Summerland Research & Development Centre
Wine Grape Research

Grapevine Winter Injury: Do Buds and Phloem Differ in Freeze Tolerance?

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INTRODUCTION

A major concern for the Canadian wine grape industry is damage to grapevines caused by extreme winter cold. Understanding the conditions that affect grapevine freeze tolerance, also known as hardiness, can help growers make decisions to avoid or prevent freeze damage. Grapevine buds, which contain the initials of clusters that develop in the next growing season, are particularly prone to cold damage. Their hardiness increases during a temperature acclimation period in the fall, and decreases during de-acclimation in late winter and spring (Bowen et al. 2016, Dami et al. 2015). We track these changes in bud hardiness with a procedure known as differential thermal analysis (DTA). Using specialized freezers that cool buds slowly, DTA detects the heat emitted when buds freeze to determine their hardiness temperature (Bowen et al. 2016, Mills et al. 2006). Biweekly hardiness assessments for 15 widely planted wine grape cultivars in the Okanagan Valley have been reported to industry since 2012 (Bogdanoff et al. 2020; https://www.bcwgc.org/resource/bud-hardiness).

For trunks, cordons, and canes, measuring hardiness is challenging because it depends primarily on phloem tissue hardiness. Whereas buds freeze distinctly, which is easily detected by DTA , phloem freezes gradually in areas extending along the trunk to cane tips. Knowing the relationship between bud and phloem hardiness would help growers predict whole-vine hardiness from reports of bud hardiness. In this study we characterized the relationship between bud and phloem hardiness by assessing their freeze damage in response to cold temperature exposure.

EXPERIMENTS

Five experiments were conducted in two winters, three in 2015-2016 and two 2016-2017, during the periods when grape buds were at maximum hardiness. For each experiment, 169 five-bud cane segments

Figure 1 Cold damage was assessed on cane segments that included basal (proximal) buds 3 to 7. Black lines show the locations where the cane and buds were sectioned for damage assessments after exposure to cold temperatures.

were harvested from Merlot grapevines growing at Summerland Research and Development Centre. An additional 27 five-bud cane segments were harvested on the same day to sample buds for DTA analysis.

DTA was conducted on excised buds as described previously (Bowen et al. 2016) to determine the temperature at which 50% of the buds froze, known as the low temperature exotherm 50 (LTE50). Similarly the cane segments were cooled in a specialized freezer programed to cool gradually by 2 °C/hr.

During cooling, 13 canes were removed at each of 13 set temperatures between -12 °C, which does not cause freeze damage, and -28 °C which causes severe damage to phloem and buds. Upon removal, the canes were put in plastic bags and stored at 22 °C. Five of the canes were removed from storage the next day and cultured with their proximal ends in water to initiate root and shoot development. The remaining eight canes were stored for five days to allow freeze damaged tissue to become brown and apparent. These canes were cross-sectioned through their compound buds and at 4 positions between each pair of nodes (Figure 1). Bud death was confirmed by the appearance of brown necrotic tissue (Figure 2). Cane phloem damage, which appeared as brown necrotic areas, was visually rated for severity based on percent necrosis: light, from 1% to 10%; moderate, from 11% to 80%; and severe, from 81% to 100% (Table 1, Figure 3). The cultured canes were allowed to develop for 6 to 8 weeks after which their development was assessed for effects on bud break, shoot and root growth, and cluster number by comparison to canes exposed to -12 °C which does not cause freeze damage.

Figure 2 Levels of freeze injury to compound buds: no damage (A), necrotic (dead) primary bud (B), and fully necrotic (C).

Table 1 Effects of canes exposure to decreasing temperatures on phloem damage, and percent reductions in bud break, clusters/shoot, and shoot and root growth for subsequently cultured canes.

Phloem damage range (%)	Hardiness(°C)*	Decrease in bud break (%)	Decrease in clusters/shoot (%)	Decrease in shoot growth (% of length)	Decrease in root growth (% of length)
1-10	-20.4	0	5	2	9
10-80	-22.0	0	16	25	69
81-100	-23.5	69	30	59	99

*Estimated from five experiments conducted during the periods of maximum hardiness in 2015-2016 and 2016-2017. Normal shoot and root growth was determined from canes exposed to a minimum temperature of -12 ˚C. Average bud LTE_{50} was -22.3 ˚C.

