Abiotic Winter Damage

Compiled by Lee Schmelzer

"Winter damage" is a broad term that refers to damage to plants incurred in fall, winter, and early spring. Fundamentally, nearly all winter damage is desiccation damage--cold temperatures kill by drying plant tissues either directly by freezing cellular water or indirectly by freezing soil water, making it unavailable for uptake. Mechanical damage is simple breakage of material from the weight of snow or ice.

How Cold Temperatures Kill

Cold kills in one or more of the following ways:

1. *Denatures proteins*
Plant proteins, among them enzymes, are temperature sensitive and must remain intact and in the presence of liquid water to remain functional. Cold inactivates proteins by making liquid water unavailable for their function.

2. *Causes mechanical injury to the cell wall*
Ice crystals may form inside (intracellular) or outside (intercellular) cells. Their sharp edges can puncture the cell walls and cause cellular contents to leak away. Intercellular ice crystals form under normal circumstances, but if cooling is rapid intracellular crystals may form. This damage leads to occlusion of wood vessels with wound gum. If 50% or more of the vessels in a branch (or trunk) become occluded, the branch (or tree) dies.

3. *Precipitates protoplasm*
Winter conditions can cause protoplasm to denature and its contents to settle out, halting cell function.

4. *Causes desiccation*
As ice forms, water is pulled out of the cell sap, lowering the freezing point. This is part of the plant's way of protecting itself from freezing to death. If too much water is pulled out, the tissues dry out. It has been estimated that a mature apple tree loses about 300 grams of water per day in winter. Sap flows during mild winter days and some water conduction has been measured in some pines even at 0° F. As the sap flows it can be lost through evaporation from the plant. If the water in vessels is frozen no new water can flow into the smaller twigs and branches whose water has evaporated--the tissue dries out. If soil water is frozen, the tree cannot replace the moisture lost in evaporation and the same thing happens. Vessel occlusion by frozen water or wound gum causes another barrier to water reaching the upper parts of the tree. High evaporation rates, as occur under bright sun and dry winds, exacerbate the problem.

Direct Damage

We see direct damage from winter kill as bud kill, browning of evergreen foliage (sometimes called scorch), dieback of twigs and small branches, frost collars at the bases of tree trunks, frost cracks, and bark splitting. Also, trees damaged in winter often throw up numerous suckers in spring. This is common on the marginally hardy Norway maple.

Indirect Damage

The plant may not be killed outright but can be stressed to the point that it is predisposed to infection or infestation from pests that eventually kill it. In fact, indirect effects of cold may occur more commonly than direct kills and manifest themselves as cankers, collar rots, and dieback because of attack by fungal and bacterial parasites. Sometimes disease damage is the only outward sign of freezing damage.

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THE PLANT IN WINTER

As winter approaches, plants respond to the shortening days and cooler temperatures by using a number of evolutionary mechanisms. Deciduous plants drop their leaves to decrease water loss from tissues in this normally dry time. Evergreens do not drop their leaves at this time, a fact that makes them more prone to desiccation damage. Herbaceous perennials overwinter beneath the ground where they are afforded some insulation from extreme cold and desiccation. Both woody and herbaceous perennials also store food reserves to see them through the lean months.

The above-ground parts of Montana plants enter our cold period in fall and emerge in spring after having gone through two types of dormancy, called rest and quiescence. Different authors use different terms, but these will serve our purpose here. Plant roots normally don't undergo a true rest period, but become quiescent when soil temperatures fall into the mid to upper 30s, depending upon species.

Rest

The woody plant begins preparing for rest near the end of summer. Tissues harden, or become more woody, and food reserves are increased in the roots and trunks. Buds are protected with hardened and sometimes waxy or resinous scales, properties which decrease desiccation. Nutrients are pulled out of leaves and moved into trunk, crowns, and roots before the leaves are shed in a stupendous conservation effort on the part of the plant.

