Evaluating Tree Fruit Bud & Fruit Damage from Cold

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Freeze / frost events can damage fruit buds and young fruit. The level of damage is directly related to cold intensity and duration as well as bud developmental stage. Research done in Washington State has been used to develop critical temperature charts that relate bud developmental stage with cold injury and these are posted on the internet at several locations including Colorado State University – Western Colorado Research Center's webpage (see:
http://www.colostate.edu/programs/wcrc/pubs/research_outreach/fruitinfo.htm
and click on the critical temperature chart of your crop choice). The charts include color photos of the bud stages and development. The PDF files range between 70 and 130 kb in size.

Grower's can benefit from evaluating damage following freeze events in order to determine future protection efforts and thinning programs. Several newer growers have asked how one does such an evaluation. The following describes that process.

Fruit crops differ in bud structure and arrangement on the shoots (Fig. 1). Apricots, peaches, and nectarines have simple flower buds with a single flower within each flower bud (Fig. 1, a & b). In peaches and nectarines, these are arranged in pairs (rarely in three's) on last season's shoots with a single vegetative bud between the flower buds. Apricots, like cherries and plums, may have single to multiple simple buds on the last season's shoots or clusters of simple buds on short branches, called spurs. Apple, pear, cherry, and plum have compound flower buds with multiple flowers within a single bud (Fig. 1, c - h). Apple and pear buds are positioned as single buds on spurs or along last year's shoots; cherries and plums have single to multiple compound buds in clusters on the shoots or on short spurs.

Fruit buds pass through up to eight stages in development from fully dormant to full bloom. At the early stages (stages 0 through 3 or 4), the buds are fairly tight and cuts on compound flower buds (apple, pear, cherry, plum) can be done horizontally across the bud to examine all the flowers within the bud at one cut if the cut is properly positioned. Later, once the individual flowers within a compound bud have separated out and have longer flower stems (stages 4 through 7 or 8), flower buds will need to be cut individually by an angled, vertical cut to examine the flower pistil structures for damage evidenced by tissue darkening. Crops with simple buds (apricots, peaches and nectarines) will require cutting of each simple bud. In peaches and nectarines, the flower buds are in pairs with a vegetative bud between them at each node. They can easily be cut in pairs clear up through bloom with an angled vertical cut to show the pistil structures of both buds within the pair at the same time. Because apricot buds tend to be in clusters, the buds will have to be cut individually.

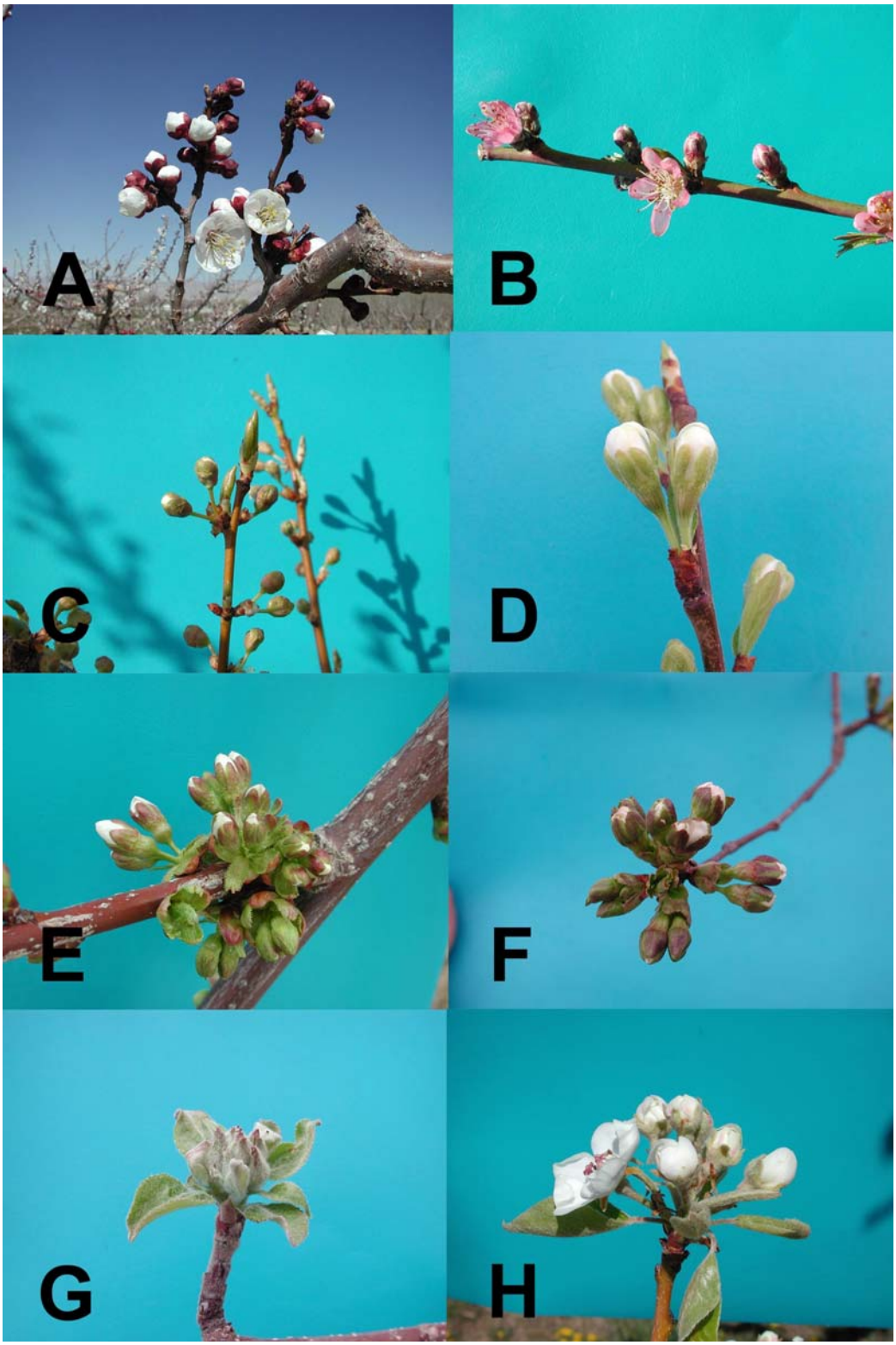

Fig. 1. Fruit bud types. A & B: Simple buds – apricot and peach/nectarine, respectively) C - H: Compound buds – European plum, Japanese plum, sweet cherry, tart cherry, apple, and pear, respectively. (photos by HJLarsen).

