Dealing With Cold Injury

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Introduction

Extreme winter minimum temperatures that result in significant vine damage and crop reduction in Vitis vinifera cultivars occur every four to eight years in Washington State [2]. Since the late 1960's, six such freeze events have occurred: 1968, 1972, 1979, 1983, 1990 and 1996 [1, 2, 3, 4, 6]. During these events, minimum temperatures typically range from -8 to -15 degrees F and duration may last from one to a few days and may occur more than once each winter. Depending on the site, cultivar and temperature of each event, damage to vines may range from simple bud injury to complete loss of the aboveground vine structure. Fortunately, V. vinifera cultivars in Washington State are own-rooted and are readily retrained from belowground suckers. Rarely is the root system and entire vine killed due to the insulating nature of soil. However, the 1978 freeze resulted in the lost of several hundred acres of both V. vinifera and V. labrusca cultivars due to a combination of shallow planting, deep ground freezing, low soil moisture and insufficient snow cover [2]. This experience resulted in the adoption of prophylactic practices of planting vines at least 12 inches deep and post-harvest irrigations to replenish soil moisture [5].

Because of the infrequency of freeze events and rapid expansion of the industry, advice on how best to respond to the resulting injury has varied. As a general practice, growers do not to prune V. vinifera before February 15, the predicted last date of damaging winter temperatures. Prior to the 1991 event, typical recommendations called for increasing bud numbers to compensate for moderate injury, but more conservative pruning for extensive injury involving the trunk. The logic behind the latter recommendation was to avoid development of canopies and crops that might overtax the damaged vascular system and result in mid-season vine 'collapse.' With the 1991 event, it was observed that many vines with high bud damage and relatively severe vascular injury that had been lightly or 'hedge' pruned went on to develop full canopies and moderate crops with no apparent detriment [6]. During the 1996 freeze, more extreme temperatures were experienced than in recent previous events. Between January 30 and February 3 of that year minimum temperatures ranged from -8 F in the warmest sites to below -22 F in the coldest. Damage was so severe and wide spread that growers were forced to delay pruning to evaluate extent of possible vine dieback. In many cases growers delayed pruning decisions until after budbreak and in some cases did not prune vines at all for the season. This situation presented the industry with an opportunity to evaluate vine response to the range in treatments and to reconsider the appropriate approach to pruning when confronted with such injury in the future.

Procedures

Immediately following the low temperatures in 1996, bud injury was evaluated by randomly selecting 10-20 canes from each block, allowing them to warm to room temperature, and cutting through buds with a

sharp, single-edged razor blade while viewed under a 10-power lens. Only damage to primary and secondary growing points were recorded. For all blocks, bud positions basal through five were rated for injury.

For several blocks, positions six through 10 were also rated. In a selected number of blocks, positions 11-15 were rated. A few blocks had been pruned prior to the freeze, restricting the samples to bud positions basal through two or three. The majority of samples were collected and rated by Hogue Cellars' staff; growers provided the remaining samples. Blocks were sampled throughout four subregions of the Columbia Valley (CV), including the Yakima Valley (YV), Wahluke Slope (WS), Tri-Cities (TC) and Alderdale Ridge (AR); samples were not collected from the Walla Walla (WW) Valley. Cultivars sampled included Chenin blanc, Chardonnay, Cabernet Sauvignon, Cabernet franc, Gewürztraminer, Merlot, Sauvignon blanc, Semillon, Syrah and Riesling.

Pruning recommendations for bud injury compensation were made to growers through private consultations, newsletter and industry sponsored meetings. Growers who observed temperatures below -15 F or primary bud damage approaching 100% were advised to delay pruning until after budbreak to assess potential for vine dieback. Growers who observed primary bud damage less severe than 75% were advised to increase bud numbers using the following formula:

ABN = NBN/CP, where CP = (LP% + 0.25 x LS%)/100 and
ABN = adjusted bud number per vine,
NBN = normal bud number per vine,
CP = crop potential,
LP% = percentage live primary buds and
LS% = percentage live secondary buds.