The first outward sign that the plant has entered rest is leaf coloration and drop. From late summer until this time the plant has become less responsive to environmental conditions, grudgingly forsaking its ability to grow in return for winter protection. Slowly it hardens, but a misapplied stimulus such as drenching irrigation, a late application of nitrogen, or severe pruning can disrupt the slow slide into sleep and cause some of next spring's buds to bloom or send out a spurt of shoot growth. This comes at a time when it is too late for the vegetative growth to harden before winter. The certain result will be dead shoots. From late summer until the leaves have colored and begun to drop better to let the tree or shrub alone. Except in cases of severe drought, don't water, don't prune severely, and don't apply nitrogenous fertilizer. In short, do nothing drastic to the plant, because it can still respond with soft new growth.

When the leaves have fallen the plant is surely in rest. It cannot respond to conditions outside itself, no matter how much they entice the plant toward growth. Bring a branch of your favorite flowering crab into the greenhouse in late October and watch what happens. Keep the temperature at a balmy 70° F, give it 16 hours of daylight and plenty of water and fertilizer. Nothing happens. You wait for months and still nothing happens. The plant will remain in the dormant state practically forever. It has entered a cage from which it cannot escape until it has gone through a cold period. A trial by cold!

Rest is the time when the plant is most hardy and can tolerate the greatest cold and desiccative conditions.

The cold period that must be satisfied before the plant can grow once again is called the chilling requirement, or chilling period, and is expressed as the number of hours below 45° F the dormant plant has accumulated. Begin counting when the leaves drop. There is some evidence that temperatures above 45° F, say in the 60s and 70s, can negate the effects of lower temperatures, but the concept is difficult to explain and does not hold in all cases. Our purposes are best served by looking at the numbers of hours below 45 F the plant has accumulated.

Different species require varying numbers of chilling hours to break rest. Within species, different cultivars may require a different number of hours. Most of the work has been done on fruit plants and so their numbers are readily available.

Table 1. Chilling requirements in hours below 45° F for some perennial species grown in Montana.

Species	Hours	Species	Hours
Apple[z]	250-1700	Amer. plum	700-1700
Dom. plum	900-1700	Pear	200-1500
Walnut	400-1500	Peach	800-1200
Sour cherry	600-1400	Sweet cherry	500-1300
Apricot	300-900	Jap. plum	300-1200
Raspberry	800-1700	Ribes	800-1500
Blueberry	150-1200	Blackberry	200-400
Grape[y]	100-1500	Strawberry	200-300
Daffodils[x]	1000-1500	Iris	700-1400

Hyacinths 700-900 Tulips 2200

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[z] Some low-chill cultivars like Anna and Dorsett Golden flower with less than 50 hours.
[y] Grapes need little chilling but most cultivars start better in spring with moderate chilling.
[x] Most bulbs chill well in temperatures around 50° F.

As a rough rule of thumb we can say that most woody species in Montana require at least 1000 hours of chilling to break rest. The longer the cold period beyond the plant's minimum requirement the faster it can respond to warm temperatures. With 168 hours in a week, that's only about 6 weeks of cold temperatures that plants need. Certainly, then, the chilling requirements of most of our woody plants are satisfied by Christmas, even allowing for possible negation by some warm days. let's throw in a few more days for good measure and call 1 January the magic date.

When the chilling requirement has been satisfied, the plant is no longer in rest and can respond to warm temperatures and more clement growing conditions. Bring that branch of the flowering crab into the greenhouse in February and it will bloom. Bring it in in March and it will bloom faster.

Quiescence

But during the cold of January and February the plants do not grow outside. Their internal mechanisms indicate they could, but they won't because the environmental conditions are not conducive to growth. The plants have entered the second type of dormancy called quiescence. Roots don't display rest as does the top of the plant, but display quiescence when soil temperatures drop below about 45° F. Some roots may grow at colder temperatures (still above freezing) but growth is so slow as to be of academic value only.

