ACCELERAREA RECUPERĂRII POMILOR FRUCTIFERI ȘI A VIȚEI DE VIE DUPĂ ÎNGHEȚ
ACCELERATING RECOVERY IN FRUIT TREES AND GRAPEVINES AFTER FROST

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Abstract

Frost events during winter and early spring pose a significant threat to the productivity of fruit trees and grapevines by injuring reproductive and vegetative tissues. The severity of frost damage is closely linked to the species, cultivar, and phenological stage at the time of exposure. Bud mortality rates increase with developmental progression, with critical damage thresholds ranging from approximately –17 °C in dormant buds to –4 °C during full bloom in various tree fruits. Grapevine tissues, particularly young shoots, are sensitive to temperatures near –1 °C. Accurate assessment of frost injury is crucial for determining appropriate recovery strategies, which often include targeted pruning, regulated irrigation and nutrient management, and application of plant growth regulators to stimulate regrowth and fruit set. This review summarizes current knowledge of critical frost injury temperatures, diagnostic approaches, and horticultural practices aimed at facilitating recovery and compensatory yield formation. Gaps in understanding cultivar-specific thresholds and validated intervention protocols are highlighted.

Cuvinte cheie: daune provocate de îngheț, toleranța mugurilor la frig, praguri de afectare a mugurilor, tăiere de regenerare, recuperare după stres, răspunsul viței de vie la îngheț
Key words: frost injury, bud cold tolerance, bud damage thresholds, recovery pruning, stress recovery, grapevine frost response

1. Introduction

Frost (freeze) damage represents a significant threat to temperate fruit crops, particularly during unexpected late-spring frosts or extreme winter freezes. Such events severely affect fruit production by causing death of flower and leaf buds, damaging young fruits and leaves, and disrupting vascular tissues, leading to substantial yield losses. Damage severity is influenced by several factors, including the minimum temperature reached, duration of the cold event, developmental stage of the plant, and the specific species or cultivar involved (Mertz, 2020; Longstroth, 2021). Understanding these factors and their interactions is crucial for informed frost management and recovery.

With increasing climate variability and more frequent extreme weather events, the risk of frost damage to fruit crops has become more pronounced, underscoring the need for effective mitigation and recovery strategies. The variation in frost sensitivity among species and phenological stages complicates establishment of universal injury thresholds. For instance, apple buds at the half-inch green stage sustain up to 90% damage at temperatures around –12 °C (Longstroth, 2021), whereas the threshold temperature for full bloom may be as high as –4 °C (Anonymous, 2025). This variability underscores the complexity of frost damage management, requiring consideration of both species and developmental stage when assessing frost impact.

Effective recovery from frost damage requires a multifaceted approach, including careful assessment of plant health and implementation of targeted horticultural practices. These practices typically focus on identifying and preserving viable tissue, reducing damage through timely pruning, optimizing irrigation and nutrition to support regrowth, and applying biostimulants or hormones to enhance plant resilience (Torres and Miarnau, 2024; Sherif, 2025). In addition, management of pest and disease pressures that may exacerbate frost injury is necessary. Understanding and implementing these recovery strategies is critical for minimizing yield losses and ensuring long-term crop sustainability.

This review summarizes current knowledge of frost damage thresholds in various fruit crops (including apples, grapes, and other temperate species) by developmental stage. It also reviews methods for assessing frost injury, including visual inspection and laboratory testing techniques. The discussion then focuses on recovery strategies such as pruning, irrigation and nutrient management, the application of biostimulants and hormones, and pest control, drawing on recent research and extension literature. By providing evidence-based guidance, this review aims to help growers improve their response to frost events and minimize associated losses.

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2. Frost injury thresholds and symptoms

Dormant buds can survive temperatures well below –6 °C (Fiola, 2023), but susceptibility rises sharply as buds begin to swell. Bud-break stages typically incur damage in the mid-20s °F (around –4 °C), and young shoots with three to four unfolded leaves become vulnerable at approximately 30 °F (–1 °C) (Purcell, 2022). Consequently, late-spring frosts near 28–30 °F (–2 to –1 °C) often cause significant damage in many cultivars.