Evaluation of bud and fruit damage begins with collection of shoots with flower buds. The target is around 100 buds for evaluation (usually it is wise to have a few extra to replace any buds that might be knocked off the shoots in the collection process). And shoots should be collected from differing heights within the tree and locations within an orchard / orchard block. Varieties (and locations / height within the tree, if you need that information) should be kept separated and bundled w/ flagging tape and a label. These are then brought back from the orchard, the base of the shoots placed into a bucket (or can) with water, and allowed to warm up at 70 ºF for a minimum of 2 hours to allow the damaged tissue to develop the characteristic brown / dark brown / black color due to oxidation of phenolic compounds released by the injury. Discoloration intensifies within injured tissues with time, so four hours is better than 2 hours for detection purposes.

Buds are then cut and examined for brown to black discoloration of the fruit pistil (young fruit within the flower, Fig. 2). Assessing dead / injured flower pistils and ovaries in 100 buds provides a good estimate of percentage crop loss.

The cutting process requires a very sharp razor blade; single edge blades work well because they are stiffer and easier to control for cutting. These can be purchased in a bulk package of 100 blades at any hardware store with relatively inexpensive cost. They can be discarded when the cutting edge becomes dull or damaged. Debris and sap on the blade can be removed by rubbing the edge carefully with water.

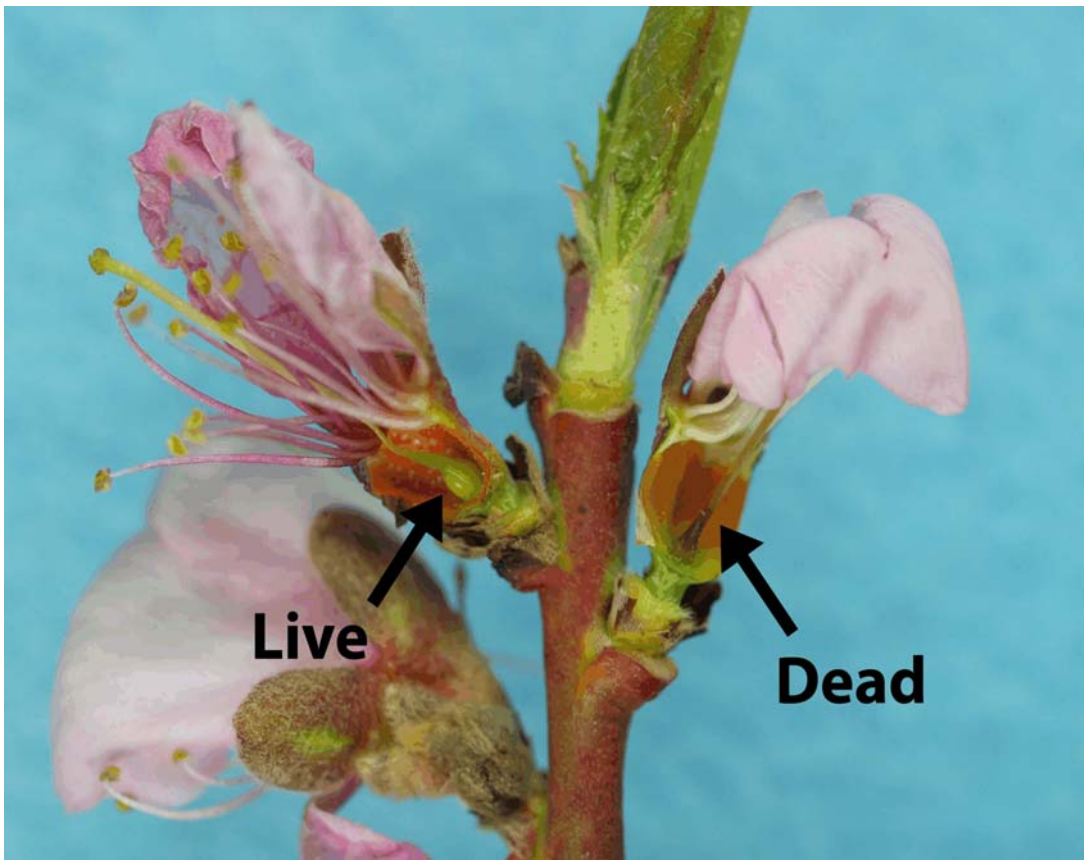

Fig. 2. Fantasia nectarine buds, cut longitudinally to show the pistil, one live and one dead (photo by HJLarsen).

