AIP – Activity 5: Factors affecting winter grapevine hardiness

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IR Tool for Measuring Grapevine Hardiness

In assessing the commercialization possibilities for the IR Tool for determining grape hardiness the following points should be considered:

1) The IR tool for measuring Low Temperature Exotherms (LTE) on whole potted grapevines or on large grapevine structures is largely a research tool that would be useful to a limited number of researchers.
2) The advantages of this tool over the standard LTE measuring protocol currently used are:
   - grape bud, wood or root samples larger than 2 cm in size can be used which avoids the effects that excision wounds and sample dehydration may have on LTEs,
   - it can be used for a non-destructive measurement of grapevine hardiness that would allow for the post-treatment observation of whole vine response to cold temperature exposure and freeze injury.
   - that identification of LTE peaks is automated, thus saving time and removing technician subjectivity in interpretation of LTE spikes.
   - and it might be used outdoors to capture actual real-time bud and wood freeze damage,
3) Equipment requirement for this tool are a large programmable chest or walk-in freezer (which may or may not be available at many research facilities), a CS CR1000 data logger with multiplexers, IR sensors, IR sensor holders, and a computer algorithm to identify LTE peaks from large data sets.
4) The adaptability of this tool for other purposes has yet to be explored.

This tool, which is in a prototype stage of development, is currently being used in our lab and is yielding valuable data.

Varietal Bud Hardiness Model

A model has been developed that predicts grapevine bud hardiness for Chardonnay, Cabernet Sauvignon and Shiraz grown in the Okanagan Valley. This model is in the prototype stage of development and will be tested against this year's Varietal Bud Hardiness data later this spring. Adjustment to the model from this, the sixth year, of data should be small. Beginning in the winter of 2018-19 results from this model will be posted along with actual bud hardiness measurements in real time, and pending approval of the 2018 – 2023 AAFC-CAP proposal the model will be further developed for other varieties. Depending on the success of this model, in 2 or 3 years the basic constructs of this model will be used to develop a varietal bud hardiness model for specific grape growing regions in Ontario.

Overall, the wine and grape industry has increased its understanding and desire to optimize grapevine winter hardiness for the purpose of minimizing cold injury, crop loss and grapevine mortality from extreme cold weather events. Growers are now keenly aware that site conditions and varietal selections for new or replanted vineyards are important factors in reducing this risk. Research has also shown that grapevine bud hardiness is an innately stable attribute when crop load and overall vine balance are kept within normal ranges. Only management practices that tend to reduce vine vigor such as drip over sprinkler irrigation, the use of rootstocks for newly planted grapevines and vineyard conditions that promote early vine senescence tend to optimize bud hardiness. Research under this activity has also recognized the importance and vulnerability of whole grapevines structures to winter freeze injury, and has thus expanded research efforts into wood and root hardiness, where cold tolerance is difficult to measure and quantify. This year, significant progress has been made in investigating the relationship between bud and phloem hardiness, and preliminary work investigating grapevine root hardiness has been started in anticipation of continued funding for grapevine hardiness research in 2018-2023 AAFC – CAP proposal. Lastly, a new experiment to assess the impacts of Grapevine Red Blotch Virus on Cabernet Franc hardiness has been initiated with the expectation of completing this work by mid-March 2018.

This activity is on track with all planned milestones completed for all objectives. All funds for this activity were spent as budgeted. Research and knowledge transfer to industry members regarding grapevine winter hardiness continues.

Success Story

Since 2012 the bud hardiness of the 12 most widely planted varieties in the Okanagan Valley has been reported biweekly from leaf fall to bud break revealing significant differences in cold tolerance among *Vitis vinifera* varieties. Growers can now use this information to select cold tolerant varieties for sites within their vineyards that are prone to colder temperatures. Also, because of the year to year consistency of vines sampled and the constant biweekly interval of this data a varietal bud hardiness model has been recently constructed that has proven accurate ($r^2 > 0.95$) when tested against the past five winters. Based on daily average temperatures growers could use this model to predict their vineyard's hardiness and thereby optimize wind machine usage to reduce grapevine winter injury. An economic study of Ontario's VineAlert Program reported a potential annual savings of more than 55 million dollars for the industry when growers are armed with accurate vineyard hardiness information (https://brocku.ca/webfm_send/33924). Currently there are costly programs in Washington, Ontario, and BC that publish regularly measured bud hardiness data for this purpose. The ultimate goal for this objective will be to develop a bud hardiness model that can be used for all winter cold climate grape growing regions in Canada and around the world.

