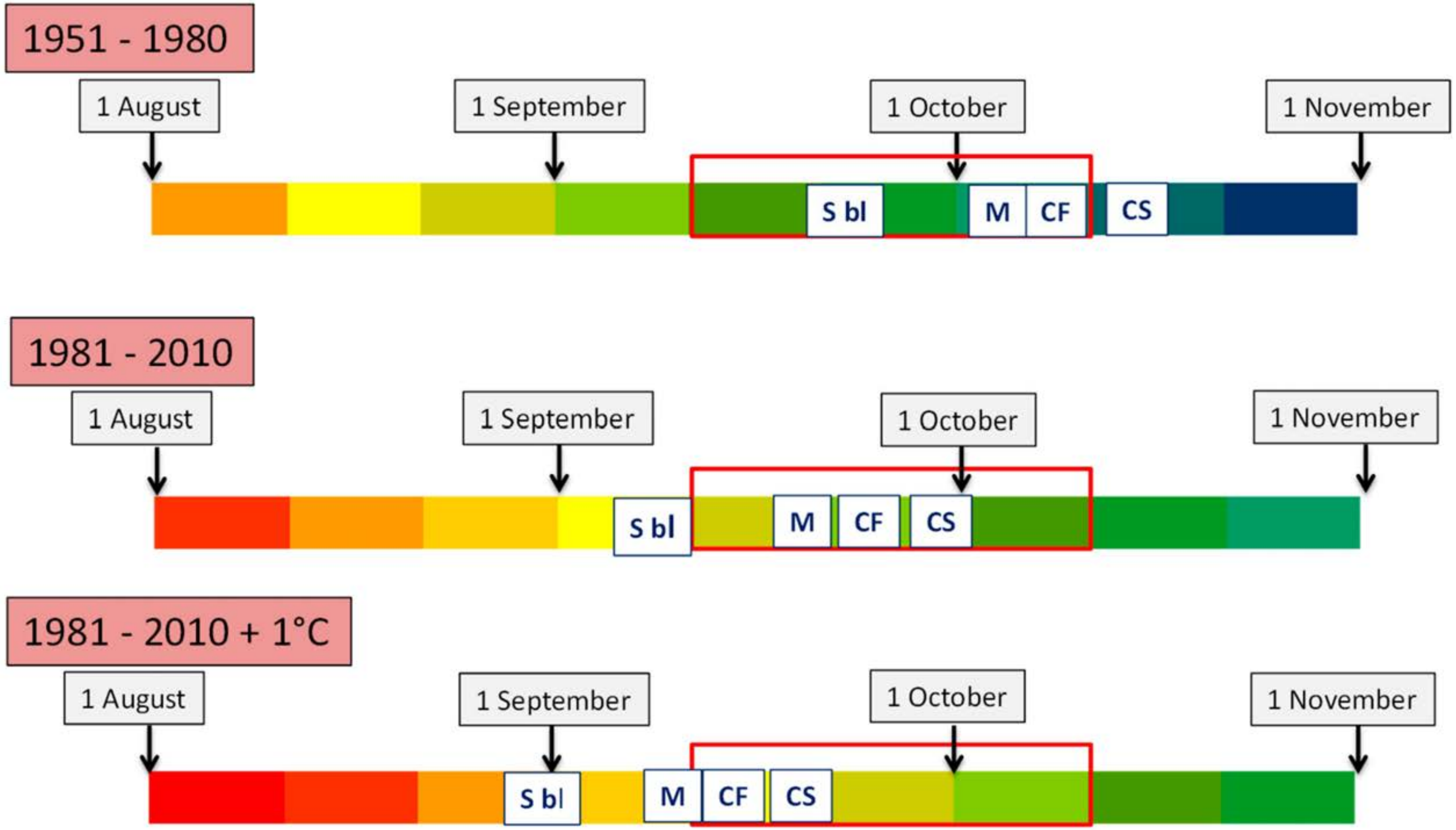
Timing of harvest

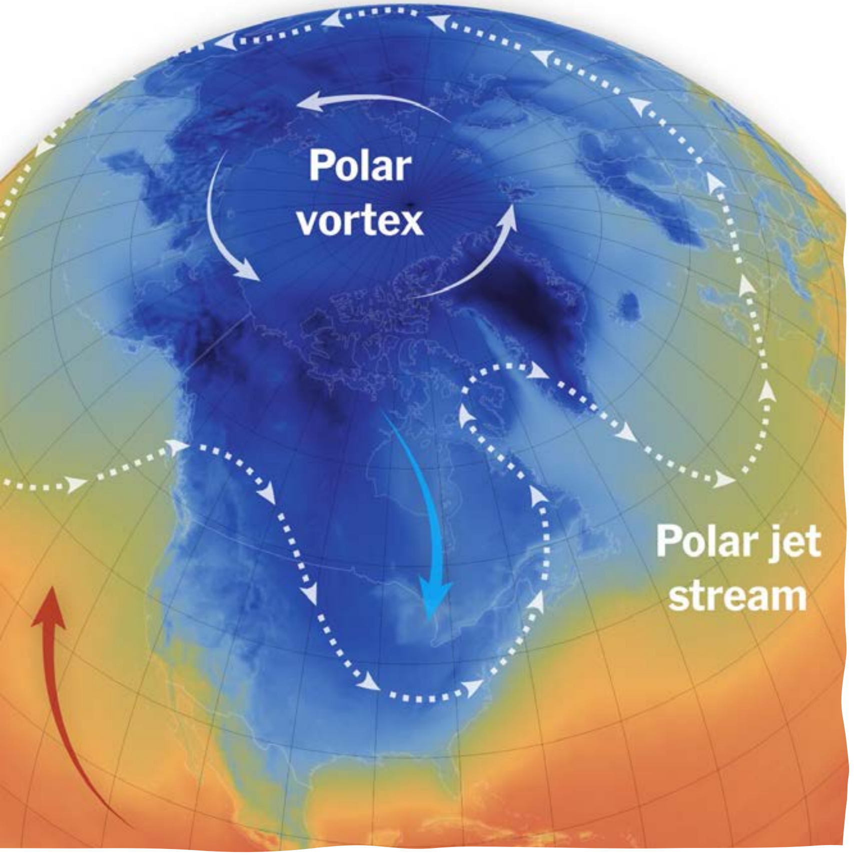
(van Leeuwen and Darriet 2016)

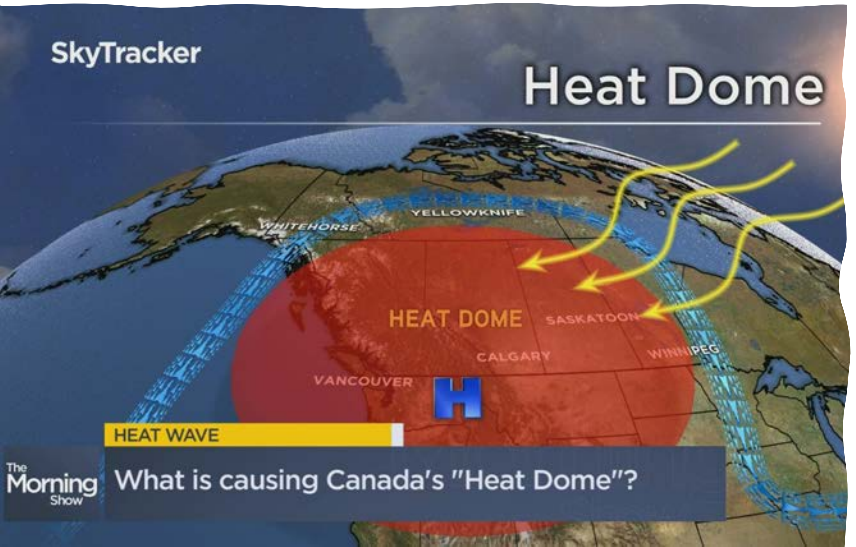


Source: ONERC, 2014.