Quiescence protects plants from harsh late winter conditions. However, because they can respond to clement conditions, late winter thaws and warm spells can cause the plant to deharden, that is, to lose its ability to tolerate extreme cold. A red raspberry plant in deepest rest can tolerate cold of say, -30° F. But the plant can begin to deharden in quiescence when air temperatures rise above about 27° F. The warmer the temperatures, and the longer they remain warm, the greater the dehardening. So, during a long, warm midwinter thaw, as occurred between Christmas 1997 and New Years Day 1998, when temperatures in northern areas of the state rose into the 50s and 60s and into the 40s in Bozeman, raspberries and other plants, having fulfilled their rest, could deharden substantially. In this state they could withstand perhaps only 10° F temperatures, rather than -30° F temperatures. If this long dehardening period is followed by abrupt extreme cold, as it was during the time period mentioned above when temperatures in Cut Bank dropped to -10° F literally overnight, the potential is there for considerable winter damage. We cannot predict for sure the extent of damage because we do not know the precise degree of dehardening the plant has undergone beforehand.

As you can see, warm weather after Christmas can be worse than warm weather around Thanksgiving.

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Factors influencing the degree of winter damage

1. *Species*

Some species are inherently more cold tolerant than others. For example, green ash is highly cold tolerant, magnolia is not. Apple and gooseberry are more hardy than apricot and most grapes. The USDA cold hardiness zone ratings given to perennials are a rough indication of their cold hardiness. Many trees commonly found in Montana, such as ponderosa pine, western white pine, lodgepole pine, blue spruce, and alpine fir have survived freezing in the laboratory after hardening to temperatures between -76° F and -112° F. By comparison, some southeastern coastal species, such as slash pine, live oak, longleaf pine, and southern magnolia die out at temperatures below a balmy 5° F. American elms can tolerate -40° F and paper birch, black willow, and cottonwood down to -100° F. By comparison, sweet gum will tolerate only -15° F and Virginia oak only
19° F.

2. *Cultivars*

Within species, some cultivars are more hardy than others. For example, 'Dutchess of Oldenburg' apple is more hardy than 'Baldwin'.

3. *Predisposing Factors*

How well the plant comes through the winter depends in part on how well it was prepared before winter.

Plants that are stressed in summer often suffer more winter damage than healthy plants.

Summer drought can prevent the plant from absorbing sufficient nutrients for healthy growth. Nitrogen deficiency and deficiencies of other nutrients because of the presence of too little water for their absorption can interfere directly with photosynthesis. Drought also prevents the plant from filling its water reserves before winter cold sets in. That makes the tissue more subject to desiccation. Drought to the point of wilt can reduce leaf functioning, causing the stomates to close, and reduce photosynthesis and respiration. This in turn reduces the plant's supply of nutrients for overwintering.

Defoliation from drought, pests, or other causes, prevents effective photosynthesis altogether.

Delay in the onset of rest, often from artificial causes in Montana, can significantly increase some types of winter damage.

Trauma to the plant, such as might occur from severe pruning or hurricane-force winds, can throw the plant into growth and bloom late in the summer and early fall. I have seen apple orchards in full bloom in October following a hurricane. These tissues were meant for next spring's growth. Of course they are killed by winter conditions and there will be little crop the following spring.

Other stimulants of late growth, such as late nitrogen fertilization and/or excessive irrigation (or very heavy rains), delay the onset of rest and can result in damage from early freezes.

Fruit bearing plants that produce a heavy crop are weakened and late to harden off, making them prone to early freezes. Their nutrient reserves are also exhausted in maturing the heavy crop and so they go into the winter in a weak condition. The situation is worse if harvest is delayed.

Hardening is the plant's way of coping with winter. In most species it begins long before leaf drop. The greater the summer leaf canopy, the greater the degree of hardening.

Table 2. Some factors that delay hardening in woody plants. Conditions opposite those below encourage hardening.

