AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
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TITLE: Developing New Cherry Bud Hardiness Charts to Aid Crop Protection Decisions

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SUMMARY:
The critical temperatures associated with 10%, 50% and 90% flower-bud mortality were determined for a subset of sweet cherry cultivars throughout spring development. A consistent relationship was observed between developmental stage and critical temperature over several years of evaluation. With the exception of 'Regina', critical temperatures were similar among all cultivars evaluated for a specific developmental stage. Developmental differences among cultivars, however, resulted in perceived differences in bud hardiness on a given date. 'Regina' was markedly delayed in development and significantly hardier (by ~6°F) than other cultivars at early phenology stages (i.e., first swell and side green); however, for advanced developmental stages (i.e., between green tip and bloom) critical temperatures of 'Regina' could not be distinguished from the other cultivars. Artificial manipulation of temperatures at early bud stages indicated that flowers could 'gain' ~3°F of hardiness per day if temperatures remained below freezing. Exposure of buds to higher temperatures (50°F) did not affect hardiness levels at early stages.

OBJECTIVE: Develop cherry bud hardiness charts for sweet cherry growers of Oregon

PROCEDURES:
Differential thermal analysis and visual inspection of cherry buds. Weekly experiments were conducted between January and March to determine the kill points of sweet cherry flower buds. Buds were photographed then placed in programmable freeze chambers and frozen at 1°C per hour. Differential thermal analysis (DTA) was performed on early bud stages using a high-throughput system comprised of thermo-electric modules (TEMs) wired to a data logger and computer. Advanced bud stages were visually examined under a stereo-zoom dissecting microscope for ovary browning. Curves were generated by fitting the data to mathematical functions. Critical temperatures relating to 10%, 50% and 90% bud kill were then estimated from the line equation. Photographs of buds were used to scale their developmental bud stage (i.e., phenology stage). Phenology stages were related to critical temperatures to develop a sweet cherry critical temperature bud chart.

Temperature requirements for growth and development. Limb sections containing reproductive spurs and flower buds were exposed to a range of temperatures (14°F to 50°F) using programmable freeze chambers and other controlled environment chambers . These preconditioning experiments were designed to test the effect of preceding temperatures on flower hardiness and development. After preconditioning periods were satisfied (24, 48 and 72 h), kill points were determined using the procedures outlined above.

SIGNIFICANT ACCOMPLISHMENTS:

Phenology and flower bud hardiness. We were successful determining and reproducing critical temperatures of sweet cherry flower buds for each phenology stage using a diverse subset of sweet cherry cultivars. Differences in bud mortality among sweet the cherry cultivars 'Skeena', 'Sweetheart', 'Rainier', and 'Bing' at any given phenology stage were not significant. Flower buds of 'Regina', however, were significantly hardier during dormancy and early bud swell. After bud swell, the critical temperatures of 'Regina' were similar to other cultivars. A broader cultivar assessment performed at Stage 0 (dormant) confirmed our previous data for 'Regina' (**Fig. 1**). All other cultivars froze within 2 degrees of each other and did not significantly differ from one another.

Pre conditioning. We also exposed buds to sub-freezing temperatures (14° F) for 48 h to determine whether or not flowers could responds by increasing their hardiness as similarly documented for other species. For all cultivars, flowers gained ~3° F hardiness per day (**Fig. 1**). These data help to explain the observation that bud survivability during extended freeze events tends to be greater than that predicted by bud charts.