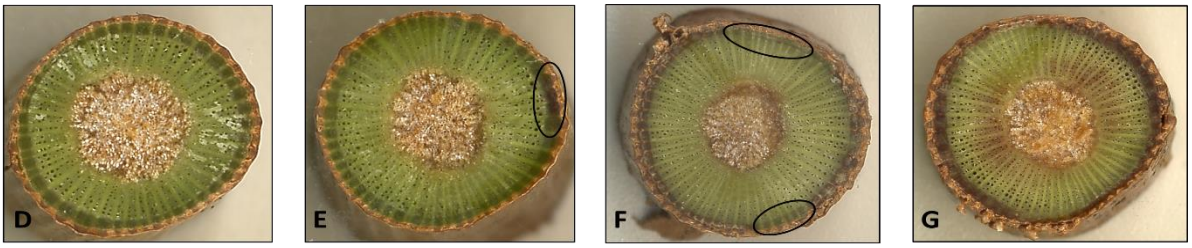

Figure 3 Levels of freeze injury to cane phloem: no injury (D); 5% injury (E) showing areas of necrotic phloem cells (circled); 80% injury (F) showing areas of non-necrotic phloem cells (circled); and 100% injury (G) and with interior areas of injured (brown) xylem.

FINDINGS AND CONCLUSIONS

Among buds sampled in all experiments in both years, LTE50 determined by DTA ranged from -24.6 °C to -20.8 °C, and averaged -22.3 °C (Table 2). From the assessed damage to cane segments exposed to cold temperatures, 50% bud death was estimated to occur at -23.6 °C. The discrepancy in bud hardiness estimates may indicate that buds left attached to canes will freeze at a lower temperature compared with buds excised for DTA. The onset of bud death on the cane segments, i.e. when 10% of buds were killed, occurred at -21.6 °C.

Exposure temperatures that caused low to severe phloem damage were 1.0 °C to 1.6 °C warmer than temperatures causing low to severe bud damage, possibly indicating that phloem is less hardy than buds (Tables 1 and 2). However, light levels (1-10%) of phloem injury, resulting from exposure to -20.4 °C, had no effect on bud break and only minimal effects on shoot and root growth (Table 1). Moderate levels (11-80%) of phloem injury, resulting from exposure to -22.0 °C, led to significant reductions in root and shoot growth, but no effect on bud break. Canes exposed to -23.5 °C had severe damage to phloem, and substantially reduced root and shoot growth and bud break.

Table 2 Hardiness of primary buds, determined by DTA as LTE_{50}, and by visual inspection for bud necrosis after exposure to set temperatures.*

Assessment method	Hardiness (°C)**
DTA measured as LTE_{50}	-22.3
Visual necrosis after exposure: 10% of buds	-21.6
Visual necrosis after exposure: 50% of buds	-23.6
Visual necrosis after exposure: 90% of buds	-24.5

*LTE_{50} was determined by DTA of excised buds. Visual necrosis was assessed on buds attached to cane segments.
**Means determined from five experiments conducted during the periods of maximum hardiness in 2015-2016 and 2016-2017.

The effects of cold exposure on bud break and shoot growth were not substantial until more than 80% of phloem was damaged. Vine recovery from low to moderate phloem damage occurs through regeneration from undamaged phloem tissue. Recovery from severe phloem damage, as results from exposure to temperatures below -23.5 °C, is unlikely to be adequate to prevent vine death.

The increase in bud damage resulting from exposure to colder temperatures was associated with decreases in the number of clusters/shoot developing on the cane segments (Tables 1 and 2). This association revealed the lower cold tolerance of primary buds compared with secondary and tertiary buds which normally have fewer or no cluster initials. Damage to mainly primary buds can result in lower cluster numbers and yield in vineyards despite having no apparent effect on budbreak.

Results of this study indicate that when winter temperatures fall to below the LTE50 determined by DTA, phloem damage and reductions in shoot growth and cluster numbers are likely. For temperatures 1 to 1.5 °C colder than the LTE50 , death of whole vines is likely.

CITED

Bogdanoff C, Bowen P, Estergaard B, Marsh S, and Jean E. 2020. Bud Hardiness of Wine Grape Cultivars in the Okanagan Valley, British Columbia. SuRDC Wine Grape Research. December, 2020.

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RELATED NEWSLETTERS

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