Bud cold tolerance declines rapidly during development. Critical temperature thresholds for injury have been quantified across temperate fruit species and phenological stages. Table 1 summarizes the average temperatures at which 10% and 90% bud mortality occur under typical spring frost conditions, offering a practical framework for frost risk assessment during vulnerable growth phases. To complement these data, Figure 1 illustrates the comparative 10% and 90% kill thresholds at full bloom across selected fruit species, highlighting interspecies variability in frost sensitivity during this critical stage.

Environmental conditions preceding a frost event (especially prolonged cool weather) can temporarily increase bud hardiness. However, during rapid bud expansion and bloom, susceptibility to freezing injury increases markedly. The temperature values in Table 1 are primarily derived from radiation-frost scenarios; under advective (wind-driven) frost conditions, actual injury may exceed these expectations.

Frost injury is typically identified by browning or blackening of sensitive tissues. In apple and cherry blossoms, pistils and anthers turn dark brown or black following a freeze (Larsen, 2010). Cross-sectional examination of frozen flower buds often reveals necrotic pistils and desiccated petal bases (Larsen, 2010). Within frozen buds, internal damage may appear as water-soaked or necrotic tissue, even while outer bud scales appear intact. Injured buds often fail to open, and affected fruitlets frequently abort or mummify.

On developing tree fruits, frost rings (russeted circular scars on young fruit) may form around areas of partial freezing. Frost damage can also manifest as patchy bud mortality along shoots. In grapevines, frost effects are commonly observed as bud necrosis on cordons, with entire shoots wilting after freezing. A practical field diagnostic is to slice buds to compare live (green) versus dead (brown) tissue. The full extent of injury may not become apparent until 24–48 hours after the frost event, as surviving buds swell and shoots begin to emerge (Fiola, 2023).

3. Frost damage assessment methods

Both qualitative and quantitative methods are used to assess frost injury in the field and laboratory. Simple visual inspections are widely applied. For example, buds and flowers can be dissected to check for brown or black tissue, a classic indicator of freezing injury (Larsen, 2010). In sweet cherries, horizontal sections of flower clusters can reveal the ratio of dead (brown) to live (white) florets (Larsen, 2010). In apple and pear buds, cross-sections of flower buds display the central “King” bloom pistil; a browned King pistil alongside white side blooms indicates partial injury (Larsen, 2010). General tissue discoloration (in stems, wood, leaves) is also noted in both field observations and controlled tests (Yu and Lee, 2020). For example, Ehlenfeldt et al. (2006) documented blueberry buds turning black after freezing (Yu and Lee, 2020, Fig. 1). Visual evaluation is reliable but inherently qualitative, and it requires time (typically several days) for symptoms (such as browning) to fully develop after thaw (Yu and Lee, 2020).

Quantitative laboratory assays can supplement visual checks. A standard test is electrolyte leakage: plant tissue samples (buds or shoots) are frozen under controlled conditions, then thawed in distilled water, and the electrical conductivity of the solution is measured (Yu and Lee, 2020). Damaged cells lose membrane integrity and leak ions, increasing the solution’s conductivity. The percentage of injury at each temperature is calculated by comparing conductivity before and after complete tissue kill. This method is simple, rapid, and requires only small samples (Yu and Lee, 2020). It has been widely used in fruit crops (grape, peach, blueberry, etc.) to determine the LT_{50} temperature (the temperature causing 50% injury) (Yu and Lee, 2020). Similarly, TTC (triphenyl tetrazolium chloride) assays are employed: living cells reduce colorless TTC to red formazan, so that the intensity of staining (or spectrophotometric extraction of formazan) indicates the fraction of viable tissue (Yu and Lee, 2020). TTC-based tests are common in cold-hardiness studies of woody plants, although the colorimetric response can vary among tissue types (Yu and Lee, 2020).