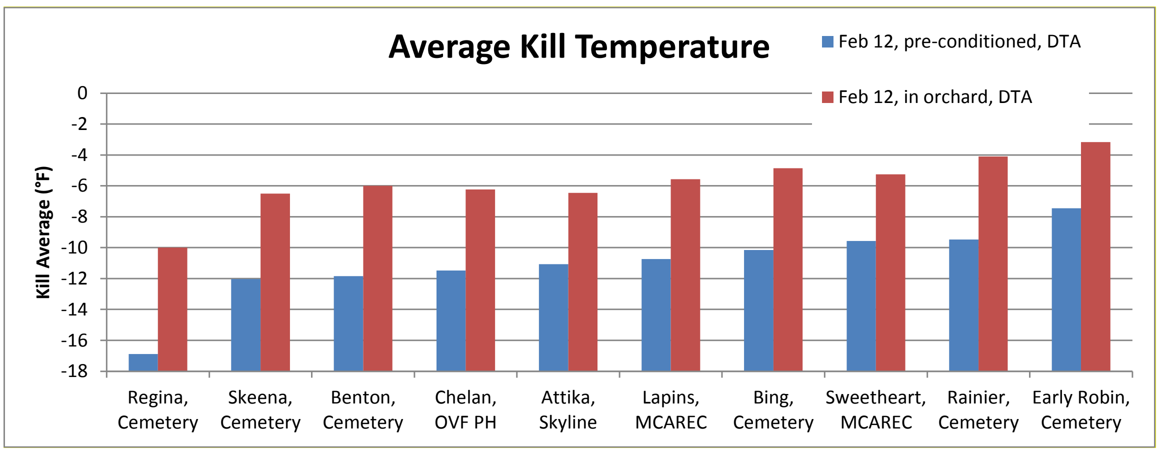


Figure 1. *Maximum hardiness level (dormancy) of 10 cultivars. Limbs containing spurs and flower buds were either frozen in a programmable freeze chamber directly after harvest from the orchard (red data bars), or placed at 14°F for 48 hour (pre-conditioned, blue bars) and then frozen.*

For 'Regina', we tested this idea further by exposing buds to 14°F, 30°F, or 50° F for a 56-hour period. Buds that were preconditioned at 14°F gained ~3° F of hardiness per day as previously observed (**Fig. 1**). A preconditioning environment of 30°F was apparently insufficient to elicit a similar response and did not differ from the 50° F preconditioning treatment (**Table 1**). While thermocouples appressed to buds indicated 30°F temperatures, internal tissues and organs probably remained unfrozen. While warm temperatures have been associated de-acclimation, this was clearly not the case for sweet cherry during dormancy. In this same experiment, we also evaluated the effect of freeze rate on hardiness. Buds that were frozen at a faster rate (1.8°F per hour vs. 7.2°F per hour) were killed at much higher temperatures, irrespective of their preconditioning treatment (**Table 1**). A slow rate of freezing purportedly provides additional time for protective processes to occur- water migration out of flower buds to extracellular (non-injurious) ice masses and the supercooling of water. Hence, freeze rate is an important factor that modulates bud hardiness and will need to be considered when interpreting bud hardiness.

Table 1. *'Regina' buds collected from the orchard in mid-February (still dormant) and placed in 14°F, 30°F, and 50°F chambers for 56 hours prior to being frozen in a programmable freeze chamber at either a fast (7.6° F per hour) or slow (1.8° F) rate.*

Preconditioning Regime (56 hrs)	***50% kill***
14F pre-cond, 1.8F per hr rate	**-14 F**
14F pre-cond, 7.2F per hr rate	**-7 F**
30F pre-cond, 1.8F per hr rate	**-7 F**
30F pre-cond, 7.2F per hr rate	**1 F**
50F pre-cond, 1.8F per hr rate	**-7 F**
50F pre-cond, 7.2F per hr rate	**-1 F**

Dynamic shifts in hardiness and (Eco-) dormancy break. While the data in Figure 1 and Table 1 provide necessary information to develop a holistic understanding of bud hardiness at Stage 0, they are fairly static and cannot be extrapolated to other developmental stages. We are equally interested in identifying the developmental time when cherry buds can no longer gain hardiness when exposed to sub-freezing events. We addressed this question by preconditioning limbs at weekly intervals beginning at Stage 0 through bloom. We selected Bing and Regina, given that Bing adequately represents a multitude of cultivars. Flower buds maintained the capacity to gain hardiness during a 72-h exposure to sub-freezing temperatures up to ~side green/green tip (Stage 2 to 3), at which point they could no longer harden below their orchard-condition average kill temperature (**Fig. 2**). Interestingly, no differences were observed in hardiness for buds held at 41°F or 50°F throughout development. The increased hardiness of Regina was once again notable. These data also indicate the release of eco-dormancy (i.e., upward inflection of the LT_{50} vs. date curve) and represent a critical period for modeling the growth and development of cherry (complimentary project).