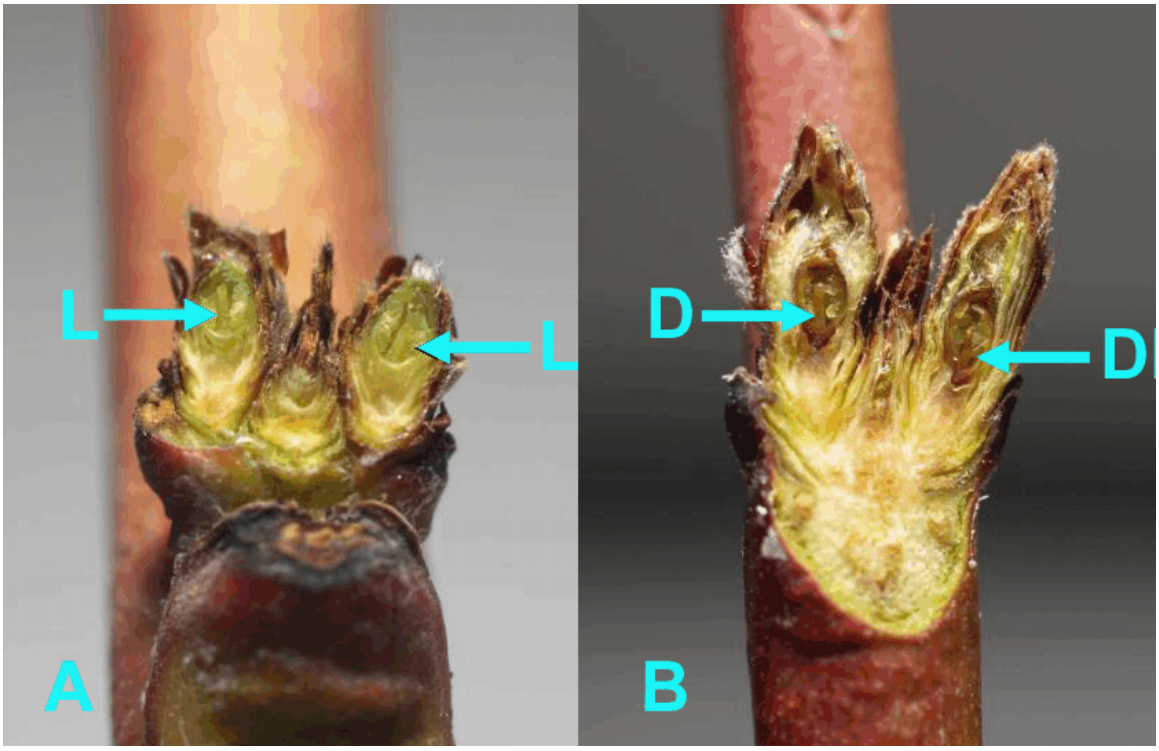

Fig. 3. BerendaSun peach buds (first swell stage) cut vertically to show pistils. A. Both buds alive. B. Both buds dead (photo by HJLarsen).

Apricot, peach, and nectarine buds are easiest to cut by starting at the base of the bud (or flower) and cutting on a vertical diagonal. Buds in early stages of development will often have the cut expose the stigma & style part of the pistil and make assessment fairly easy (Fig. 3). Buds in later stages of development (near bloom) often work best by simply cutting the petal corolla vertically to expose the entire pistil to view for evaluation. Buds killed within the past day or two will have pistils that are the same size or only slightly smaller than live pistils while buds killed several weeks previously will have a very small pistil with a much darker discoloration (Fig. 4). Apricot pistils often turn dark blackish brown within hours after being killed (Fig. 5).

Once bloom is done and the young fruit is present, one needs to make a transverse (horizontal) cut through the fruit about 1/3 of the distance from the stem end to the stylar end in order to cut through the embryo structure called the funiculus, an "umbilical cord-like" connection to the exterior fruit tissue (Fig. 6). A vertical cut can also be used if one cuts through the suture (fruit crease) to the back of the fruit, but that often is more difficult. Damage to the funiculus often results in the embryo within the young fruit either dying (and the fruit dropping in mid-June) or stopping development with the fruit never sizing beyond the size of a walnut. This can be seen at harvest in years with frost around the time of shuck-fall for peach and nectarine.