It was assumed that secondary growing points have only 25% of the fruit potential of primaries. To simplify this formula, it was suggested that bud numbers could be increased by 50% for primary injury near 25%, doubled for primary injury around 50% and tripled for injury around 75%. Since most V. vinifera cultivars in Washington State are cordon-trained and spur-pruned, normal bud adjustment was achieved by leaving additional spurs. For injury above 75%, it was recommended that growers 'hedge' prune vines by reducing all one-year canes to two or three-bud spurs. Many growers chose to supplement bud numbers by leaving two to four 12-bud canes in addition to spurs. The canes were tied to wind catch wires and spread to avoid overlapping with each other.

Results

Temperatures: The more moderate temperatures during the freeze episode were recorded on the Alderdale Ridge (a ridge system that runs along the north side of the Columbia River between Oregon and Washington), the Wahluke Slope (a subregion located to the northwest of the Tri-Cities at the base of Saddle Mountain) and higher elevations of the Yakima Valley. In general, vineyards in these subregions above 900 feet elevation experienced the least severe temperatures and injury. Temperatures at these locations ranged from -8 to --14 F. Vineyards near the Alderdale Ridge had the added benefit of fog forming on the Columbia River at night, helping moderate the temperatures. The western Yakima Valley, Tri-Cities and Walla Walla Valley experienced the coldest temperatures, ranging from -16 to - 26 F. These temperatures were unusual in that the Tri-Cities had historically experienced more moderate temperatures relative to Alderdale Ridge and the Yakima Valley. Growers with fans were able to increase minimum temperatures on calm nights by about 4 degrees F in an 260 foot radius around the fans. This local moderation in temperature was sometimes the difference between total crop loss and a modest crop.

Complicating the issue of damage from the January-February freeze was a spring frost that subsequently occurred in early May in limited areas of the Yakima Valley and Alderdale Ridge. This frost damaged new shoots, either reducing crop further or eliminating it completely in a few blocks. It was

estimated that several hundred tons of Chardonnay, Chenin blanc, Gewürztraminer and Riesling were lost.

Trunk injury

Trunk phloem injury as rated by discoloration was universal throughout the region, with injury being slightly less in the warmer locations, for the more hardy cultivars (e.g. Riesling, Cabernet Sauvignon and Cabernet franc), and on the north sides of individual trunks. Injury dropped to zero below the snow line, which at the time of the freeze extended to about 6 inches above the soil line. Xylem injury as rated by discoloration was also widespread, but not as extensive as that to the phloem. The same pattern of xylem injury severity was observed as that for the phloem. Extensive xylem discoloration was observed for all cultivars throughout the Tri-Cities and Walla Walla Valley subregions where temperatures had been coldest. For this reason, growers in these subregions were advised not to prune until dieback could be accurately evaluated. Eventually, all blocks in the Tri-Cities and Walla Walla Valley except for a few of Cabernet Sauvignon were cut down and retrained during the 1996 season. The critical temperature that caused trunk loss appeared to be around - 15 F. The extent of discoloration to trunk xylem, but not phloem, appeared to be a good indicator of potential trunk loss.

Bud injury

Table 1 shows the range of primary and secondary bud survival observed in various cultivars throughout the Columbia Valley following the 1996 freeze. Several observations regarding bud survival can be drawn from this data. First, the range of survival varied greatly for a given cultivar, even within the same subregion. For example, Chardonnay primary bud survival in the Yakima Valley (YV) ranged from a high of 53% in vineyard 'WB' to a low of 5% in vineyard 'AS.' These differences were attributed most directly to the individual temperatures experienced at each site. Second, for those cultivars with wide distribution throughout the region, such as Chardonnay, Cabernet Sauvignon and Merlot, the pattern for survival was usually highest for Yakima Valley, lowest for Tri-Cities and intermediate for Wahluke Slope. This reflects a combination of minimum temperatures experienced in each subregion and at individual vineyard sites. Third, on average for all samples taken, Cabernet franc, Cabernet Sauvignon, Gewürztraminer and Riesling experienced the least damage, while Chenin blanc, Merlot, Sauvignon blanc, Semillon and Syrah experienced the most damage. Chardonnay was intermediate between these two groups. This reflects the relative cold hardiness of these cultivars, but to some extent also reflects their location distribution and exposure to different minimum temperatures. The most unusual feature of this cultivar injury distribution was the relatively high damage experienced by Chardonnay. The likely explanation was greater deacclimation of Chardonnay compared to other cultivars during a warm spell immediately preceding the freeze.