Thermal analysis techniques (e.g., differential scanning calorimetry or NMR imaging) are primarily research tools for studying cold acclimation and freezing processes (Yu and Lee, 2020). For immediate on-farm decisions, one practical test is a “forced regrowth” assay: cut shoots bearing buds are placed in water at room temperature, and living buds will swell and bloom within days to weeks, revealing viable flowers without microscopy (Larsen, 2010). In summary, combining visual inspections (bud cuts, blossom evaluation) with optional laboratory assays provides a robust basis for estimating frost damage (Yu and Lee, 2020).

4. Post-frost recovery strategies

After frost injury is confirmed, the objective is to stimulate recovery of healthy tissues and optimize the remaining crop. Effective recovery strategies overlap in the short and longer term. Crucial tactics include careful pruning, irrigation and nutrient adjustments, use of biostimulants or hormones, vigilant pest and disease control, and crop-load management. Each is discussed below, noting differences among crop types.

4.1. Pruning

Pruning is one of the most critical responses to frost damage. It removes dead wood (thereby reducing disease risk), restores tree balance, and opens the canopy for light and new buds. However, timing and severity are crucial. It is advised that pruning be delayed until after bud swell but before bloom (Mertz, 2020). Shane (MSU Extension) cautions that pruning too early (in late winter) can prematurely break dormancy and expose trees to subsequent freeze events, whereas pruning too late (after bloom) stresses trees that have only a limited leaf area (Mertz, 2020). The optimal “window” is between green tip and full bloom: once living buds are confirmed, dead limbs should be removed.

Pruning severity should be moderate. Extreme rejuvenation (e.g., “flat-top” pruning in the same season) should be avoided. Shane recommends limiting cuts to no more than roughly 25% of the tree’s branches at one time (Mertz, 2020). Similarly, Longstroth advises that even severely cold-damaged trees often require pruning of only 25–33% of scaffolds and cautions that removing all older scaffolds is “way too brutal” (Mertz, 2020). In practice, the guiding principle is to remove as much dead tissue (indicated by brown cambium) as necessary, while retaining about 70–75% of the canopy to support recovery (Mertz, 2020). Conversely, neglecting pruning entirely can also be harmful: if a tree has no fruit, leaving it unpruned may allow its fruiting zone to shift upward unchecked (Mertz, 2020). Thus, balance is key: even in a fruitless year, moderate thinning is recommended to maintain structural integrity.

Determining which branches to prune can be guided by examining cambial color. Slicing a small branch reveals that green or cream-colored wood indicates live tissue, whereas brown or black wood indicates kill (Mertz, 2020). Branches should be cut back to healthy wood, removing entire shoots or limbs that show inner browning. In stone fruits, it may be necessary to remove whole canes if tip kill is evident. In apples and pears, spurs may be cut back to a lower spur or lateral that shows live buds. In cherries, where buds are clustered, multiple cross-cuts may be needed to verify live flowers within a cluster (Larsen, 2010). Over-thinning should be avoided: trees pruned too severely may experience canopy imbalance and require extra energy to regrow, further delaying return to full productivity (Mertz, 2020). The overarching advice is to “avoid extremes” in both timing and severity of pruning (Mertz, 2020).

If frost has caused structural injuries (such as trunk splitting, especially in peaches), immediate attention may be needed. If splits are detected soon after freezing, the loose bark can be nailed back into place to support healing (Mertz, 2020). For older splits, the peeled bark should be trimmed away, and clean cuts should be made just beyond the wound to encourage callus formation (Mertz, 2020). In all pruning and repair operations, tools should be sanitized and wounds protected. For example, after repairing a trunk split, a systemic insecticide or boron spray can be applied to deter borers that attack damaged wood (Mertz, 2020). Michigan State Extension specifically recommends trunk sprays against peach and dogwood borers on winter-injured trees (Mertz, 2020).

In grapevines, pruning plays a slightly different role because vines fruit on 1-year-old wood. If buds on a cane are killed, the cane may be removed and replacement shoots trained from secondary buds or new canes. Grapevines often do not require immediate spring pruning after a frost event; pruning decisions are typically made during dormancy based on which buds survived. However, leaving extra buds (“spare parts”) during pruning can serve as insurance: these buds can produce fruit if primary buds fail (Fiola, 2023).