Late watering	Late N applications	Early defoliation
Cultivation	Poor soil drainage	Late summer pruning

4. *Time and duration of cold*

Early fall cold can damage plants before they have hardened sufficiently. Early spring cold can damage blossoms and young shoots. Midwinter cold following a thaw can damage dehardened tissues. Cold that comes on suddenly is more damaging than a gradual cooling, and deep cold more damaging than moderate cold. For example, temperatures that drop overnight from 50° F to 0° F or below are more damaging than those that drop through that range over a week's period. A rapid temperature drop will kill tissue at several degrees above that of a slow drop.

The duration of the cold period is also important. The longer it stays deeply cold, the greater the damage. Here I am talking about temperatures below -15° F.

5. *Rate of thaw*

There is some evidence to indicate that shaded tissue is less damaged by cold temperatures than tissue exposed to bright sunlight. This is probably due to the exposed tissue being deacclimated too rapidly or because the tissues warmed by the sun are less able to handle cold temperatures after sunset.

6. *Sunlight*

Under a cloudy sky there is little difference in temperature between the south and north sides of a tree but there is a substantial difference under a sunny sky. This can cause tremendous internal wood stress and the tree will crack radially or, more commonly, vertically.

7. *Humidity*

Cold air holds less moisture than warm air. The term for the total amount of moisture in the air is "absolute humidity". "Relative humidity" is an expression of humidity relative to the air temperature. For example, air at 0° F and air at 75° F may have the same relative humidity but the colder air will hold less water and therefore have lower absolute humidity. Moisture content of plants varies from about 95% for some fruit down to about 5 to 20% for some woody tissues. This is, in a sense, absolute humidity. Since water moves from areas of greater to areas of lesser concentration, water will move out of the plant into air that is drier than the plant tissue. The greater the gradient, the faster the moisture moves along it. Winter air in Montana is apt to have a lower absolute humidity (be drier) than the plant tissue, so plants often desiccate faster in winter. The following psychrometric chart graphically demonstrates absolute and relative humidity.

8. *Wind*

As moisture moves out of plant tissue it forms a moisture gradient in the air surrounding the tissue. The air closer to the tissue is most moist and air farther away from the tissue becomes gradually less moist. Its absolute humidity is lowered. If the air is calm, the high humidity air layer immediately adjacent to the tissue reduces the amount of moisture leaving that tissue. Wind mixes drier air with moister air, effectively removing the gradient and increasing the rapidity of moisture loss. Tissue dries faster in wind; so do clothes.

9. *Snow*

Snow is highly reflective and on a bright winter day a great deal of sunlight that does not impinge initially upon plant tissue is reflected back into the canopy or against the tree trunk. The light is converted into heat and warms the outer plant tissues. Dark barked trees--those with black, brown, and brown-red bark (honeylocust, apple, Prunus spp., etc.)-- absorb the heat to a greater degree than those with white and red bark (some birch, poplar, dogwood, etc.). At temperatures just below 32° F, the bark can freeze and thaw repeatedly with every passing cloud. This creates stress cracks that contribute to desiccation of underlying tissue and to invasion of that tissue by pests. Bright sunlight on snow increases the incidence of damage to the bark of plants by raising bark temperatures, especially when the sun shines. This increases the incidence of sunscald.

10. *Tissue in question*

Above-ground tissues--Not all parts of the plant are equally hardy. Different tissues attain varying degrees of hardiness. Thrown into the mix is the time of year we are considering. For example, when the plant is actively growing the cambium is among the least hardy of all tissues and most prone to cold damage. Damage to this tissue might occur when a sudden deep cold spell occurs after shoots have begun to grow in spring. Such damage will interfere with new phloem and xylem production and hence with water and nutrient transport. On the other hand, the cambium is among the most hardy tissues in winter when the tree is in rest. Cambium damage at that time is unlikely.

Flower buds are among the most tender of all above-ground parts in winter. Within these, the female parts (pistils) are the most sensitive. In fall, flower buds are more hardy than leaf buds, but in winter the leaf buds are more hardy than flower buds. Flower bud injury usually occurs when trees enter the fall in an immature condition or when a very early fall cold snap occurs. Flower buds can also be damaged when fully mature buds are subject to extreme winter cold or when warm temperatures after 1 January are followed by rapid and extreme cold.