When primary and secondary growing points were compared for bud positions 1-5, on average the secondaries had about twice the survival rate as the primaries. This pattern has been observed in Washington State following previous freeze events. However, when survival of growing points was compared for positions 6-10, this ratio increased to about threefold. Due to lack of previous information for these more distal positions, It is uncertain whether this difference is common, unique to the 1996 event, or due to limited sampling.

Bud positions 6-10, and to very limited extent positions 11-15 (data not shown), were sampled because of observations made by other growers that greater survival rates were found for the more distal primary growing points. This was of particular interest for heavily damaged cultivars, such as Merlot, which had sustained very high mortality rates in positions 1-5. This was the reason that many growers supplemented bud numbers with canes. Although there were individual cases when this was found to be true (e.g. 'OL' Sauvignon blanc), it appeared to be more prevalent in blocks that had sustained intermediate levels (40-80%) of damage. Table 1 shows that for most individual blocks and for most cultivars on average, this relationship did not hold up. This is especially true when primary survival was less than 10% for positions 1-5. The two possible cultivar exceptions were Cabernet Sauvignon and Sauvignon blanc. However, these exceptions may be due to the limited sampling of the more distal

positions.

Pruning recommendations

Table 1 shows the type of pruning strategy applied to the recorded blocks. 'Spur' usually indicates bud adjustment following the formula described in the Procedures section. There were a few cases where blocks had been pruned prior to the freeze (i.e. 'FR' Merlot, 'SR' Riesling), in which case there was not opportunity to adjust bud number. 'Spur+Cane' and 'Hedge+Cane' indicates a combination of spur bud adjustment plus leaving two to four 12-bud canes. 'Hedge' means all or most one-year canes were pruned back to two or three-bud spurs with minimal effort at spur positioning. Two blocks (i.e. '7H' Cabernet Sauvignon and 'CR' Merlot) were left unpruned for the season. 'Retrain' means that there was no effort to crop the vines and the block was 'pruned' by severing the trunk at 6 inches and reestablishing the vine with ground suckers. Some vineyards with multiple blocks of the same cultivar (e.g. 'SS' Chenin blanc, 'BK' Merlot and 'BR' Lemberger) that experienced different levels of die-back are indicated by 'Spur +Retrain' or 'Hedge+Retrain.' There were a few cases where growers initially hedged vines, then adjusted spur number down after the level of bud and vine survival could be better assessed. One such case was 'OL' Riesling.

Crop estimation

Many blocks underwent a rigorous crop estimation procedure using whole vine cluster counting and weighing by destructive harvest in July. The results of this crop estimation were communicated to growers with thinning recommendations by late July of 1996. The accuracy of this process was evaluated by repeating the process pre-harvest and by harvest yields. The detailed results and discussion of this process will be not be reported here, but in a companion report. Although it tended to overestimate actual yields, it was extremely effective in identifying over-cropped blocks in need of thinning.

Yields

Target yields for red varieties were 4-5 ton/acre and for white varieties were 5-6 ton/acre. Most blocks were unable to achieve these targets due to winter damage and the inability of pruning adjustments to compensate sufficiently. As can be seen from the comment column in Table 1, many blocks ultimately did not produce a commercial crop either due to trunk removal and retraining or because the crop was too small to be harvested. However, the early May spring frost was responsible for eliminating crop in a few blocks (e.g. 'AS' and 'HO' Chenin blanc) where otherwise there had been considerable potential. This frost reduced the yields in several other blocks (e.g. 'HO', 'BK' and 'CX' Chardonnay, 'CX' Cabernet Sauvignon, 'SS' and 'AS' Gewürztraminer, 'HZ' and 'BK' Merlot, and several blocks of Riesling).

Evaluation of bud adjustment strategies to maximize yields: There was little incidence of vine 'collapse' as a result of leaving high bud numbers at pruning. Blocks that developed average to large canopies remained healthy even in midsummer heat. However, many of the more severely damaged blocks whose trunks were not removed produced erratic, sometimes stunted growth and marginal crops. This was regardless of the method of pruning or the number of buds left. Several Merlot blocks in the Yakima Valley fell into this category. In fact, it appeared that delaying pruning or leaving more buds produced healthier vines than early or severe pruning. Although the two unpruned blocks ('7H' Cabernet Sauvignon and 'CR' Merlot) grew relatively well and produced small crops, trunks were replaced after harvest using retained ground suckers because of loss of fruiting positions and concerns about the vines' long term productivity.