Modelled harvest dates for Sauvignon blanc (S bl), Merlot (M), Cabernet franc (CF), and Cabernet-Sauvignon (CS) in Bordeaux for the following periods: 1951–1980, 1981–2010, and 1981–2010 + 1 °C. *Warm colors indicate higher temperatures and cold colors cooler temperatures.* (Van Leeuwen et al. 2019)







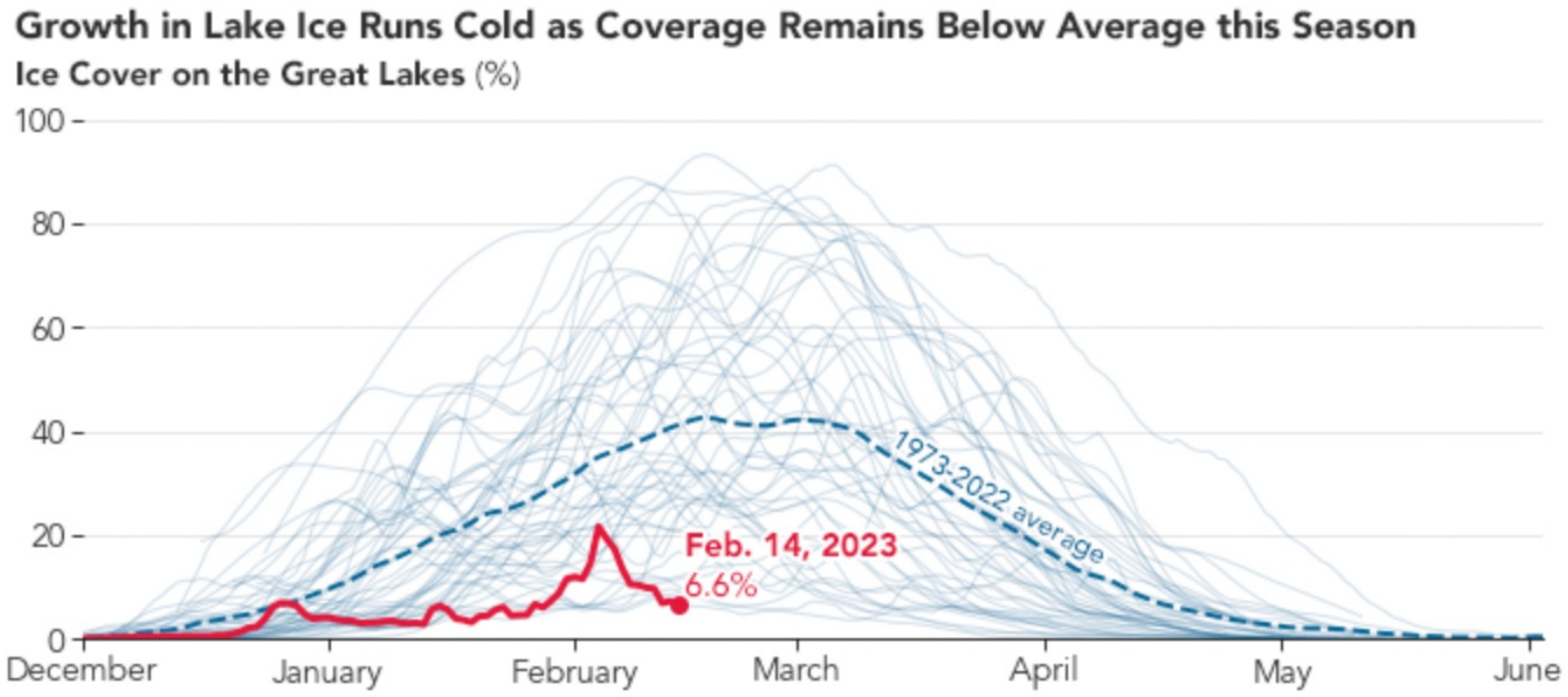
Climate change and grape growing in Canada

- Studies indicate a:
  - Rise of the average temperature
  - More heat waves and days with >30°C
  - Higher drought incidence
  - Reduced snow cover and increased rainfall in winter
  - More extreme weather events

  - We farm extremes and weather has a significant impact on production

The Great Lakes play a key role in our cool climate region and mitigating climate extremes but are changing with our climate.

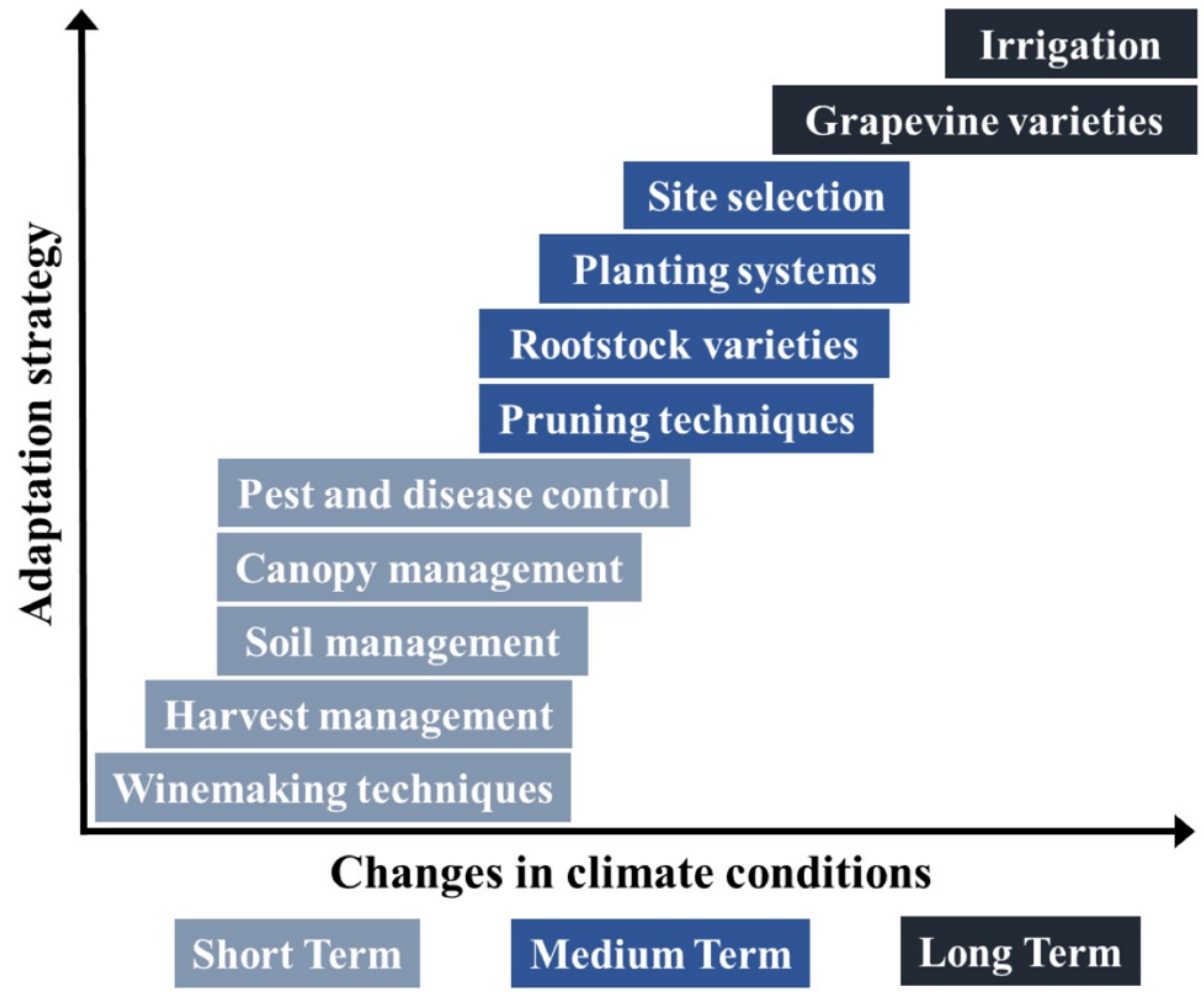
Lake Ice coverage (1973-2023) NOAA 2023



1973 - 2023

Adaptation strategies in viticulture

- Training systems and Canopy management
- Cultural practices and freeze mitigation strategies
- Irrigation
- Expansion of regions
- Plant material
  - Selection, breeding, evaluation of material



Adaptation strategies in viticulture

Quénol et al. 2016

Plant material

- The selection of plant material is an important resource for climate adaptation

- Species or crossings of different species
- Cultivar
- Clone
- Rootstock
- Quality of material

Cultivars are very diverse

- Grapevines are diverse
  - 60 species of *Vitis*
  - Roughly 14,000 cultivars of *V. vinifera* and 1000's of synonyms
  - Intravarietal diversity (clones and ecotypes within major cultivars)
- Differ with respect to:
  - growing season requirements
  - drought tolerance
  - chilling requirements, cold acclimation/deacclimation and max hardiness
  - fruit maturation
  - growth habits, etc.
- Changes in environment will impact how they perform