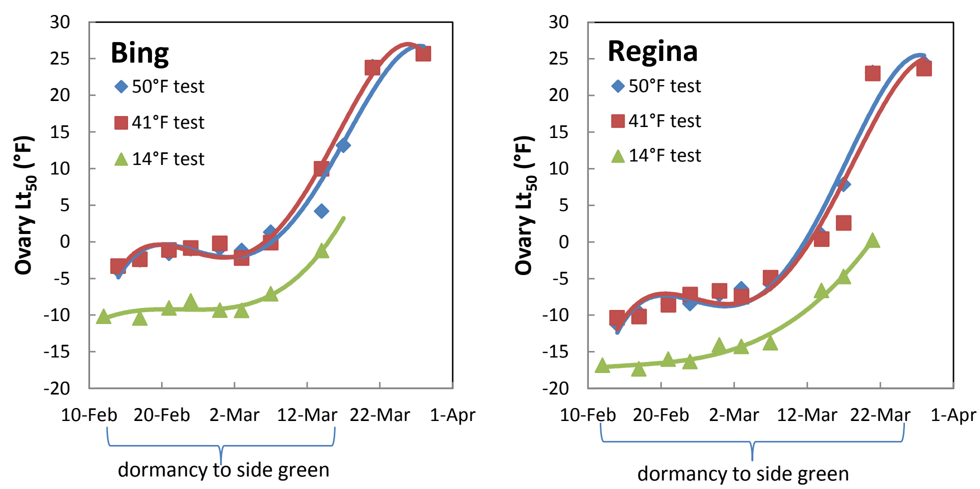
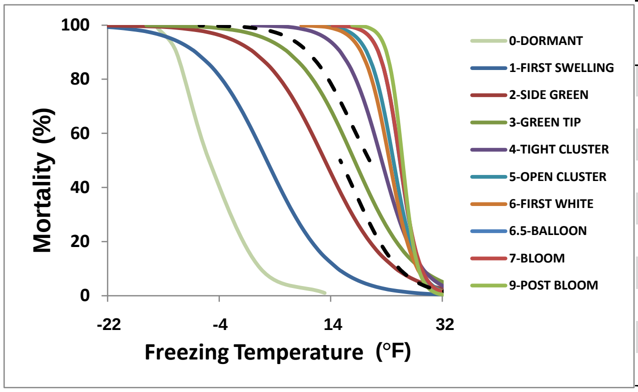


Figure 2. *Kill points of Bing (left) and Regina (right) flower buds after exposing limbs to 14, 41 or 50°F for ~72 hours. Hardiness is expressed as the lowest temperature to kill 50% of buds (Lt_{50}) using DTA.*

Bud hardiness charts. We have generated new bud charts for sweet cherry and are developing an OSU Extension Bulletin that will produce updated information for cherry producers based on the data generated via this report (**Fig. 3 & Table 2**).



Bud Stage	Phenology Description	Critical temperatures (F°) 10% bud kill	50% bud kill	90% bud kill
0	dormant	**3**	**-4**	**-21**
1	first swell	**15**	**4**	**-7**
2	side green	**25**	**13**	**2**
3	green tip	**29**	**18**	**7**
4	tight cluster	**29**	**22**	**16**
5	open cluster	**29**	**24**	**19**
6	frist white	**29**	**24**	**19**
7	balloon stage	**29**	**25**	**22**
8	full bloom	**29**	**25**	**22**
9	post-bloom	**29**	**26**	**23**

Figure 3 and Table 2. *Critical temperature associated with mortality of sweet cherry flowers throughout development. The black, dashed line bracketing the green tip curve is the 95% confidence interval. The table shows the critical temperature for 10%, 50%, and 90% bud mortality. Not all commercial cultivars were evaluated. Sweetheart, Skeena, Regina, Rainier, and Bing were systematically evaluated at all bud stages in separate or consecutive years. Additional cultivars were assessed periodically at specific developmental stages. The bud chart above accurately reflects the critical temperatures throughout development for all cultivars evaluated except Regina. For Regina, flower buds at dormant, first swell and side green developmental stages were ~5°F hardier than the chart predicts. For stages 3-9, Regina does not differ from the other cultivars evaluated.*

BENEFITS & IMPACT:

Background: Over the past several decades the sweet cherry industry has become vertically integrated. Presently, growers select from many new cultivars that were bred to improve profitability, primarily by expanding the harvest season. A systematic assessment of the bud hardiness of these cultivars, however, did not accompany their commercialization. Growers have described discrepancies between the levels of bud-kill observed following freeze events from that predicted by past bud charts developed using antiquated cultivars.

Results, benefits and impacts: The information that was generated, in part, from this project will result in an updated critical temperature bud chart for current commercial sweet cherry cultivars. Detailed information regarding the cultivar Regina will support decisions for establishing and managing the cultivar. The entire Pacific Northwest cherry region will benefit from possessing up-to-date information.

ADDITIONAL FUNDING RECEIVED: 'Detection of winter and spring bud hardiness in pear and sweet cherry cultivars', funded by the Columbia Gorge Fruit Growers Commission for $21,668 (2013), $22,275 (2014) and $22,900 (2015).

FUTURE FUNDING POSSIBILITIES: We are CO-PIs on a 2016 NIFA-USDA-SCRI proposal entitled, 'Mitigating cold damage in fruit crops'. We have assembled a national, multi-disciplinary team with the primary focus of elucidating the molecular mechanisms and physiological factors that promote cold resistance (or sensitivity) and the development of models to predict injury and inform tree fruit and grapevine management decisions. The requested budget is $6.7 million. We received notice in January 2016 that the proposal was voted on favorably by the stakeholder review panel and advanced to the full-proposal stage.