The tolerance of some imperfect flower buds to cold also depends upon their sex. For example the female buds of Douglas-fir are more susceptible to cold injury than the male buds or vegetative buds.

The degree of cold tolerance, except in cases of extremely deep cold when even the hardiest buds are killed, is also dependent upon the degree of bud advancement in the spring; the more advanced the buds, the more susceptible they are to damage. Table 3 illustrates this point for buds of fruit plants.

Root tissues-- As mentioned above, roots do not enter a true rest period but only enter quiescence. They can grow so long as the soil temperature is reasonable for growth. That temperature is species-dependent and varies from around 32° F to 42° F. For example, roots of highbush blueberry can grow anytime soil temperature is above about 40° F. In milder climates, apple roots can grow through the entire winter in soils above about 40° F even though the aerial portions of the plants may be in rest. In that respect the tops and the roots act independently. Because they don't enter a true rest the roots cannot harden to the same degree as above-ground parts. Fortuitously they seldom need to do so since they are insulated from cold by a layer of soil and, if they are lucky, an additional insulating layer of snow of mulch. Various root tissues show varying degrees of hardiness, with the cambium and immature xylem near the cambium being the most tender.

Table 3. The relative resistance of fruit buds to cold damage according to their degree of development. The table shows critical temperatures below which tissue damage is severe. Other factors, such as wind and humidity also enter into the degree of bud damage, so the temperatures given only approximate critical conditions. The stage of development is followed by the critical temperature.

Strawberry

Buds emerge: 10° F   Buds closed:25° F   Bloom: 30° F   Small green fruit: 28° F

Grape (`Concord')

Scale crack:22° Fw/15° Fd[z]   First swell: 24° Fw/18° Fd   Full swell: 26° Fw/19° Fd
Burst: 26° Fw/21° Fd   Exposed shoot: 27° Fw

Apple		
Buds closed, some color showing: 25° F	Full bloom: 28° F	Small green fruit: 28° F

Peach		
Buds closed, some color showing: 25° F	Full bloom: 27° F	Small green fruit: 30° F

Sweet Cherry, Pear, Plum		
Buds closed, some color showing: 25° F	Full bloom: 28° F	Small green fruit: 30° F

Apricot		
Buds closed, some color showing: 25° F	Full bloom: 28° F	Small green fruit: 31° F

English walnut		
Buds closed, some color showing: 27° F	Full bloom: 27° F	Small green fruit: 30° F

[z] w = wet; d = dry

Table 4 gives you some examples of tissue hardiness.

Table 4. Various above-ground plant tissues attain varying degrees of hardiness depending upon the time of year. In general, other things being equal, tissue farthest from the leaves and on the shaded and undersides of branches is least hardy.

Most tender during active growth	Most tender in rest
Cambium[z]	Twig pith
Young cortex	Sapwood
Sapwood	Old cortex
---	Flower buds

[z] The cambium is among the most hardy tissues in winter.

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CLASSIFICATION OF COLD DAMAGE AND WINTER INJURY

As mentioned above, a discussion of cold damage can be confusing since there are so many variables to consider. It is not a simple phenomenon. For clarity we can categorize cold damage into the six broad classes discussed below.

CLASS 1 : LACK OF TISSUE MATURITY

A. Killing of twig terminals

By late summer shoots of most Montana species can tolerate temperatures of 15° F to 20° F. If temperatures drop below that, especially in an early fall freeze period, or following stimulation of late growth, twig terminals die back.

Prune out dead terminals in spring.

B. Crotch/collar injury

The most tender tissue on a branch or trunk is near their bases. These tissues are among the last to harden in fall and for this reason are most often damaged by early cold relative to the degree of tissue hardening.

Depending upon the extent of damage you may have to remove a limb during spring pruning. Repair severe collar damage by bridge grafting where feasible.