2. **Objectives/Outcomes**

A5.1 Can conventional vineyard management practices affect grapevine cold hardiness?

Crop Load Expt 1 (2013-2015) Merlot and Sauv Blanc, two varieties that are widely planted throughout the Okanagan Valley, are cropped at various levels depending on quality and production demands. For these two varieties crop loads, determined by yield/pruning weight, normally range between 2 and 10. In this experiment low, medium and high crop load treatments were applied to single vines by thinning shoots and clusters targeted at 1.0, 1.5 and 2.0 clusters per shoot, respectively. The treatments were replicated 4 times at each of 9 Merlot and 9 Sauv blanc sites. In all three years, results showed that adjusting crop loads within normal ranges did not greatly affect winter bud hardiness.

Crop Load Expt 2 (2015-2016) These experiments, conducted at 2 Shiraz and 2 Viognier vineyards, included two additional treatments; 1) an extreme low crop load treatment where individual vines were thinned down to 24 shoots & 6 clusters, and 2) an extreme high crop load treatment where only shoots without clusters were thinned leaving vines with 25 to 40 shoots and 35 to 60 clusters. Results were again largely similar to those previously found. Varying crop loads minimally impacted bud hardiness. Only during acclimation (late October) in 2015 was hardiness reduced or enhanced by the extreme high and low crop load treatments, respectively. For all other bud hardiness measurements made in 2015-16 & 2016-17 there was a conspicuous lack of correlation between crop load and bud hardiness.

SuRDC Cover Crop – Irrigation Expt (2013-present) The treatments, which included cover crops seeded in 2013 and firmly established by 2015, were 1) dual irrigation (sprinkler & drip) with a grass/flower cover crop, 2) dual irrigation with a grass/legume cover crop, 3) drip only irrigation with a dry native grass cover crop and 4) sprinkler only irrigation with a non-native grass cover crop. The biggest differences were found when comparing the sprinkler only vs drip only irrigation treatments. In 2017 the drip irrigated vines had reduced yield and berry weight and increased soluble solids and titratable acidity. Vine senescence, as measured by leaf greenness in the fall, was also hastened by the drip irrigation treatment, but differences in bud hardiness were not significant. Bud hardiness however was found to be improved in the fall (during hardiness acclimation) when drip irrigated vines were compared to the other 3 irrigation/cover crop treatments. Among the 2 dual irrigated treatments there were few differences in yield and fruit composition, and no difference in bud hardiness.

Early Vine Senescence Trial (2015 – present) In the 2013-2015 crop load experiment, where vine senescence was collected at harvest for all Merlot and Sauv blanc sites, early senescing vines were often more winter hardy than late senescing vines throughout the winter season. This phenomenon however was not related to crop load. In 2015 leaf fall was late and early and late senescing vine were easily identified, hence in a Merlot vineyard ten early senescing vines were paired with ten neighboring normal senescing vines. That winter the early senescing vines were hardier than the normal vines in November and December. In 2016 vineyard senescence was fairly uniform and the early senescing vines flagged in 2015 were only hardier than the normal senescing vines in early December, but not before or after that. Comparison of the two groups in 2017 found no difference in senescence or in bud hardiness, and the factors that enhance early vine senescence remain largely unknown.