4.2. Irrigation and nutrient management

Frost injury can significantly disrupt a tree’s water and nutrient transport. Damaged tissues may obstruct xylem or phloem flow, and the loss of leaf area impairs transpiration and water uptake. Therefore, maintaining adequate soil moisture is crucial for promoting recovery and supporting new growth. Irrigation (or rainfall) should be maintained to support the expansion of surviving buds and development of new leaves, since avoiding drought stress is critical. Conversely, over-irrigation should be avoided, especially if roots or bark have been damaged by freezing. Following severe winter freezes, deep watering in early spring may stimulate growth of fine roots, thereby enhancing nutrient uptake needed for recovery.

Fertilizer applications should be adjusted to match the tree’s reduced crop load. A widely recommended approach (derived from citrus management) is to apply nutrients in smaller doses but more frequently, scaled to the extent of damage and expected yield (Zekri et al., 2016). For example, if roughly 50% of buds are lost, one strategy is to apply about 50% of the normal NPK rate in multiple light dressings throughout spring and summer. This ensures that nutrients remain available for regrowing shoots and any surviving fruit without promoting excessive vegetative growth that could deplete the tree's reserves. Adequate potassium and calcium should be supplied to strengthen tissues and promote wound healing. Over-fertilization (especially with nitrogen) should be avoided, as excessive nitrogen can stimulate tender new growth that is vulnerable to additional cold injury. Soil or leaf tissue tests can guide fertilizer rates in the season following the frost event.

If foliage has been burnt by frost or bark freezing is evident, foliar nutrient sprays can provide immediate supplementation. For example, foliar applications of calcium or seaweed extract (which contains cytokinins and other beneficial nutrients) are commonly used in frost-impacted orchards to enhance cell wall integrity and support recovery. Frost events may also reduce fruit load. In such cases, potassium applications should be scaled back (since potassium promotes fruit growth) while maintaining balanced nutrition to support vegetative recovery. The primary objective is to meet the tree's requirements under a reduced canopy: irrigation should prevent moisture stress, and moderate fertilization should facilitate recovery without overstimulating the plant (Zekri et al., 2016).

4.3. Biostimulants and hormonal aids

A variety of biostimulants and growth-regulating products can support recovery and compensate for crop loss. These include seaweed extracts, amino acid complexes, vitamins, and plant hormones. Some of these products improve cold tolerance prior to a frost event, whereas others promote growth or fruit set without the need for fertilization.

A well-established recovery practice in apples is the post-freeze application of a gibberellin–cytokinin mix (e.g., Promalin®, Perlan®). These sprays replace hormonal signals normally provided by fertilized seeds. When flowers are partially damaged but still alive, a combination of GA_{4+7} with 6-benzylaminopurine (6-BA) can induce parthenocarpic (seedless) fruit development. Field trials and extension reports indicate that such treatments can recover on the order of 20–30% of yield in a severe frost year (Sherif, 2025). Sherif (2025) notes that applying GA_{4+7} + 6-BA within 1–2 days after a frost or hail event stimulates cell division and enlargement in flowers that would otherwise abort, resulting in seedless fruit of acceptable quality. Therefore, when live blossoms remain after a frost, an immediate post-frost Promalin spray is recommended to maximize fruit set (Sherif, 2025). It must be noted that this treatment does not restore buds that are completely killed, but it maximizes the potential of surviving flowers. Parthenocarpic fruit produced via this treatment are edible, although typically smaller.

Other hormonal or nutrient sprays may also be beneficial. Cytokinins alone (such as 6-BA) can enhance cell division in surviving buds, while auxins and brassinosteroids may improve shoot vigor. Some growers apply amino acid or seaweed extracts after frost events, reporting accelerated shoot flush and flowering. Although field data remain limited, controlled studies suggest that certain antioxidant-rich biostimulant mixtures (e.g., formulations containing α-tocopherol, boron, or glycols) applied before freezing can lower the lethal temperature by approximately 1–3 °C in peach and almond flowers (Torres and Miarnau, 2024). This implies that similar products could mitigate post-freeze stress by protecting cells against oxidative damage. Further research is needed to confirm these effects, but the principle is that enhancing antioxidant status and membrane stability enables buds to better tolerate or recover from near-freezing injury (Torres and Miarnau, 2024).