Grafted plants often show damage at or near their graft union which is positionally analogous to the collar area in trees. Grafted roses often succumb in Montana. Tissue at graft unions are often less mature and more tender than other tissues. Damage to this part of the plant usually means its subsequent death. Bridge grafting to repair the damage may not be feasible.

Mulch protects the collar and graft unions but may make the plant more prone to girdling damage from rodents.

C. Frost cracks

A sudden early fall cold can cause the bark and wood on young trees to crack, probably due to drying and rapid contraction. This bark is thin due to the age of the plant. Both young and mature trees can suffer the same damage during extremely deep cold (<-30° F) in midwinter.

Tack lose bark back over the wound as soon as possible, preferably before it dries. Tree cracks usually close rapidly as temperatures warm the following morning and need no attention. Refer to the discussion under Class 4 for more information.

D. Bark split

This is a variation on damage discussed under "C" and is also caused by immaturity of the bark tissue, usually happening in early fall following a cold snap. Tack the split and curled b ark back over the damaged area.

E. Dead patches on limbs and trunks

Dark, dry, sunken spots sometimes occur on no particular side of the tree as a result of tissue immaturity (early fall) or deep midwinter cold.

F. Blackheart

Immature conducting and storage tissue subjected to early and/or extreme cold are damaged and the vessels occluded. This causes a darkening of the surrounding tissue, hence the name. If decay does not set in new tissue may form over the damaged wood and the tree recover, although probably in a somewhat weakened condition.

TACTICS for reduction in the incidence of all the above problems include encouragement of hardening in late summer and protection of the plants from summer defoliation.

CLASS 2 : LACK OF ABILITY TO RESIST WINTER DROUGHT CONDITIONS (DESICCATION)

Smaller diameter shoots (near the tops of plants, grapevines, raspberry canes, etc.) have a smaller surface to volume ratio and so lose proportionately more water faster than thicker shoots. Cane dieback in raspberries is the result of insufficiently hardened late growth or early dehardening in midwinter followed by deep cold.

Evergreens lose water through their leaves, although at subfreezing temperatures transpiration is substantially diminished. Most damage is apparently due to intercellular freezing. When the leaves are damaged they brown (scorch), often on the windward side of the plant. Damage can also be extensive on the south and southwest sides due to heating. There can be considerable difference among species. If the needles remain brown but flexible, they may green again in spring; if brown and brittle, they will probably drop. Evergreens can be severely damaged by just a single defoliation.

Flower buds, usually being in an exposed axillary or terminal position, are subject to desiccation, especially if they are insufficiently hardened.

TACTICS for reduction in the incidence of the above problems include fall watering to fully hydrate tissues before winter, practices that speed hardening, and the use of windbreaks where feasible.

CLASS 3 : TOO READY RESPONSE TO SHORT PERIODS OF WARM WEATHER

A. Cane or twig dieback

Some plants respond rapidly to warm temperatures once rest is completed. For example, raspberry canes can deharden when temperatures rise above about 27° F. Dehardening occurs first near the tips of the canes and proceeds downward if warm temperatures prevail. If this occurs in midwinter and is followed by sudden deep cold the canes die back. The rate of dehardening is species and temperature dependent. For example all species deharden faster the higher the temperatures, but peach dehardens faster than apple, sweet cherry faster than lilac.

B. Sunscald

This usually occurs on the south or southwest side of trees in late winter. Young trees with thin bark and all dark-barked trees are most susceptible. Snow cover, white siding on a nearby building, concrete, and stone mulch exacerbate the problem. After completion of rest in the plant the sun, higher and brighter and therefore more dangerous in late winter than in mid winter, heats the bark and initiates some metabolism. The cells deharden and the tissue thaws. Sometimes there can be extreme differences in temperatures from one side of the tree to the other. For example, bark temperatures on apple trees can vary from 32° F on the northeast side to 69° F on the southwest side at the same time. Consider a more extreme situation: A very cold, still sunny afternoon when the shaded side of the tree remains at about 5° F or less and the sunny side thaws with bark temperatures above 32° F. Follow this with a very cold night when bark temperatures drop from above freezing to 0° F or below in a couple hours or less and the potential exists for sunscald damage.