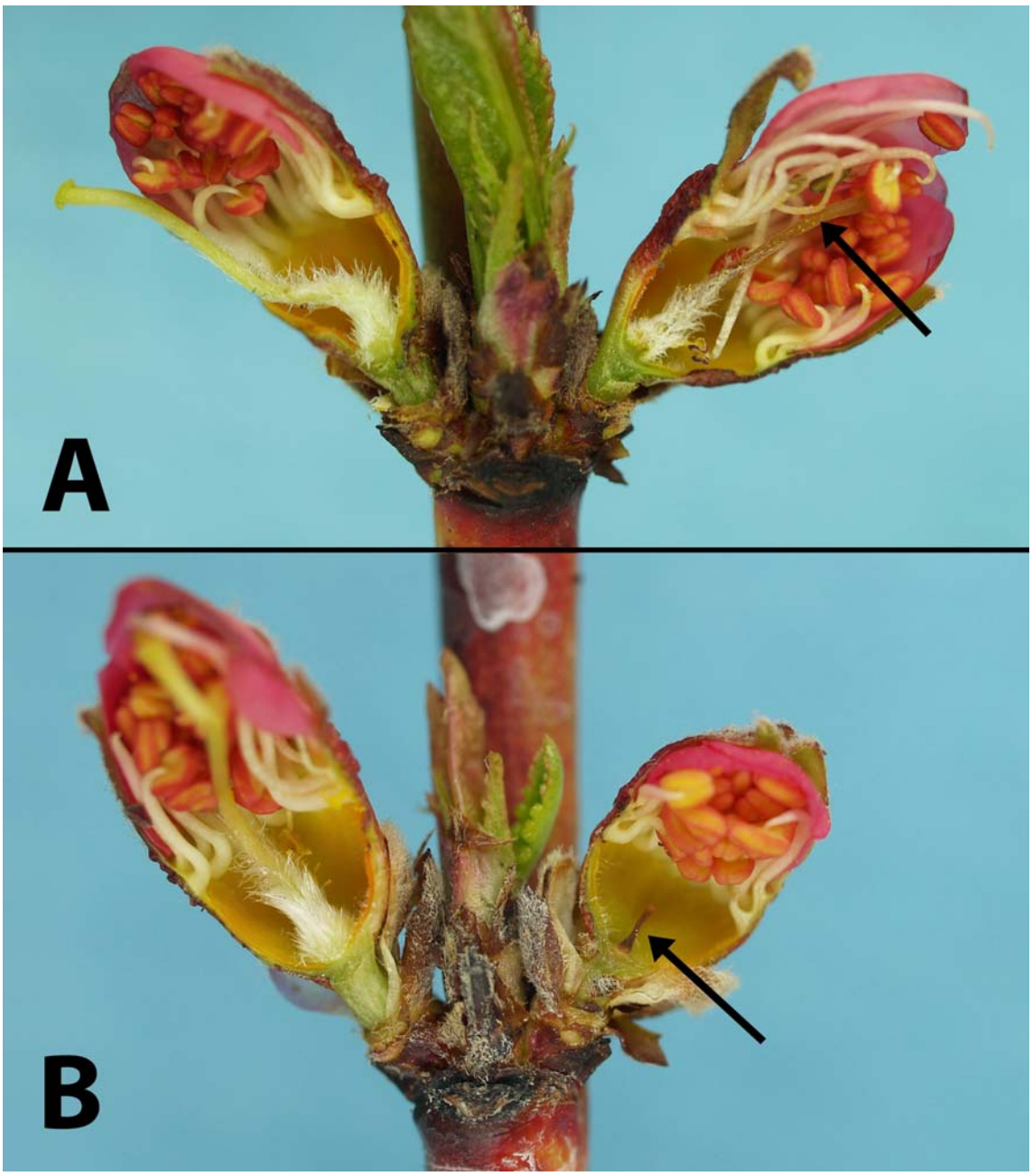

Fig. 4. BerendaSun peach buds (first pink stage) cut vertically to expose the pistil for freeze injury evaluation. Arrows: damaged or dead pistil (right side each photo). A. Right bud shows pistil damaged by freeze the prior night; note brownish discoloration of pistil. B. Right bud shows pistil killed by freeze 2 - 3 weeks prior to evaluation. Note smaller size and darker brown color of the older freeze-killed pistil in B than in A. (photos by HJLarsen).

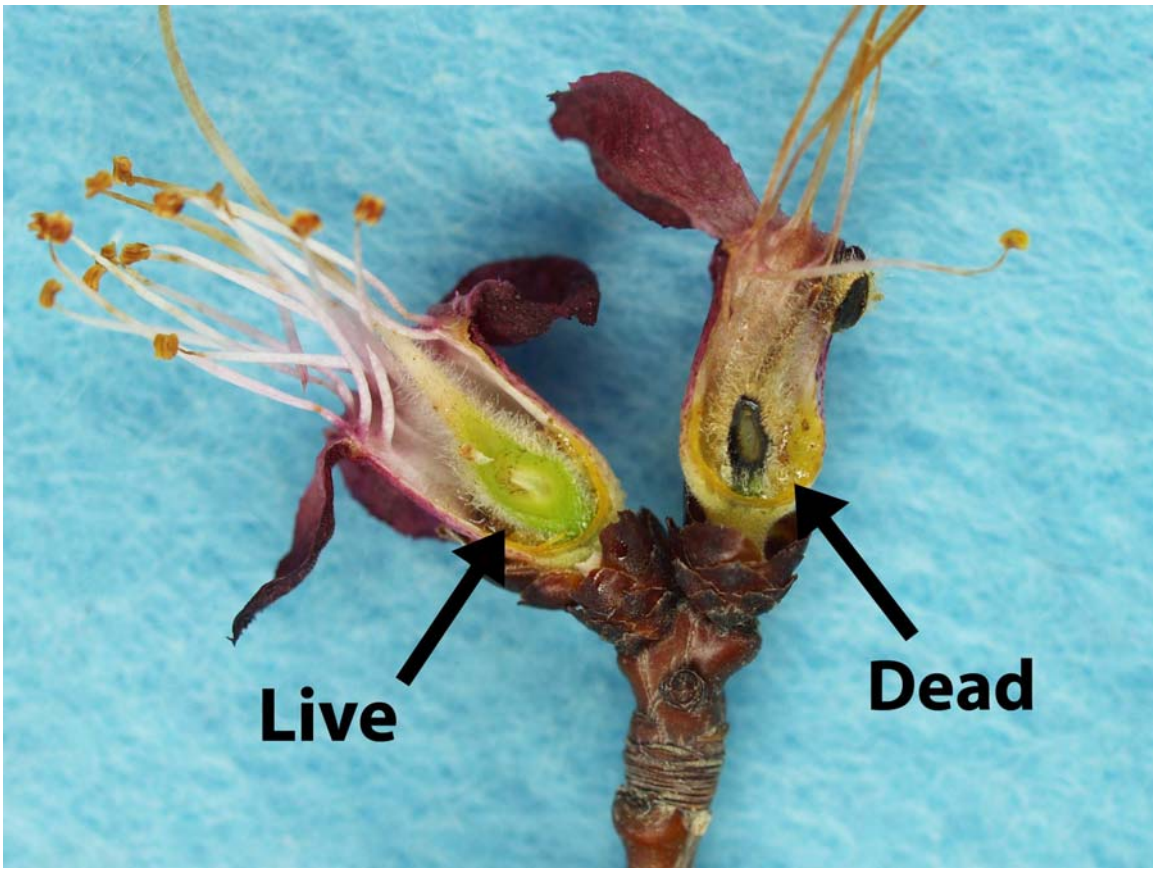

Fig. 5. Apricot buds (full bloom stage) cut vertically to expose the pistil for freeze damage evaluation. Note the blackened pistil on the right, killed by the prior night freeze (photo by HJLarsen).