Bud adjustment by cane pruning compared to that by spur pruning or hedging did not add enough benefit to justify the increased cost. If canes were left in blocks with less than 10% primary bud survival (e.g. 'CW' Chardonnay, 'HZ' and 'CW' Merlot), it did not add significantly to cluster number or yield. Visual inspection of these blocks showed erratic bud-break and few clusters on the canes.

An exception was 'OL' Sauvignon blanc, one of the few blocks where higher bud survival was observed in more distal bud positions. Conversely, if cane pruning was applied to blocks with greater than 20% primary bud survival, it frequently resulted in congested canopies, excessive cluster numbers and over-cropping. Examples of this include 'WB' and 'ST' Chardonnay, 'WB', 'HI' and 'BK' Cabernet Sauvignon and 'HI' Merlot. Between 10 and 20% bud survival (e.g. 'RS' SB), cane pruning may have added some benefit.

The fate of hedge-pruned vines depended on the level of trunk survival. When applied to blocks with less than 10% primary bud survival, they produced little or no crop and often required retraining (e.g. 'SR' Chenin blanc, 'BR', 'SR' and 'CL' Chardonnay, 'GO-2' Cabernet Sauvignon, 'CP' Ge-würztraminer, 'AP' Sauvignon blanc, 'DH' and 'CW' Semillon). For blocks with 10-20% bud survival, results were mixed, sometimes producing modest crops (2-4 t/ha) and sometimes no crop. For vines in these first two categories, new growth came mainly from latent and basal buds on the cordon and from secondary and tertiary buds on the spurs. For blocks with more than 20% bud survival (e.g. 'HP' and 'GO-1' Cabernet Sauvignon, 'CR' and 'VS' Riesling), vines generally recovered and produced modest to large crops. Conclusions about hedge-pruning were somewhat clouded because several of these blocks (e.g. 'WB' Merlot, and 'OL' and 'RS' Sauvignon blanc) had bud numbers supplemented with canes. However, the method does appear to be the most cost effective solution in dealing with vines with less than 20% bud survival and long-term viability is uncertain. With greater than 20% bud survival, there is potential for overcropping as with cane-pruning. In this latter case, the ideal solution appears to be hedge-prune first, then thin out spurs after bud-break when crop potential can be better assessed. With a trained eye, the percentage of growth coming from primary, secondary and tertiary growing points on count buds can be assessed at bud-break.

For spur pruning, the application of the bud adjustment formula or its simplified version described in the Procedures section appeared to be quite effective when bud survival exceeded 25%. On a 1.8 m in-row spacing, normal bud numbers for Washington range between 28 and 45 per vine, depending on cultivar. At 25% bud survival, this placed the adjusted numbers at 84-135 buds/vine, the upper limit that can be achieved using three-bud spurs, and was equivalent to hedging. At intermediate bud survival and in absence of spring frost, growers were able to achieve target yields using this approach. Examples from Table 1 include 'WI' and 'ST' Cabernet franc, 'HP' and 'FR' Chardonnay, 'CN', 'CX', 'SS', 'SG' and 'FR' Cabernet Sauvignon, 'PE' Gewürztraminer, 'CX' Lemberger, 'SG' Merlot, and several blocks of Riesling. At the higher range of bud survival, bud number and crop potential became excessive, requiring cluster thinning.

Sucker management

Management of ground suckers proved to be a critical issue during the 1996 season. For heavily damaged blocks that were allowed to bear small but valuable crops, growers kept suckers for trunk replacement after harvest. Two suckers from below the snow line were trained up the old trunk and allowed to grow through the canopy and attached to foliage catch wires. This was done to avoid congestion in the fruiting zone. In many cases (e.g. 'BR', 'CW', and 'SW' Chardonnay, 'GO-2' Cabernet Sauvignon, and 'SS', 'HZ' and 'BR' Merlot), trunks were eventually replaced using these suckers. Although they proved valuable for producing crops in 1997, bud-break along these canes, especially for Merlot, was often very erratic and required further replacement between 1997 and 1998. Since bud mortality was very low in these canes, the poor bud-break was attributed to apical dominance developed by the vertical orientation of the suckers during the 1996 season.