Young-Vine Protection Trial (2015 – present). Young grapevines are particularly prone to winter cold damage as a result of their small size and exposure to lethally cold air that pools on the vineyard floor. The effects of protective cover treatments on the temperature of young grapevine stems and roots were evaluated over two winters. In winter 2015-2016 the treatments were: empty and sawdust filled 2-L cardboard cartons, mounded sawdust, foam insulation wrap, and no protection (control). The same treatments plus a mounded soil treatment were applied in winter 2016-2017. Treatment effects on vine temperatures were influenced by snow cover and ambient temperatures in the previous week. Averaged over the treatment period, daily minimum temperatures of vine stems and roots were similar for the non-protected (control) and empty-carton treatments, and in comparison were up to 1° C warmer for the sawdust filled carton, up to 5° C warmer for the mounded sawdust or soil, and up to 1° C cooler for the pipe-insulation wrap. Snow cover further increased the minimum temperature of vines under sawdust mounds in 2015-2016. The mounded sawdust and soil treatments were the most effective at increasing nighttime minimum temperatures of vine stems, however in spring 2016 a high rate of mortality was observed for buds that had been buried in sawdust.

A5.2 Posting current grapevine bud hardiness levels for the major wine grape varieties grown in the Okanagan Valley.

Varietal Bud Hardiness (2012-present) Winter bud hardiness levels for the 12 major wine grape varieties across 65 sites in the Okanagan valley continues to be measured biweekly. This data is directly emailed to over 100 growers & industry personnel and is posted on the BCWGC website. Additionally this data has been used to rank the grape varieties for winter hardiness and for the development of a predictive bud hardiness model based on site temperature means and the regularly sampled varietal bud hardiness data. Initial model development with Chardonnay, Cabernet Sauvignon and Shiraz has achieved an average 0.95 r^2 accuracy for each year over the past 5 years.

Varietal Bud Hardiness for Vitis vinifera in the Okanagan Valley (2012 - 2017)								
Acclimation (Oct - Nov)			Max hardiness (Dec - Feb)			Deacclimation (Mar - Apr)		
variety	hardiness*	duncan[x]	variety	hardiness	duncan	variety	hardiness	duncan
Shiraz	1.72	A	Shiraz	0.82	A	Gewurzt	0.94	A
Cab Sauv	1.34	AB	Gewurzt	0.70	AB	Chard	0.74	AB
Merlot	1.10	B	Merlot	0.64	AB	Cab Franc	0.52	ABC
Cab Franc	0.48	C	Cab Sauv	0.42	AB	Merlot	0.46	ABC
Gewurzt	-0.06	C	Sauvi blanc	0.32	B	Shiraz	0.18	BCD
Sauv blanc	-0.08	C	Chard	-0.32	C	Pinot noir	-0.04	CDE
Pinot noir	-0.72	D	Pinot blanc	-0.44	C	Pinot gris	-0.28	DE
Riesling	-0.84	D	Cab Franc	-0.46	C	Sauv blanc	-0.38	DE
Chard	-0.90	D	Pinot noir	-0.52	C	Cab Sauv	-0.40	DE
Pinot gris	-0.94	D	Riesling	-0.56	C	Pinot blanc	-0.64	EF
Pinot blanc	-1.08	D	Pinot gris	-0.62	C	Riesling	-1.08	F

* Relative bud hardiness (˚C) Note: positive values are less hardy than negative values.

[x] Duncan's multiple range test - Means followed by the same letter and not significantly different

A5.3 The enhancement of grapevine cold hardiness with pre- & post-harvest ABA spray applications.

ABA applications to enhance bud hardiness (2013 – 2015). Numerous trials with various rates, timings and numbers of ABA spray applications found ABA treatments to only sometimes improve bud hardiness. Factors such as the weather and the state of vineyard senescence at time of ABA applications likely contributed to this inconsistency. A new experiment aimed at increasing endogenous levels of ABA and avoiding exogenous ABA applications was thus implemented in 2015 to see if mild water stress before and or after harvest could consistently enhance bud hardiness.