In all cases, timing of application is critical. Biostimulant and hormonal sprays are most effective when applied immediately after the frost event (ideally within 24–48 hours), while buds are still hydrated but have not yet opened (Torres and Miarnau, 2024; Sherif, 2025). Delaying application for weeks is not recommended, and such treatments should not be applied during cold, wet weather, as absorption may be limited under those conditions. In summary, growth regulators (GA + BA) should be considered to support fruit set, whereas nutrient and vitamin extracts (such as seaweed and magnesium sulfate) are recommended to improve overall vigor. These treatments should be viewed as supplemental measures, not cures, since they only affect surviving tissue.

5. Pest and disease control

Frost injury often predisposes trees to increased vulnerability from pests and diseases. Exposed cambium and decaying tissues can attract insects and pathogens. Therefore, sanitation and protective sprays are essential. As noted above, preventive insecticide or boron sprays should be applied to trunk wounds to deter wood-boring insects (Mertz, 2020). Similarly, a broad-spectrum fungicide is advisable to protect against opportunistic pathogens. For example, if blossoms have been killed or damaged, application of a fungicide (e.g., captan in apples/pears) during and after bloom can protect open flowers and developing fruit from infection. In cherries and peaches, latent brown rot spores on petals can infect young fruitlets once petals brown, so fungicide applications during bloom and immediately post-bloom are recommended (consult local spray guides for timing). If foliage has been frost-scorched, monitoring for mildew and rust is important; a light sulfur spray may be used under conditions favorable to those diseases.

Bacterial diseases also require attention. Frost-injured blossoms can mimic fire blight symptoms (blossoms turned brown). If blossom blight or shoot blight is suspected, antibiotic or streptomycin treatments should be applied following extension guidelines. Pruning tools should be sanitized to prevent spreading pathogens from damaged areas. For sunburned or frost-damaged bark, tar-based wound dressings should be avoided, as they can exacerbate injury. Instead, keep wounded areas clean and monitor for canker development.

Pests often thrive on stressed plants. Codling moth (and other fruit moths) or plum curculio may target swollen buds or scarred fruit, so early monitoring and control are recommended if population thresholds are met. Aphids and scale insects may proliferate on the vigorous new growth that follows crop loss, necessitating regular scouting. In summary, pest management should continue even in a low-yield year: frost-damaged plants are often more susceptible and maintaining a normal (or slightly intensified) spray regime on emerging tissues is important.

6. Crop-load and yield management

After severe bud loss, the resulting crop will be light and uneven. Adjustments can help balance the load on remaining fruit and set the stage for future recovery. In tree fruits, any surviving fruit should be managed carefully: thinning should be light so as not to overload the few remaining limbs, but overly aggressive thinning should be avoided given the reduced flower set. Conversely, if only a few flowers have set, thinning should be omitted to ensure all potential fruit are retained. Cultural techniques such as girdling or potassium sprays can help concentrate carbohydrates into the small remaining crop. For example, some apple growers use girdling or foliar calcium sprays to increase the size of the few retained fruits.

If an entire orchard block suffers heavy bud kill (i.e., little to no fruit set), planning for orchard renewal is advisable. In peach or nectarine blocks with little remaining fruit, rejuvenation pruning can be carried out in the next dormant season by cutting back to 1–2-year-old wood to stimulate new growth. Extension advisors caution against immediate harsh topping following a frost event (Mertz, 2020); instead, they recommend waiting until winter to assess tree survival before undertaking renewal pruning. In older or less productive trees, options such as replanting or top-working should be considered, since severe frost events often prompt such decisions.