Sucker management in blocks whose trunks were removed early in the 1996 season also proved important. In these blocks, growers cut off old trunks at 6 inches and trained up four or more suckers. The high number of suckers was used to devigorate vines. Growers typically followed one of two strategies for handling these vigorous shoots. The first, in an effort to economize, was simply to bundle the shoots together and allow them to grow vertically for the season. At pruning in 1997, suckers were thinned down to two to four healthy canes and tied horizontally to cordon and foliage catch wires.

Although inexpensive and straightforward, the problem of erratic bud-break along canes was again observed The second strategy, though more expensive, was to actively train suckers. during the 1996 season by attaching them horizontally to cordon and foliage wires and tipping them once they extended more than 24 inches down the wires. This produced well developed and positioned lateral shoots along the sucker. The following spring the lateral shoots were pruned to one-bud spurs spaced about 6 inches apart. Bud-break was more uniform, producing well-spaced spur positions and uniform fruit distribution.

Conclusions

Extreme winter temperatures present grape growers with a series of cultural practice decisions to optimize yield and minimize cost. These decisions include pruning, retraining and sucker management, irrigation, fertilization and pest management. The first and most important step is to assess bud and trunk injury and then develop a pruning strategy appropriate for the injury. Subsequent decisions will largely follow from the outcome of the first.

In 1996, the Columbia Valley of eastern Washington experienced temperatures in the range of - 8 to - 25 F that caused extensive damage to all V. vinifera cul-tivars in the region. Due to the recent expansion of the industry and severity of injury, appropriate response strategies were not well established. Different pruning strategies for optimizing yields and renovating vineyard blocks were developed and applied successfully. A combination of observed minimum temperatures and primary bud injury provided a useful guide for making these decisions. The critical values for these parameters were -15 F and 75% primary bud injury.

The best pruning strategy gave two options dependent on level of bud injury. For less than 75% primary injury, the most successful approach was to prune vines to two and three-bud spurs using a formula for bud adjustment taking into account viable primary and secondary growing points. Unless further damaged by spring frost or cutworms, blocks so treated went on to produce moderate to normal crops. Blocks at the high end of viability often required thinning, while those at the low end did not. These blocks went on to develop healthy, typical canopies requiring little change in standard cultural practices.

At 75-100% bud injury, 'hedge' pruning all one-year growth to two and three bud spurs gave the most economical results. This pruning decision could be delayed until well after bud-break to best assess dieback without ill effect. At the low end of this injury range, the trunk vascular system generally recovered and blocks so treated went on to produce low to moderate crops. At the upper end of this range, vines rarely recovered fully, resulting either in immediate dieback or weak, sporadic growth. In the former case trunks were removed early and multiple ground suckers trained up for replacements. In the latter case, two ground suckers. were trained up for trunk replacement following harvest.

Supplementing the above bud adjustments with canes added to pruning cost and rarely provided the desired crop. When used at bud injury levels below 75%, the result was canopy congestion and excessive crops requiring thinning. When left at higher injury levels, particularly above 90%, few buds pushed and little additional crop was realized. Between 80 and 90% injury, there were only a few cases and primarily for Sauvignon blanc, where benefit was realized.

Accurate crop estimations are perhaps more critical following winter injury situations due to the variability in crop levels. Levels can vary tremendously from block to block and within blocks. Vines with low to moderate damage tend to be overcompensated and should be the focus of these efforts. The method of midsummer cluster harvesting and weighing proved effective for identifying these blocks. This procedure has been refined since 1996 and has proven to be a valuable tool for crop estimation and adjustment.

Managing ground suckers for trunk replacement is the key to returning blocks with severe injury to full productivity. Whether it is working with multiple suckers following trunk removal or with two suckers being

kept for potential trunk replacement, suckers must be actively trained during the season they grow. Those suckers selected for replacements must be laid down horizontally so that strong lateral shoots develop in the future fruiting zone. Suckers so trained will produce better bud-break and cordon structure than those allowed to remain vertical as
they grow. Failing to do so is false economy. Standard practices for irrigation, fertilization, canopy management and pest control should be applied to blocks exhibiting general recovery following winter injury. For severely damaged blocks requiring retraining, all efforts should be focused on slowing growth and maximizing winter hardiness. Fertilization and irrigation should be reduced or eliminated, and maturing suckers should be protected from late-season mildew.

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