Irrigation/ABA Expt. (2015 – present). The treatments, replicated 6 times were (FI) full irrigation with 2 emitters per vine all season, (RSV) reduced irrigation with 1 emitter per vine (50% less water) from fruit set to veraison, (RSH) reduced irrigation with 1 emitter per vine from fruit set to harvest, and (PRD) reduced irrigation with Partial Rootzone Drying with 1 emitter per vine alternating every 3 weeks between emitter positions from fruit set to harvest. The frequency and duration of irrigations were the same for all treatments and were based on maintaining soil moisture at 30-60 cm depth in the FI treatment at above 4% (v/v). In 2015-16 the FI vines had higher yield than the RSV vines. All three reduced irrigation treatments decreased berry weight and increased pH, but had no effect on soluble solids and titratable acidity. During the growing season, fully irrigated vines (FI and latter half of RSV) had higher rates of photosynthesis when measured weekly from July to mid-Sept. Bud hardiness measured during the acclimation and maximum-hardiness periods of vine dormancy was lower in response to PRD than all other irrigation treatments, and higher for vines that were fully irrigated after veraison than those under the reduced irrigation to harvest regimes. Across treatments, higher rates of photosynthesis were associated with enhanced bud hardiness. In 2016-17 the PRD treatment was replaced with (RBH) reduced Irrigation with 1 emitter per vine from 2 weeks pre-bloom to harvest. Similar results for yield, fruit composition and rates of photosynthesis were found, except higher yields were produced by vines under FI compared to those under RBH. The relationship of high photosynthetic rates with greater hardiness was not present, but again mild water stress after veraison and past harvest did not improve hardiness. An unexpected improvement in hardiness occurred when mild water stress was imposed before veraison. In 2017-18 the FI vines had lower pH and higher titratable acidity than the 3 other reduced irrigation treated vines, and had higher yield over that of the RBH treated vines. Rates of photosynthesis were again higher when vines were being fully irrigated, and as in 2016, there was no correlation between photosynthetic rate and bud hardiness. Measured in November 2017 and February 2018 bud hardiness was not affected by the irrigation treatments. Wines were made from all plots for each year and will be evaluated by a sensory panel of industry winemakers this spring and in following years.

A5.4 Assessing the impacts of disease and new management practices on grapevine hardiness that are under investigation in activities 2, 3, 4, 6, & 7. (2012 – present)

A2. Irrigated cover crops in vineyard drive rows have little impacts on grapevine bud hardiness.

A3. The bud hardiness of vines with slight to moderate Grapevine Leaf Roll Virus (GLRV) symptoms were not negatively affected, but bud hardiness was reduced for severely GLRV symptomatic vines. A new experiment with obvious Grapevine Red Blotch Virus symptoms was initiated in the fall of 2017, and in this case these vines were less hardy than healthy vines.

A4. Treatment difference in bud hardiness due to Grapevine Trunk Disease was measured, but meaningful effects can't be measured until the winter of 2018-19 when the remedial treated vines have fully regrown. At all 3 sites, differences in hardiness were found due to vine location and these differences will be further investigated pending approval of 2018 -2023 AAFC - CAP proposal.

A6. Further bud and phloem testing indicated that as young grafted vines age their enhanced bud hardiness over own rooted vines decreased. In 2017 there were no differences in bud hardiness between grafted and non-grafted vines.

A7. Early and Late season leaf removal did not negatively affect bud hardiness.

Issue: In years 2013 to 2016 no issues occurred. In 2017 an Activity 2 off-station experiment "Can crop load and fertilizer adjustments reduce GLRV effects?" was mistakenly machine harvested before experimental yield data was collected. Results for yield, fruit composition and vine balance were lost, but treatment effects on winter hardiness were still collected. This experiment can be repeated without too much difficulty this growing season.

There were no severe winter events in 2017-18. However, if an extreme cold weather event were to occur then field selections of surviving vines would be possible. This opportunity would greatly facilitate the selection process for developing winter hardy varietal clones.

3. Future Related Opportunities:

Phloem hardiness of grapevines is an issue that deserves more attention. Phloem hardiness is difficult to measure and quantify, but in ancillary work a new method using IR sensors to measure phloem hardiness has been developed. Preliminary results show phloem tissue to be nearly as hardy as buds when tested under steadily declining temperature protocols. Phloem tissue however appears to be more susceptible to cold injury at prolonged constant temperatures that are up to 4˚C less than lethal (LTE50) for buds. This issue will be further explored pending continued funding for grapevine hardiness research in 2018-2023 AAFC – CAP.