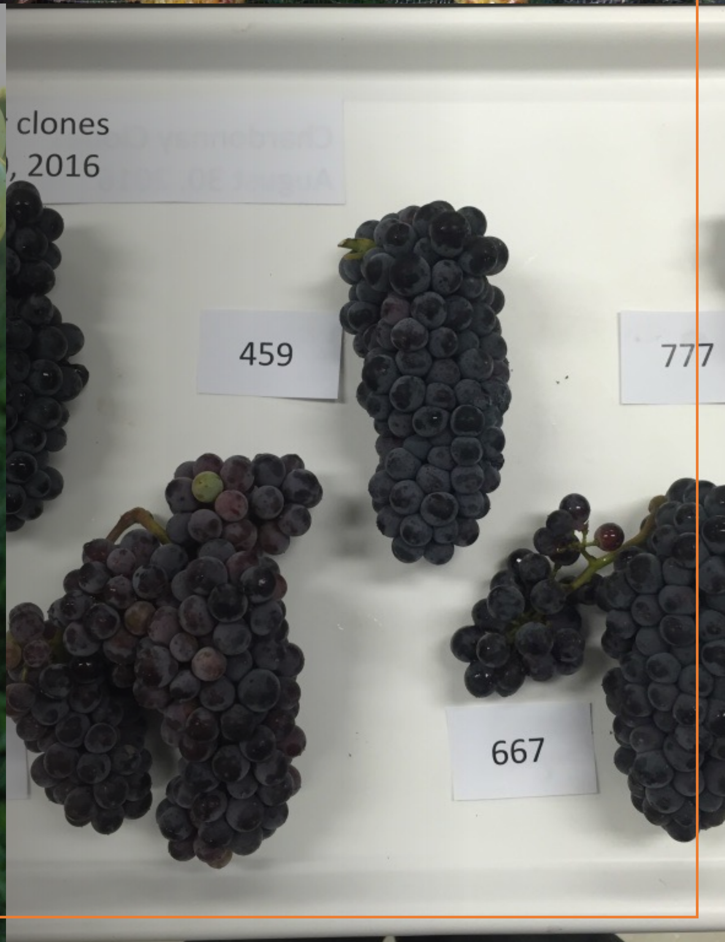
Rootstock benefits

- Resistance
  - Phylloxera, nematodes
- Tolerance
  - Lime, Salinity, Water stress
- Growth
  - Control, shorten vegetative cycle
- Uptake
  - Nutrients

Clones

Clonal selection

- Earlier or later maturing
- Growth habit
- Colour and Flavour
- Cluster morphology, berry size
- Disease
- Cold tolerance



Quality of material

- Important for quality, general performance and resistance to stress
- Quality of material
  - Good source of material
  - True to type
  - Clean from major viruses or diseases



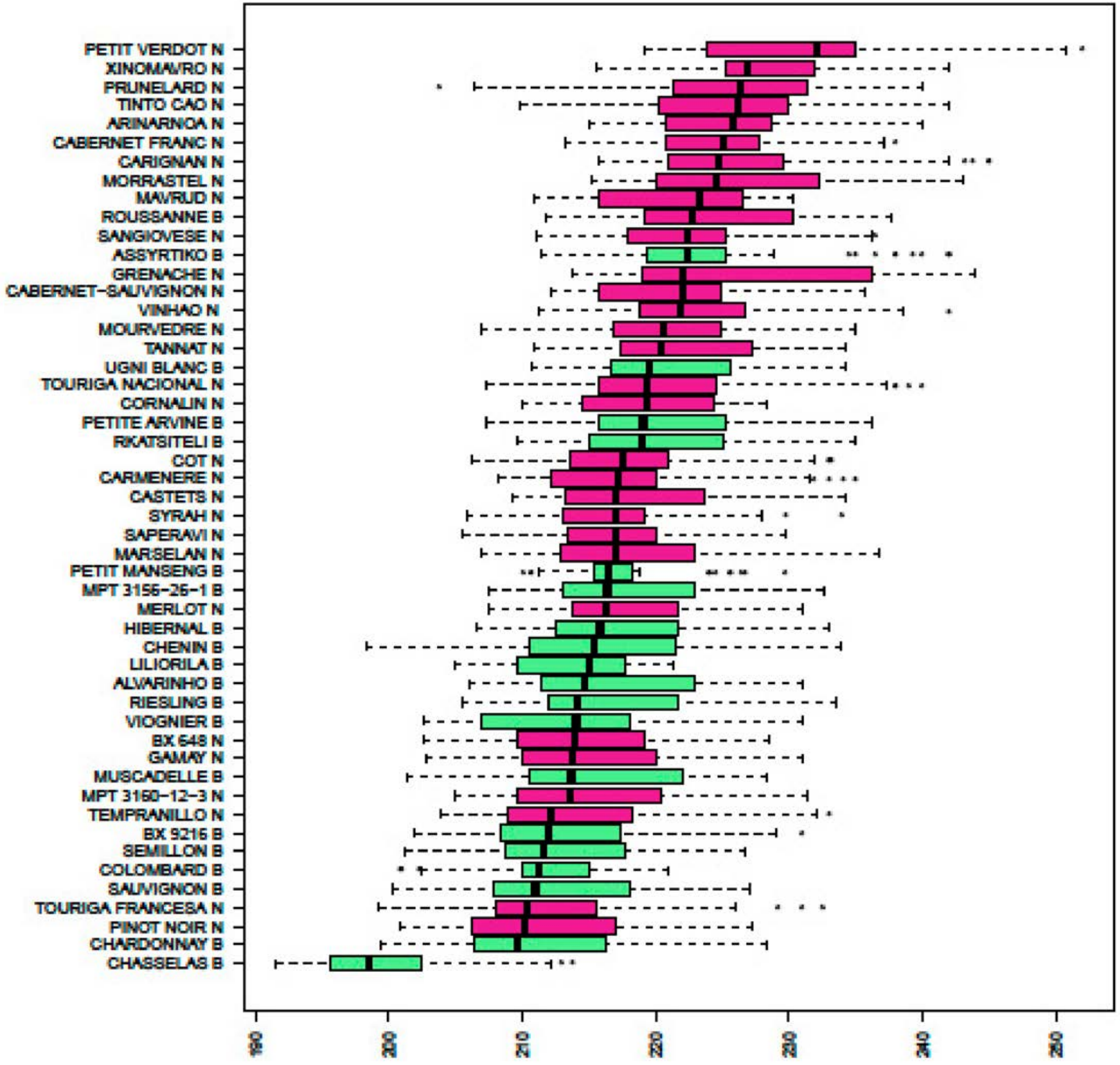
Evaluation of plant material

- Most regions continually evaluate new material
- Climate change is driving traditional regions to put even more efforts
- In established regions focus on rootstocks, clones and even varieties possibly more adapted to future climate
- New crossings, use of traditional, indigenous varieties and other plant sources all being evaluated

Regional and global efforts

- Many efforts worldwide for more disease resistance in *Vitis* particularly in high quality wine grapes
- Most major wine regions have dedicated, long-term programs
  - Strict policy on pesticide reduction and sustainability is leading the charge in many countries
  - Rootstocks
- Ontario/Canada has transitioned to more *V. vinifera* over the past few decades
  - Regional evaluations of existing and new material are important (BC, ON, QC, NS have different needs)
  - Cold tolerance is a major trait of interest
  - Clean material
  - Adaptable and more resistant material

Observed mid-véraison dates of varieties planted in the VitAdapt experiment (average day of the year from four replicates per variety over the period 2012–2018) Van Leeuwen et al. 2019



Building resiliency in grapevines to climate change

- Rootstock selection and new rootstocks may be the #1 way to deal with new or more severe abiotic stress in a cool climate region
  - Improved tolerance to drought and heat
  - New pests
  - Tolerance to wet feet
  - Vigour management
  - Cold tolerance

Current local studies here in Ontario

- Investigations of different grapevine genotypes (cultivar, clone x rootstock) to try to determine how they impact vine performance and quality
- Interactions between genotype x environment and cold hardiness
- Improving resiliency to extremes and volatility in weather through vine selection and plant growth regulators (i.e., ABA analogs)