In grapevines, compensation often occurs via development of multi-bud canes. Vines frequently “bounce back” from spring frost because secondary buds on the cane can produce a crop if primary buds fail. Fiola (2023) notes that each grape bud contains primary, secondary, and tertiary florets, allowing the vine to still yield some fruit on secondary parts if the main cluster is lost. Vines may also compensate by increasing berry size or reducing cluster compactness when clusters are few. Proper canopy management in the preceding season (maintaining open canopies and strong bud development) enhances this recovery capacity (Fiola, 2023). If a late frost damages fruit on a cane, growers might leave the shoot unpruned to allow lateral shoots to develop (“back-budding”), or remove the damaged cane and rely on fruiting spurs from an older cordon. Shoot and cluster thinning decisions should be revisited under these circumstances: vines that have lost their main buds may benefit from retaining any surviving berries to maximize sugar accumulation.

In all crops, it is prudent to retain a subset of buds as “insurance” against frost. Some stone-fruit training systems maintain two sets of buds per spur so that if one flush is killed, the next can still yield some fruit. Viticultural practices similarly employ extra “spare” canes or buds (Fiola, 2023). If bloom has already passed and losses are high, supplemental pollination (e.g., hand pollination) will not be effective. Instead, it is essential to ensure that any surviving blossoms are fully fertilized.

Finally, managing expectations and resources is important. A reduced crop allows for more aggressive pruning to restructure the tree or vine, but it also means reduced revenue. Fertilizer and pest management programs should be adjusted for the lighter crop, and investments should be made in improving overall tree or vine health (e.g., soil amendments, nutrition, and training) to better withstand the stress of the current year. Often, a frost year is followed by a heavy bloom in the next season (a biennial-like effect), so plans should be made to thin the excess fruit in the subsequent year.

7. Conclusions

Frost injury remains a critical constraint on the sustainable production of temperate fruit crops. Successful recovery depends on a timely combination of accurate damage assessment, adaptive pruning practices, and targeted cultural interventions that support regrowth and minimize further stress. Although

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practical measures such as delayed pruning, retention of surplus buds, and supportive fertilization are commonly applied, their effectiveness often varies depending on species and developmental stage. Biostimulant and hormonal applications offer promising supplementary tools, but their outcomes require further validation under diverse climatic and cropping conditions.

To optimize frost management, a deeper understanding of crop-specific tolerance thresholds, regrowth dynamics, and the long-term impacts of recovery interventions is essential. Moreover, aligning field practices with evolving climate patterns will be increasingly important. A multidimensional approach that integrates physiological knowledge with adaptive agronomy holds the most promise for ensuring the resilience and productivity of fruit orchards in frost-prone environments.

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Tables and figures

Table 1. Critical spring temperatures for tree fruit bud development stages (Approximate temperatures for 10% and 90% kill)

Apples	Silver Tip	Green Tip	Tight Cluster	First Pink	Full Pink	First Bloom	Full Bloom	Post Bloom
Old temp. (°C)*	-8.9	-8.9	-2.8	-2.8	-2.2	-2.2	-1.7	-1.7
10% kill (°C)	-9.4	-7.8	-2.8	-2.2	-2.2	-2.2	-2.2	-2.2
90% kill (°C)	-16.7	-12.2	-6.1	-4.4	-3.9	-3.9	-3.9	-3.9
Pears	Bud Swell	Bud Burst	Tight cluster	First White	Full White	First Bloom	Full Bloom	Post Bloom
Old temp. (°C)	-7.8	-5.0	-4.4	-2.2	-1.7	-1.7	-1.7	-1.1
10% kill (°C)	-9.4	-6.7	-4.4	-3.9	-3.3	-2.8	-2.2	-2.2
90% kill (°C)	-17.8	-14.4	-9.4	-7.2	-5.6	-5.0	-4.4	-4.4
Apricots	Bud Swell	Bud Burst	Red Tip	First White	First Bloom	Full Bloom	In the Shuck	Green Fruit
Old temp. (°C)	—	-5.0	—	-3.9	—	-2.2	—	-0.6
10% kill (°C)	-9.4	-6.7	-5.6	-4.4	-3.9	-2.8	-2.8	-2.2
90% kill (°C)	—	-17.8	-12.8	-10.0	-7.2	-5.6	-4.4	-3.9
Peaches	Bud Swell	Calyx Green	Calyx Red		First Pink	First Bloom	Full Bloom	Post Bloom
Old temp. (°C)	-5.0	—	—		-3.9	—	-2.8	-1.1
10% kill (°C)	-7.8	-6.1	-5.0		-3.9	-3.3	-2.8	-2.2
90% kill (°C)	-17.2	-15.0	-12.8		-9.4	-6.1	-4.4	-3.9
European Plums	Bud Swell	Side White	Tip Green	Tight Cluster	First White	First Bloom	Full Bloom	Post Bloom
Old temp. (°C)	—	—	—	—	-5.0	-2.8	-2.8	-1.1
10% kill (°C)	-10.0	-8.3	-6.7	-4.4	-3.3	-2.8	-2.2	-2.2
90% kill (°C)	-17.8	-16.1	-13.9	-8.9	-5.6	-5.0	-5.0	-5.0