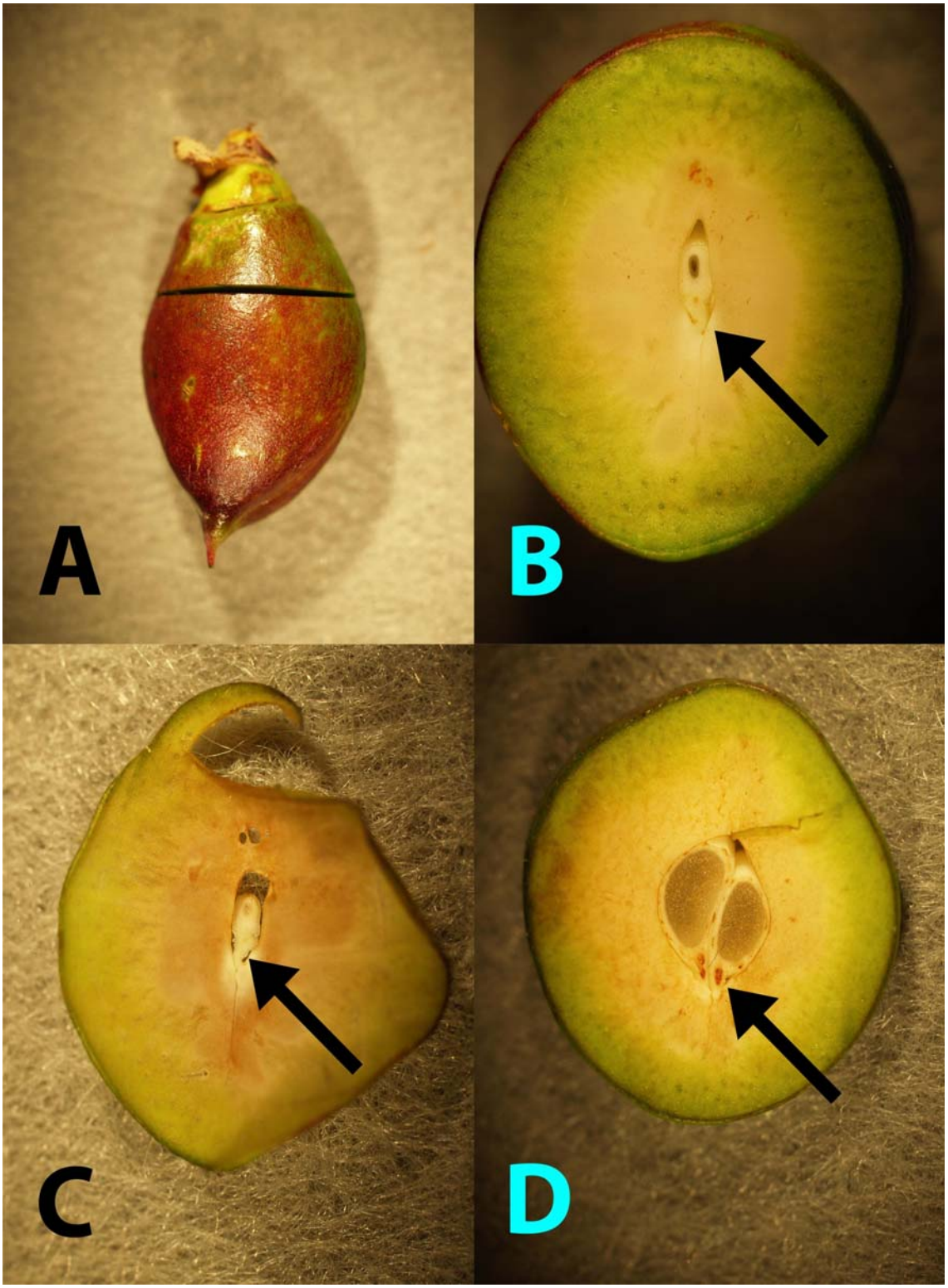

Fig. 6. Young nectarine cut to show embryo attachment (funiculus, arrows) to the fruit tissue. A. Cut orientation and location. B. Young embryo with undamaged funiculus. C. Thin section to emphasize embryo and undamaged funiculus). D. Twin embryos with damage within each funiculus; note the brown discoloration. (Photos by HJLarsen).