Regional Rootstock trials in Ontario

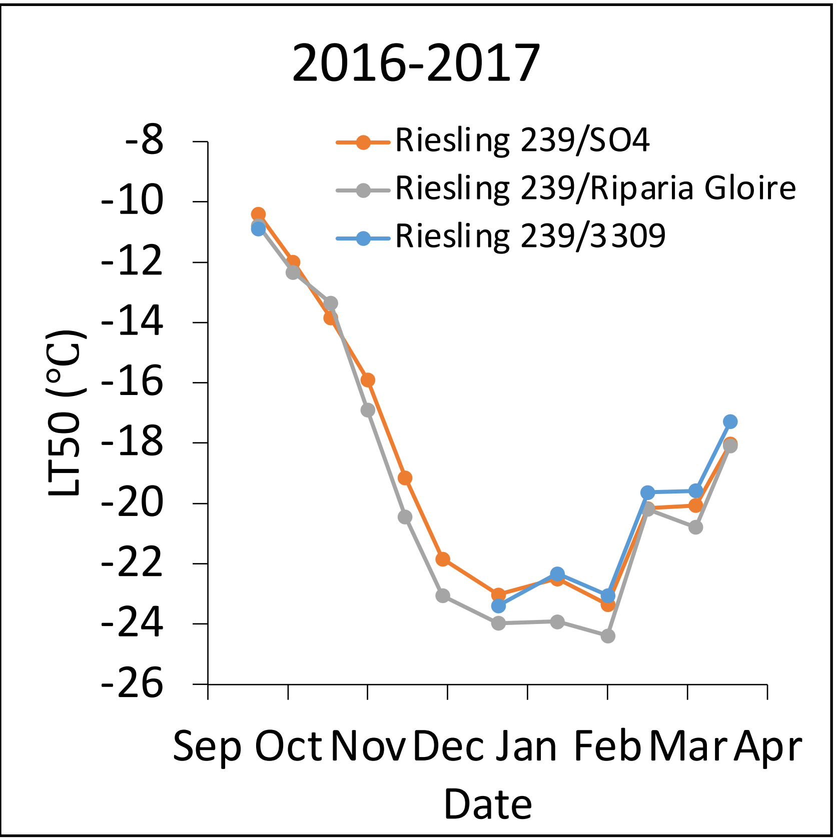
- Trials began in 2016 (Willwerth, Inglis, Kemp) NSERC/CRD then AAFC-CAP AgriScience cluster activity
- Examined variety x clone on different rootstocks in existing mature vineyards
- Newly planted variety x clone x rootstock trial vineyards in 2018
- 5 different varieties x different clones x SO4, C3309, Riparia Gloire, 101-14 and selected others (C1616, 1103P, 420A, 110R).

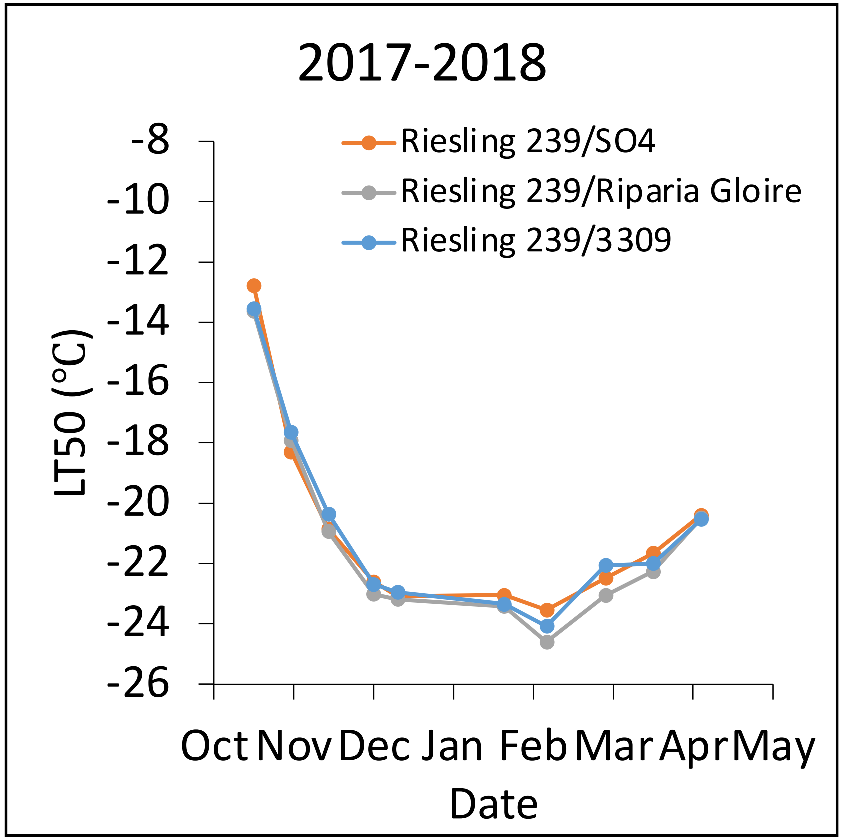
- Different soil types – heavy clay loam and sandy loam
- Examining vine performance, yield components, fruit composition and oenological potential

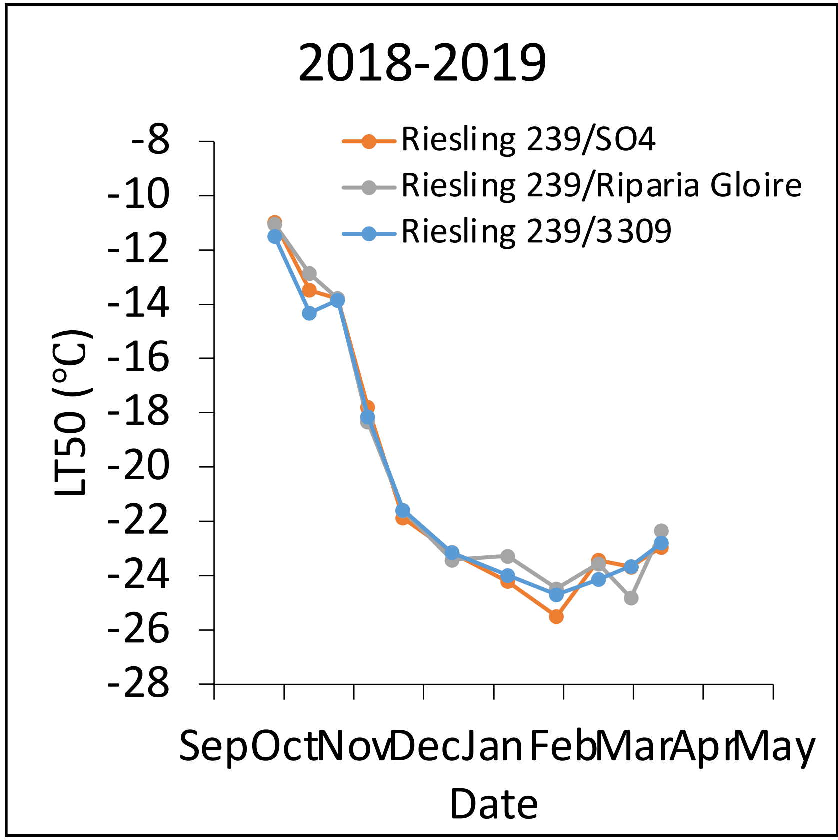
How can clone and rootstock impact yields, fruit composition and cold hardiness?

Rootstock selection (Hébert-Haché et al. 2021)

- Yearly differences but not too consistent (R. Gloire had better hardiness in some years for cl. 239)
- All vines had similar crop load and were considered "in balance"

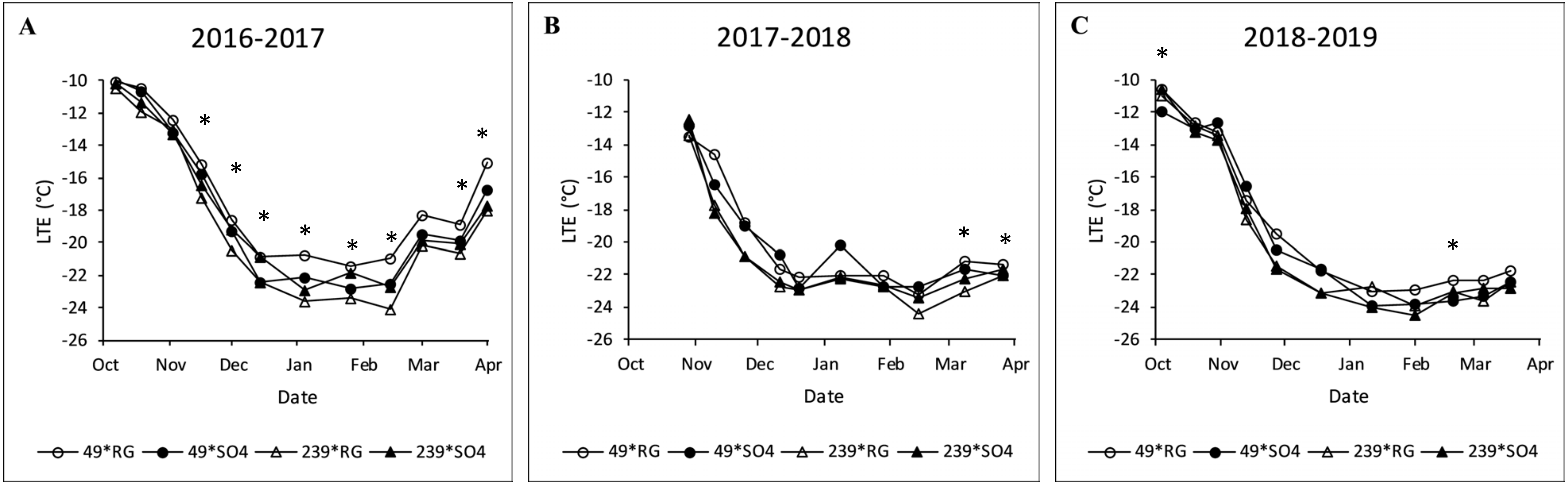






Clone x rootstock interactions (Hébert-Haché et al. 2021)