Sweet Cherries	Bud Swell	Side Green	Green Tip	Tight Cluster	Open Cluster	First White	First Bloom	Full Bloom	Post Bloom
Old temp. (°C)	-5.0	-5.0	-3.9	-2.2	-2.2	-1.7	-1.7	-1.7	-1.1
10% kill (°C)	-8.3	-5.6	-3.9	-3.3	-2.8	-2.8	-2.2	-2.2	-2.2
90% kill (°C)	-15.0	-12.8	-10.0	-8.3	-6.1	-4.4	-3.9	-3.9	-3.9
Sour Cherries	Bud Swell	Side Green	Green Tip	Tight Cluster	Open Cluster	First White	First Bloom	Full Bloom	
10% kill (°C)	-9.4	-4.4	-3.3	-3.3	-2.2	-2.2	-2.2	-2.2	
90% kill (°C)	-17.8	-12.2	-5.6	-4.4	-4.4	-4.4	-4.4	-4.4	

Adapted from Longstroth (2021)
(*): Old standard temperature is the lowest temperature that can be endured for 30 minutes without damage.

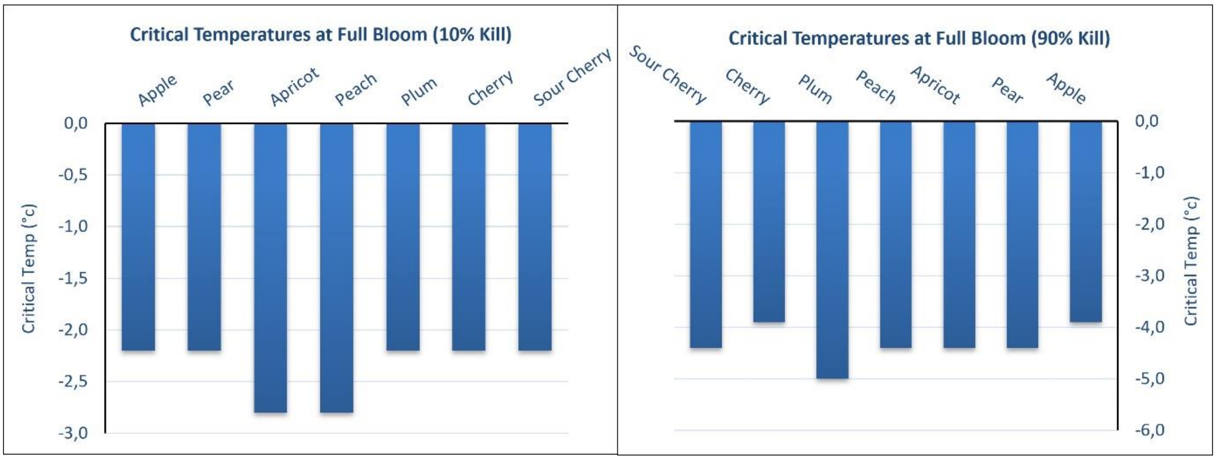

Fig. 1. Critical temperatures causing 10% and 90% bud kill at full bloom stage in selected fruit species