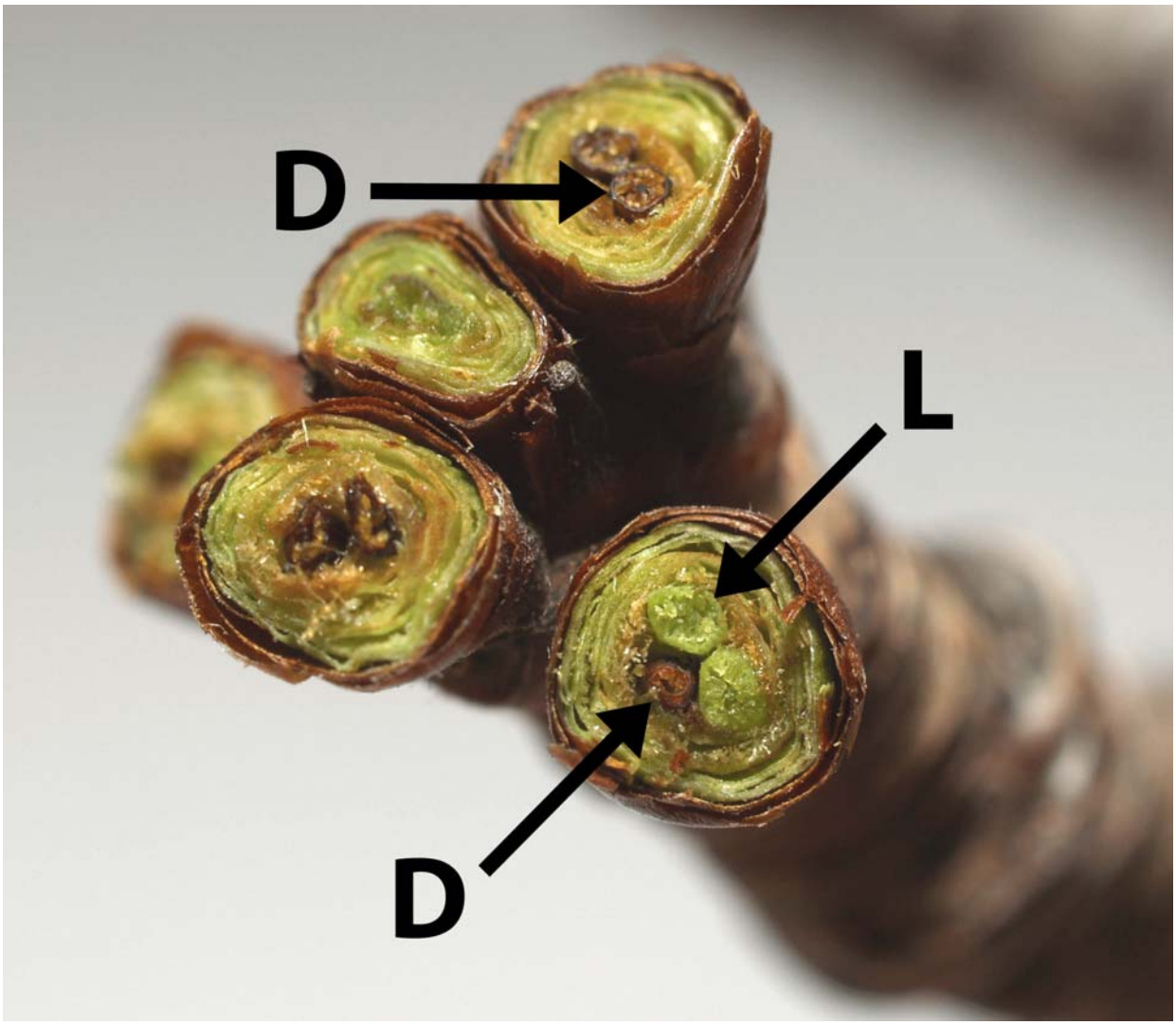

Fig. 7. Bing sweet cherry buds (compound buds) cut horizontally across the bud for flower viability evaluation. Arrows: D = dead flowers (dark brown color), L = live flower (Photo by HJLarsen).

Sweet cherry, plum, apple, and pear buds are compound buds (more than one flower inside each bud). Plums typically have two flowers / bud and cherries usually have two to five flowers / bud (Fig. 7), and apples and pears typically have six or more flowers / bud. But both plums and cherries can have only a single flower within a bud if some flower initials are killed by winter injury. A horizontal cut through these compound buds will cut through several of the flowers they contain. However, because the flowers within these buds often have differing timing for bloom, it is difficult to see all the flowers at one time. Often the most advanced flower will be the highest (furthest from the base of the bud) and the least advanced flower be the lowest (closest to the base of the bud). The earlier in bud development that the evaluation is done, the greater the possibility of seeing all the flowers within the bud; the closer to bloom, the less likely the possibility of seeing the pistils of all the flowers within the bud simultaneously with a single cut. At or near bloom, one needs to use more angled vertical cuts to reveal the pistils (Fig. 8).

Fig. 8. Sweet cherry flowers killed by frost at bloom, cut vertically to expose the blackened pistil. (Photo by HJLarsen).

Apple and pear buds, like plum, tend to have differing timing for opening of the flowers within the fruit bud. In apples, the "king bloom" is the first to open and leads the other flowers within the bud in development. It is the center flower, typically with five "side bloom" flowers forming a ring around it (Fig. 9, b). Because it leads the side bloom flowers in developing, it typically will be positioned toward the top of the bud when one makes a horizontal cut through the flower bud. When flower structures are damaged by frost or freezing temperatures, injured tissues of the style and ovary will become darkened (blackish brown with time) through formation of phenolic compounds in response to injury (Fig. 9, a). Cross-sectional cuts through the flower will reveal these darkened flower structures for counting purposes if one makes sequential cuts beginning at the upper top of the bud and proceeding toward the base of the bud. Because the style (the central portion of the pistil) is so much longer than the stigma (top portion of the pistil), it is typically the structure seen in the cross-sectional cuts through the upper portion of the flower where the petals are found (Fig. 9, c & d). Browning of this structure after a frost event is a good indication that the flower has been killed and will not become a successful fruit.

In pears, the spread in flower stage of development is even greater as the compound buds and their flowers approach bloom. However, the flowers in pear tend to develop from the base of the shoot toward the top of this shoot (Fig. 10). This makes cold injury damage evaluation even more dependent of multiple cuts through the developing buds. As with apple, damage to and discoloration of the stylar tissue within the blossom following exposure to freezing temperatures often is associated with death of the flower (Fig. 10, b - d). Pear has a tendency to develop late flowers at the tips of shoots (these are commonly termed "rat-tail bloom"). These late flowers can escape earlier frost damage and set fruit, but the fruit from such usually is substantially smaller and lower in quality.