- The clone x rootstock interaction was significant almost every sampling date on the first year of the study
- Clone 49 performed better on SO4 rootstock, but clone 239 performed better on Riparia Gloire.
- Important yearly variation



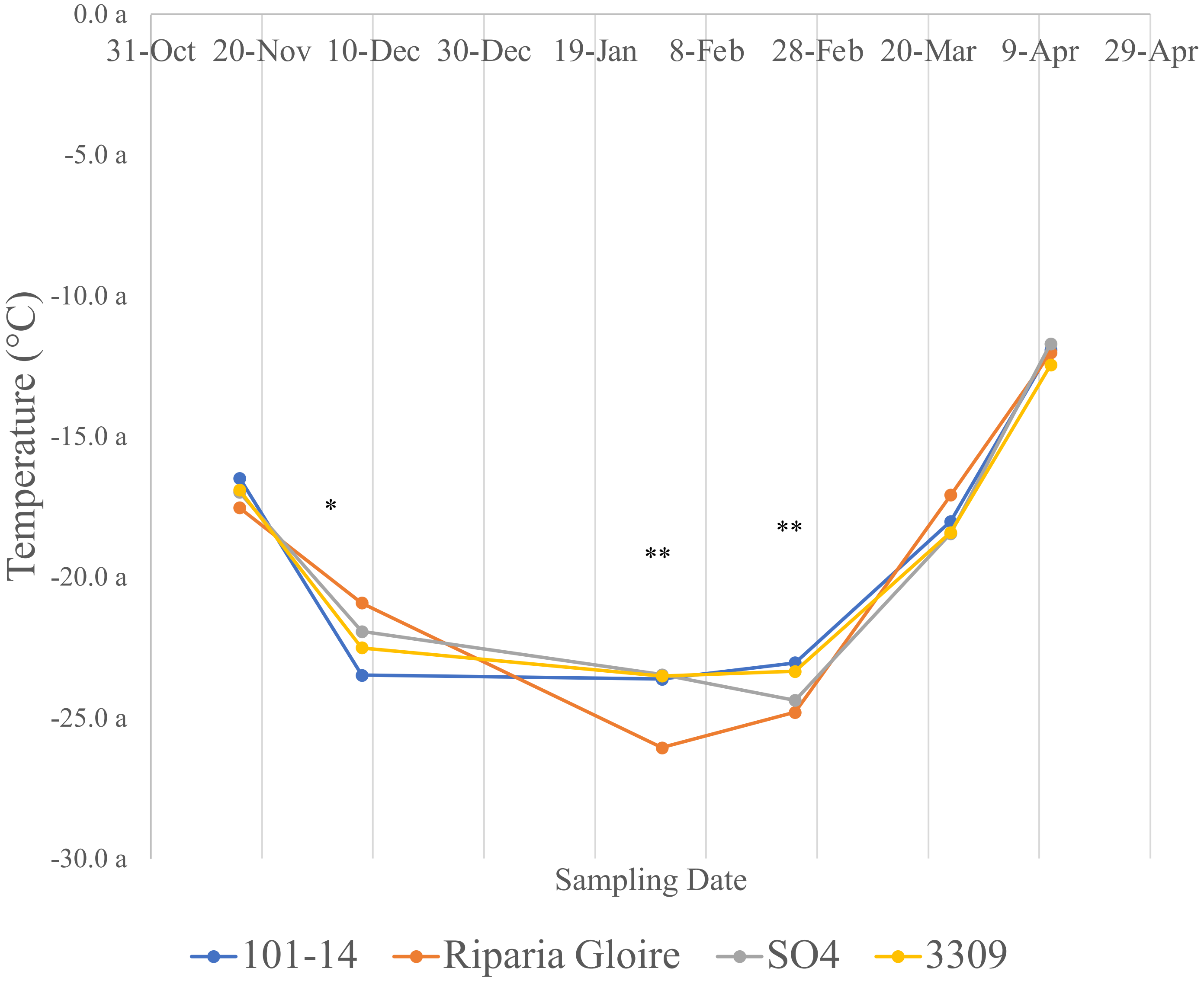
* indicates a significant clone x rootstock interaction ($p < 0.05$)

Chardonnay clone 548 grafted to different rootstocks (2021) Chung (2022)

TABLE 3.1. ONE-WAY ANALYSIS OF VARIANCE (ANOVA) FOR CHARDONNAY 548 CLONE GRAFTED TO ROOTSTOCKS OF 101-14, RIPARIA GLOIRE, SO4, AND 3309 FOR FRUIT COMPOSITION AND YIELD.

Rootstock	pH	TA(g/L)	Soluble Solids (°Brix)	Cluster number	Berry Weight (g)
101-14	3.55	6.2 ab	22.5	31 a	1.51
Riparia Gloire	3.49	6.2 ab	22.4	17 b	1.63
SO4	3.45	6.6 a	22.3	22 ab	1.56
3309	3.62	5.8 b	21.8	29 a	1.48
Significance	ns	0.024	ns	0.004	ns

Chardonnay 548 clone grafted to rootstocks of 101-14, Riparia Gloire, SO4, and 3309 for low temperature exotherms comparison of 2021/2022 dormant season. *, ** represent p<0.05 and p<0.01, respectively. Chung (2022)



Different Chardonnay clones grafted to Mgt 101-14 rootstock (2021)

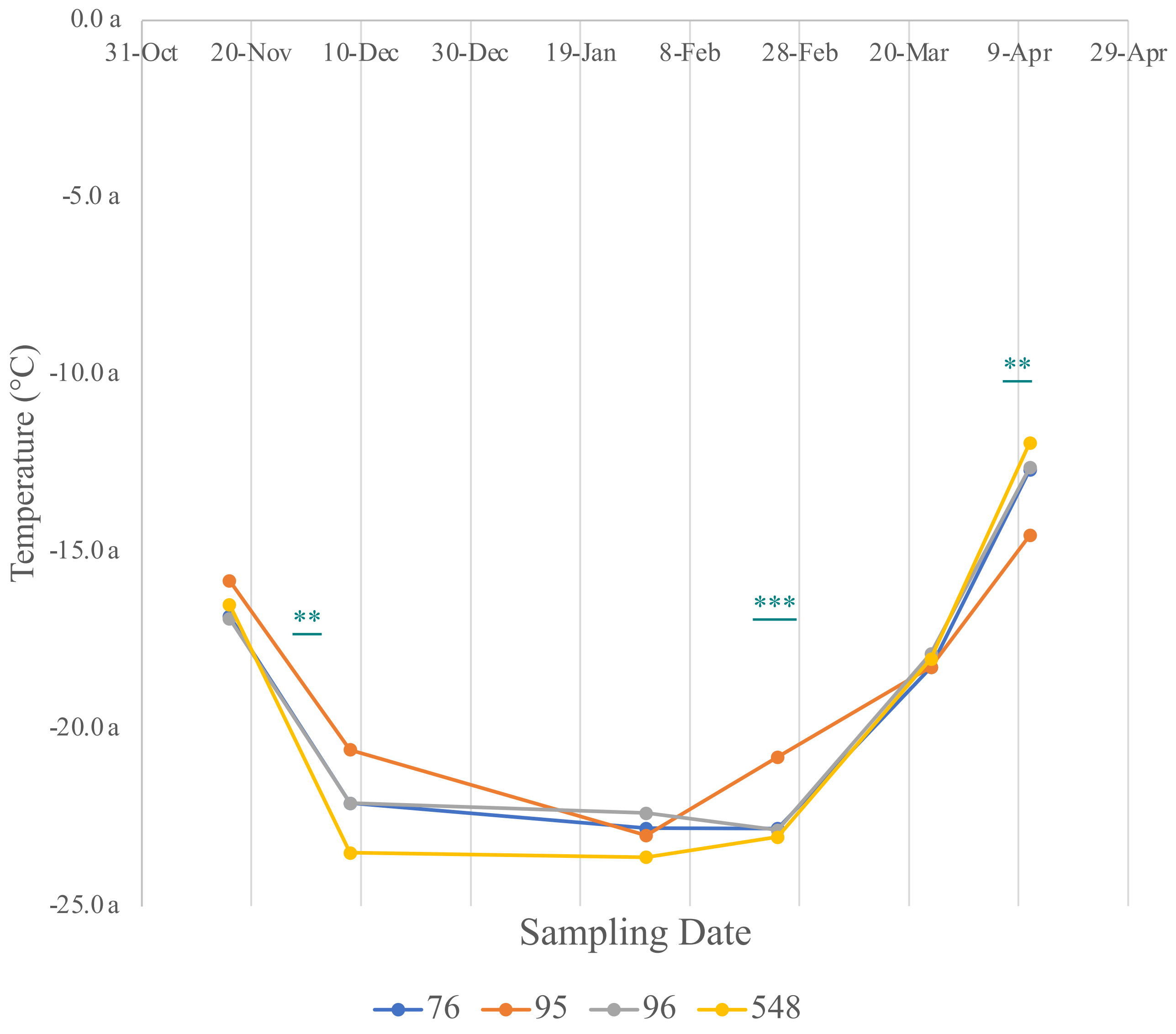
Chung (2022)

Table 3.4. One-way analysis of variance (ANOVA) for Chardonnay 76, 95, 96, and 548 clone grafted to rootstock of 101-14 for fruit composition and yield. The letter followed by different letter indicates significant difference ($p < 0.05$) that was tested using Tukey's Honest Significant Difference (HSD) test.

Clone	**pH**	**TA(g/L)**	**Soluble Solids (°Brix)**	**Cluster number**	**Berry Weight (g)**
76	3.55	5.7	21.9 ab	32 a	1.43 bc
95	3.59	5.9	22.0 ab	21 b	1.57 a
96	3.59	5.6	20.9 b	33 a	1.39 c
548	3.55	6.2	22.5 a	31 ab	1.51 ab
Significance	ns	ns	0.008	0.012	0.001

Chardonnay 76, 95, 96, and 548 clone grafted to rootstocks of 101-14 for low temperature exotherms comparison of 2021/2022 dormant season.

, * represent $p<0.01$ and $p<0.001$, respectively. Chung (2022)



Survival of vines after the 2021-2022 winter season, assessed on June 19th, 2022. (Findlater, 2022)

- ***Note: Sandy soils and a wet fall during cold acclimation***

	No Damage (%)	Vine Damage (%)	Death (%)
115/3309	28.3	21.7	50.0
667/3309	61.7	30.0	8.3
667/101-14	66.7	6.6	26.7
667/ Riparia Gloire	73.3	0.0	26.7
667/SO4	50.0	6.7	43.3
777/101-14	66.7	11.1	22.2
777/Riparia Gloire	80.0	6.7	13.3
828/Riparia Gloire	78.4	13.3	8.3
Significance	NS	NS	NS

Rootstock considerations

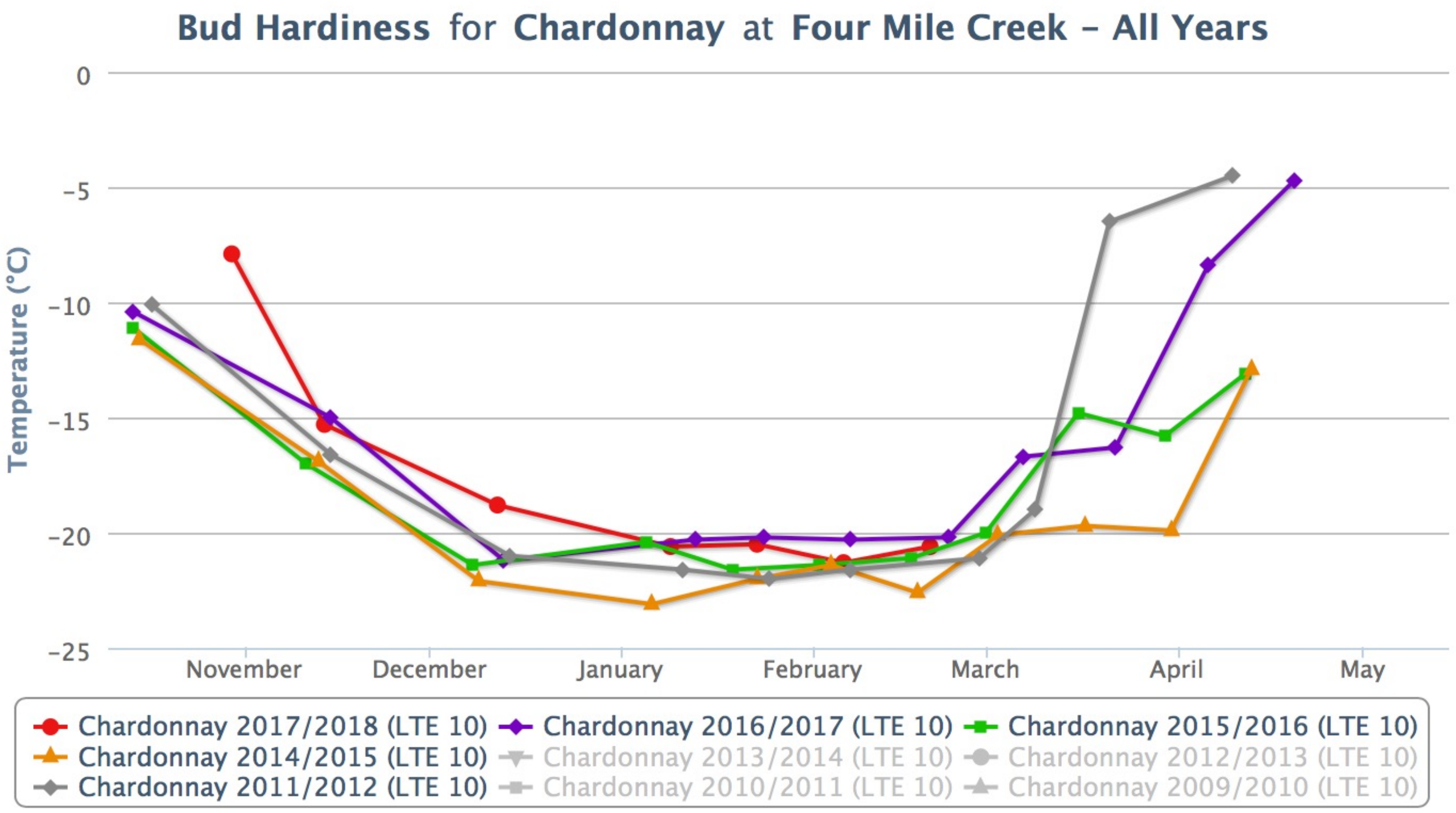
- Rootstocks can impact hardiness but it is dynamic and growing season influences should be taken into consideration.
- Vine material matched to site conditions will be most resilient to effects of climate change and just weather in general
- Aside from phylloxera tolerance and using a hardy rootstock, more important to match rootstock to soil type, fertility to manage vigour and production goals
- Poor rootstock choice has an immediate impact on winter survival

Caveats or “trade offs”

- Unfortunately, it isn’t easy to have a rootstock that is resilient to high volatility and a wide range extremes
- 1103 Paulsen and 110R are drought tolerant but are vigorous and may lack hardiness
- Riparia gloire and 101-14 Mgt are good for deep, moist soils, have lower vigor, good winter hardiness but are susceptible to drought

- Climate change, high volatility with vintage and seasonal variability from bud break to post-harvest
- Pose problems to select a “perfect” rootstock for all conditions that Mother Nature may throw our way