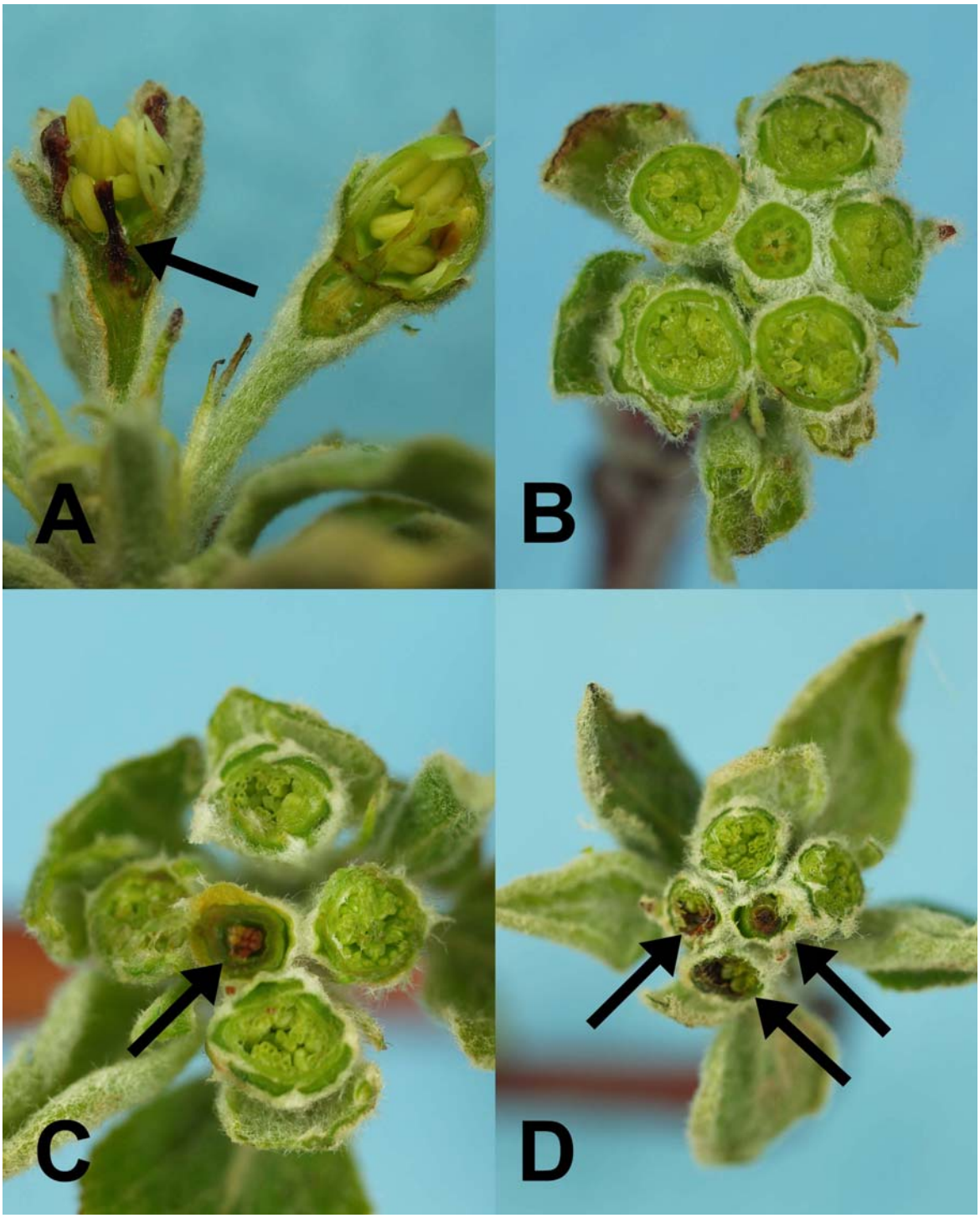

Fig. 9. Apple buds cut to show cold injury damage; arrows show killed pistil tissues. A. Longitudinal section (left flower killed). B - D: Cross-sections of flower buds. B. Six live flowers (King bloom in center); C: King bloom pistil killed, side blooms still alive; D: King bloom and two side blooms killed, two top side blooms alive.