Impacts of warm weather on deacclimation



Potential solution to addressing climate change impacts

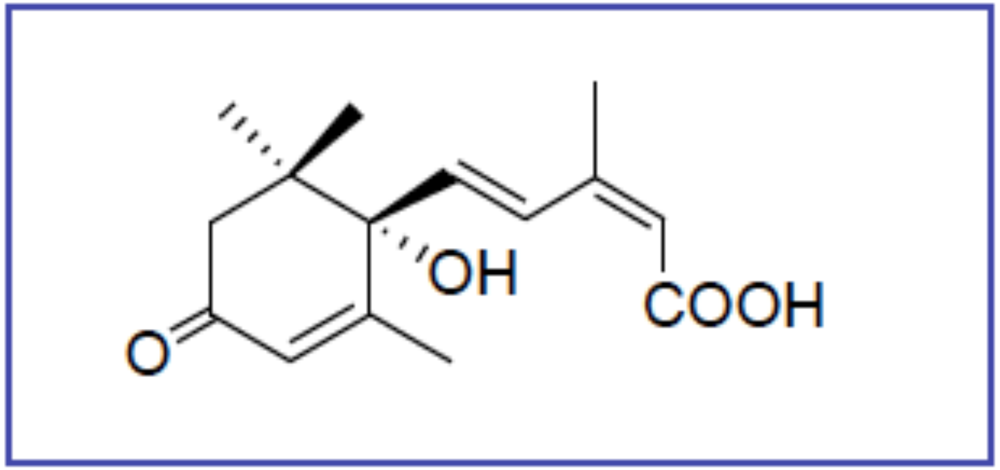
- Plant growth regulators (PGRs) can be a powerful tool
- Commonly used already in hot climate regions
  - Widely used for Table grape production
  - Tropical viticulture
- Various PGRs are used depending on the production or quality issue
- Very limited use in Canada

Use of PGRs in grape cultivation

PGR	Purpose of Use	Stage
Gibberlins (GA)	Cluster Elongation Berry thinning Berry sizing	Pre-bloom Bloom After fruit set
Cytokinins	Berry sizing	After fruit set
Abscisic Acid (ABA)	Berry coloration	Veraison
Ethylene	Berry coloration	Veraison

Background on Abscisic Acid (ABA)

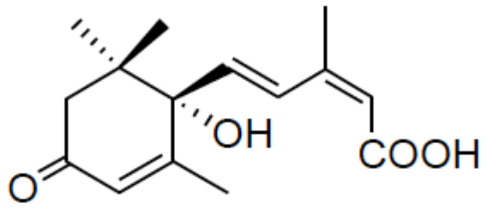
- Isoprenoid plant hormone found in all plants
- Regulates a wide range of processes in plant growth and development
  - Response to abiotic stress
    - Transpiration
    - Response to heat, drought, salinity and freezing
  - Growth and development
    - Growth inhibition
    - Abscission, senescence
    - Secondary metabolite production
  - Seed Development



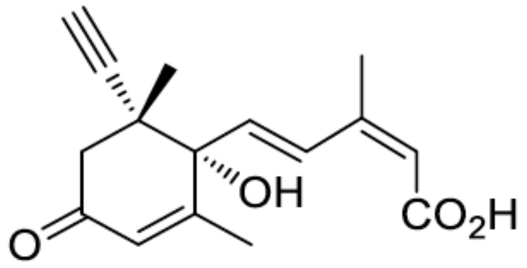
S-(+)-Abscisic acid

Abscisic Acid (ABA) analogs

- ABA analogs more effective than natural ABA for improving cold acclimation
  - 8’-Acetylene ABA and tetralone ABA
  - Purported to catabolize more slowly in plant tissues
  - Maintain high bioactivity
  - providing enhanced or prolonged effects on dormancy and hardiness



Natural ABA



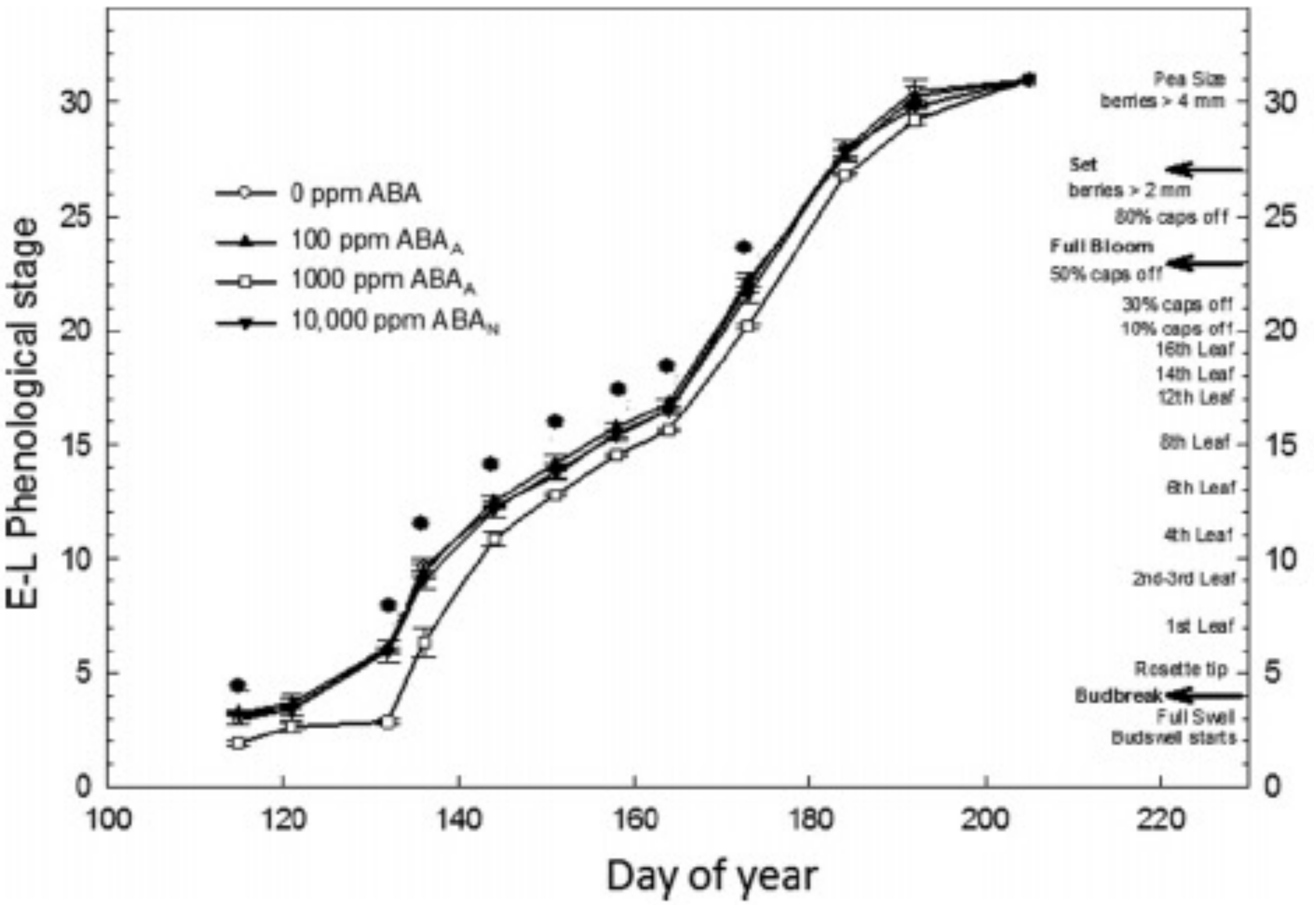
8′-Acetylene ABA

ABA_A impact on bud break and early development

Abscisic acid form, concentration, and application timing influence phenology and bud cold hardiness in Merlot grapevines

Pat Bowen, Krista C. Shellie, Lynn Mills, Jim Willwerth, Carl Bogdanoff, and Markus Keller

Can. J. Plant Sci. 96: 347–359 (2016)



Abscisic acid analog treated vines can delay deacclimation and budbreak

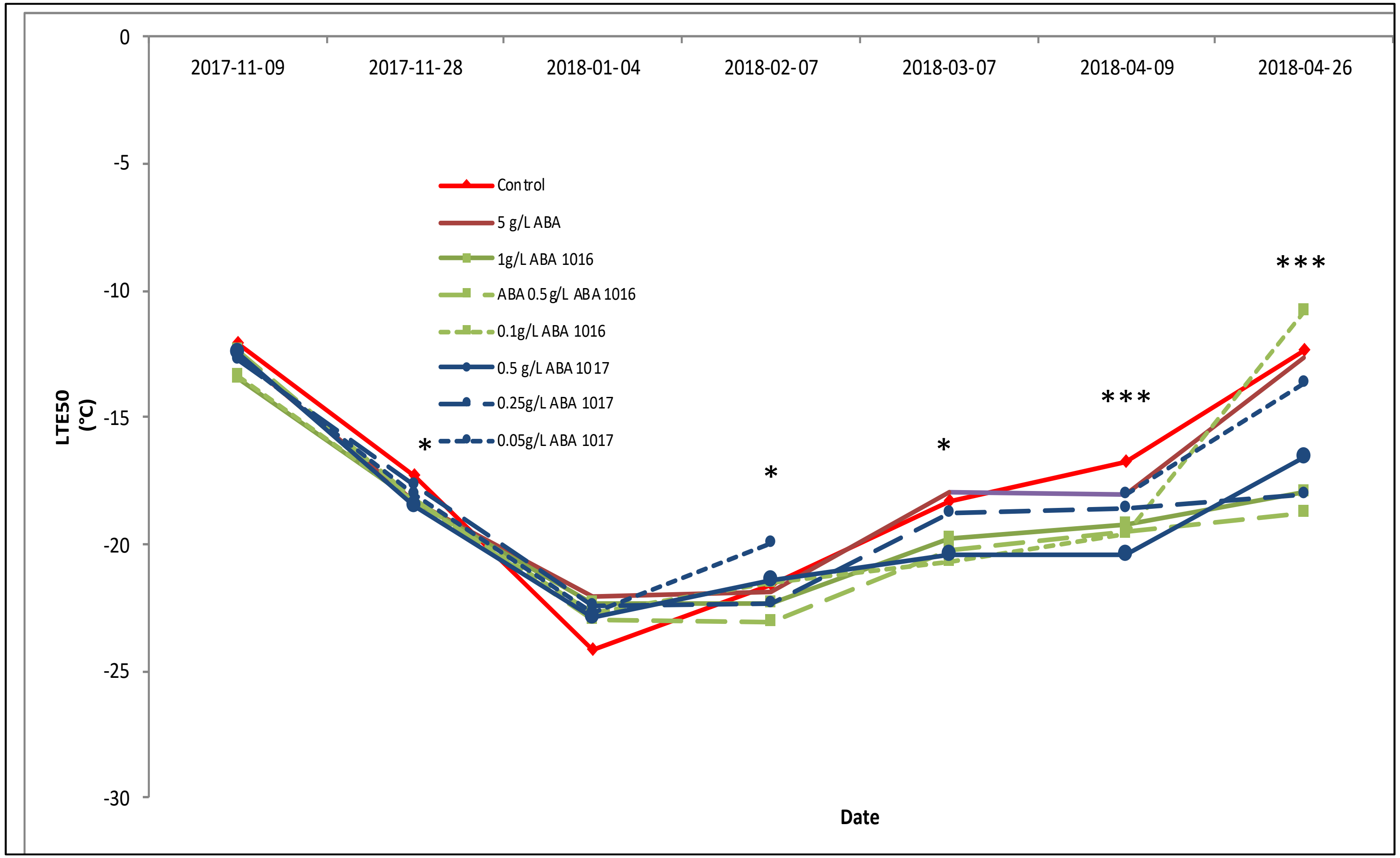
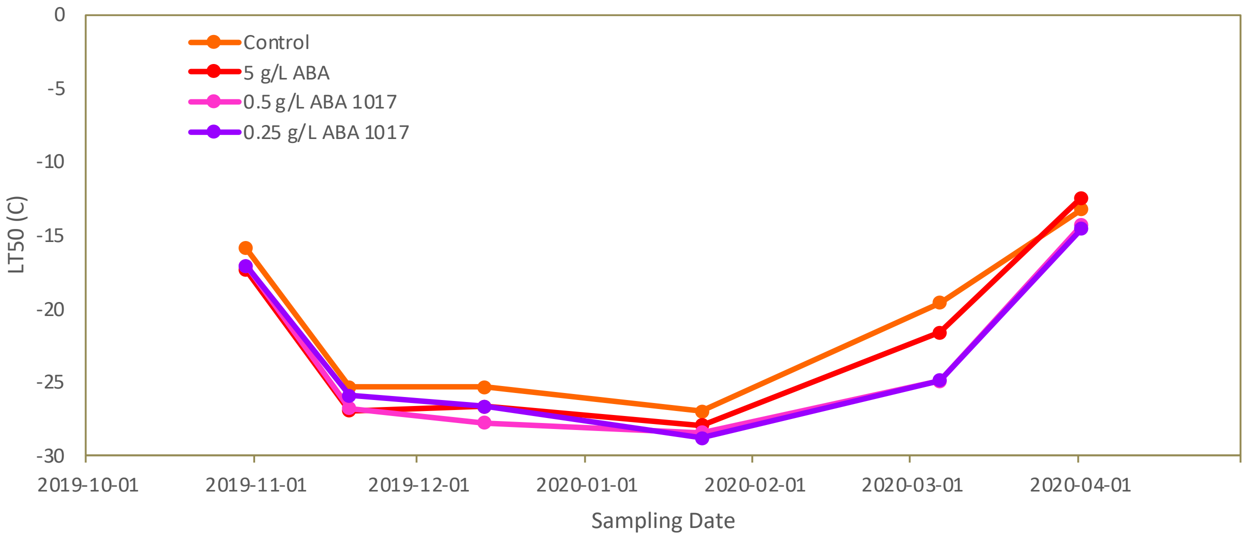


Figure 1. Cold hardiness dynamics of Merlot grapevines based on exogenous ABA_A treatments. Creek Shores, 2018. (*, ** represent statistical significance @ p<0.05, p<0.001, respectively)

Marquette

(A. Gunn, unpublished)

2019/20



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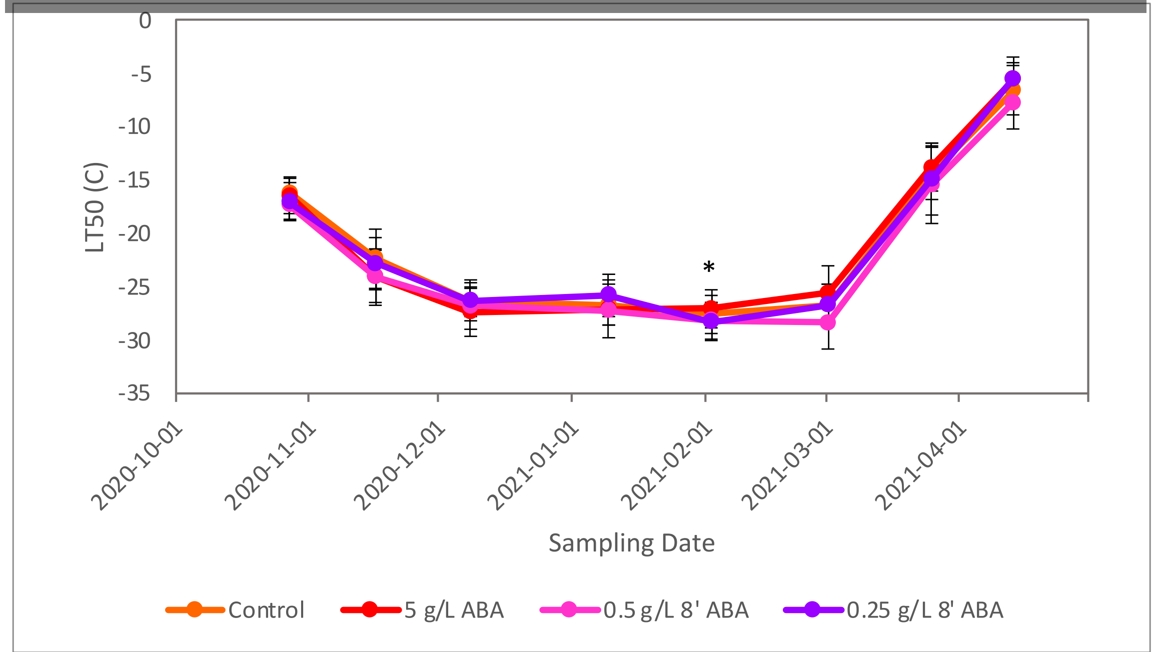

Conclusions

- Wine growing is highly impacted by climate
- Our viticultural areas have variable climates that are changing
- Proper cultivars and site selection is essential for premium wine production
- Rootstocks are an important adaptation strategy to climate change
- Clonal selection is also critical for optimizing quality and vine performance including improved cold tolerance or for earlier or later maturation
- Regional studies of cultivar x clone x rootstocks on different soils are increasingly important including new rootstocks
- More rootstock breeding worldwide is probably a necessity and probably has been lacking in cool climate areas that have not dealt with the need for drought tolerance and new pests
- Use of treating plants with plant growth regulators such as ABA analogs may be an additional tool in a grape grower's tool box to mitigate climate volatility and extremes.

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Grape Growers of ONTARIO

Ontario GRAPE & WINE RESEARCH Incorporated

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CGCN-RCCV
Réseau Canadien de Certification de la Vigne

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