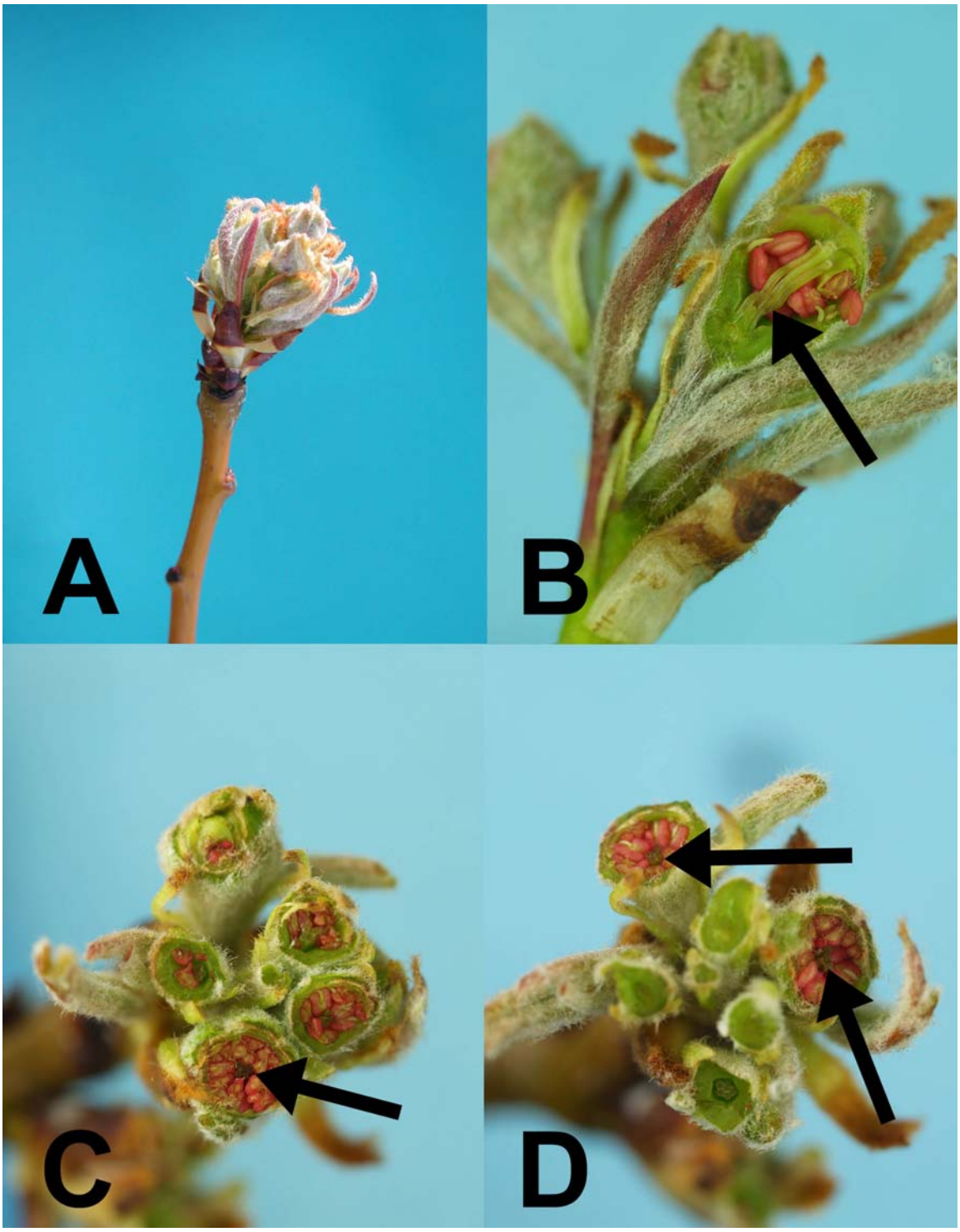

Fig. 10. Pear buds. A. Pear bud showing compound bud type. B. Longitudinal section showing pistil compound style (arrow points to stylar bundle leading to fused ovary receptacle). C & D. Cross-section cut through the multiple flowers; C is higher level cut, D is next cut lower; arrows in C & D point to stylar clusters with tissue browning that could indicate cold damage and death of the stylar tissues. (photos by HJLarsen).

Very late frost events after petal-fall can cause injury to young fruit tissues and impact fruit quality and appearance (Fig. 11). Sweet cherry fruit exposed to cold can be killed outright (Fig. 11, a). Injury to young peach fruit can result in fruit that never sizes beyond the size of a walnut. This can readily be seen as non-damaged fruit approaches ripeness (Fig. 11, b). Young apple and pear fruit so injured often have the surface cells and tissues killed and develop a pronounced scabby pattern on the fruit surface that is termed "frost ring" (Fig. 11, c & d). Such affected fruit, although edible, are not salable and often are removed by hand thinning if possible.

One additional impact of cold injury needs to be mentioned. Researchers working on cryopreservation of fruit buds have noted that buds that are frozen before they have cold acclimated (i.e., Sept. /Oct / early Nov.) often had oxidative browning of the vascular connective tissue leading to them. Buds with such damage could not be successfully grafted for subsequent germplasm recovery. This type of injury can occur from a late fall / early winter freeze, especially where mild temperatures precede a freeze event, but not after mid-winter when these tissues are very cold hardy. Buds damaged in this manner may open, but subsequently fall off as water stress becomes an issue in late spring / early summer (C.E. Stushnoff, pers. com). Consequently, fruit bud protection efforts against cold injury may need to include the periods in late fall / early winter, especially if a rapid drop to potentially damaging temperatures is forecasted to follow prolonged warm weather that slows cold acclimation by the buds.

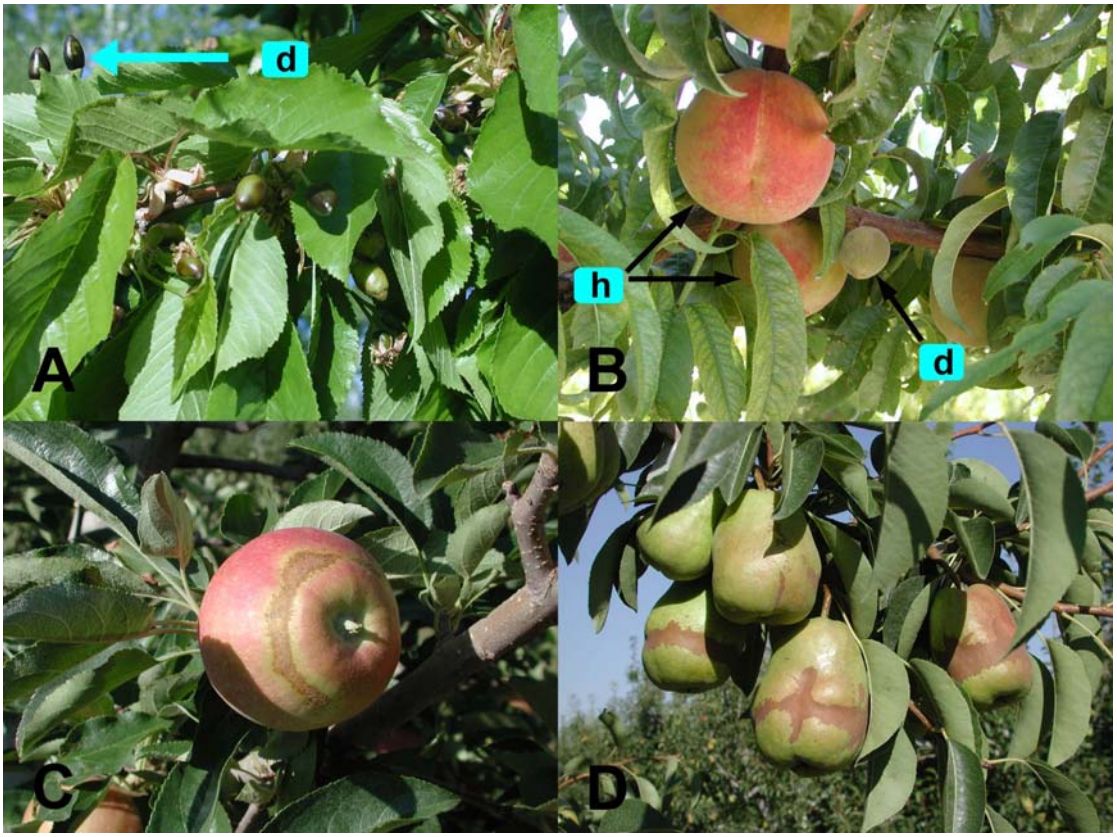

Fig. 11. Late frost injury to young fruit. A. Sweet cherry: d = killed young cherry fruit. B. Peach: h = healthy, maturing fruit; d = damaged, non-maturing fruit. C. Apple with frost ring. D. Pears with frost ring. (photos by HJLarsen).