Shrubs rarely experience sunscald since their multiple canes provide some degree of shading to lower portions.

TACTICS to decrease the problems above include shading to keep plant tissues cool (where practical) and the use of reflective material on the trunks of trees to keep the underlying tissues cool. White latex paint, special tree wraps, even cardboard wraps all help.

CLASS 4 : ABSOLUTE COLD

A. Frost cracks (Trunk split)

In this case the bark and wood split due to deep cold. The bark can loosen completely around young trees. The two cases represent varying degrees of a single problem.

Long continued freezing causes a slow contraction in the trunk equal to the magnitude of an annual ring in some cases. A rapid temperature drop causes even greater contraction in the bark and outer wood. Temperatures in the outer wood are colder than those of the inner wood, which is not contracted to the same degree as the outer wood. This sets up stress in the trunk. In mild cases, the bark splits, in more severe cases the entire trunk splits vertically. Temperatures measured on apple trees show that trees 6 to 8 inches in diameter are 1 to 2 degrees R between their center and their bark, while trees 2 feet in diameter are 5 to 7 degrees R from center to outside. This is enough to cause considerable internal stress. The "R" represents the relative difference in temperatures.

Cracking is most common on very cold, still nights between midnight and dawn and remind the listener of a rifle shot. As temperatures warm the following morning the cracks close quickly. Unless you're an early riser you may not note the crack until you notice the healed wound later in the year. The cracks are more common in deciduous trees than in evergreens, with elm, walnut, maple, Prunus spp., and ash being among the species most prone to this type of injury.

Occasionally internal frost cracks can occur with the sapwood splitting radially between annual rings and the bark held intact. These are rarely noted (except in the lumbering industry) and may heal with no permanent damage to the tree.

B. Bark split (discussed in Class 1D above)

C. Dead patches (discussed in Class 1E above)

D. Sunscald (discussed in Class 3B above)

E. Root kill

As mentioned, roots are among the least hardy plant tissues.

Soils are warmed in winter mostly from below. This is called "ground heat". At a depth of several feet the soil remains roughly at a constant 50° F to 55° F. As you approach the surface the ground heat dissipates until finally, at the surface, the heat radiates into the atmosphere. This is useful in protecting young transplants from spring cold by releasing ground heat into their canopy but it is undesirable in winter when ground heat conservation is the rule. Snow, mulch, turf, and other coverings "trap" the ground heat to keep the soil warm. In Bozeman in early January, 1998, with about a foot of snow cover, the soil temperature was about 30° F at a soil depth of 2 feet while air temperatures dipped to 0° F. In open winters with little or no snow for insulation soil temperatures can become dangerously cold for roots. The colder the air temperature and the longer the cold lasts, the colder the soil becomes along a gradient from the surface (coldest) to warmer deeper levels. Since most plant feeder roots remain only 8 to 10 inches below the soil surface this is the soil region with which we are most concerned.

Roots die at soil temperatures between 25° F and 10° F if soil cools rapidly. This is seldom the case in the field since it takes a while for soil in the root zone to reach critical temperatures. When it occurs, root death is the result of long, protracted cold spells with no ground insulation. Because they have some time to harden and defend themselves, roots begin then to die at around 12° F (soil temperature), depending upon species, the soil, and the location of the roots. Root kill is greater in dry soils than in moist soils. Roots nearer the trunk are hardiest while those more remote are least hardy. For this scenario to play out air temperatures would have to remain below -20° F for a few weeks, a phenomenon not likely in most of Montana, but still possible. It may also happen if the soil grade was recently lowered so that roots have less soil above them for insulation. So, long cold winters with no especially cold nights are good for the tops of plants but bad for the roots. The opposite situation, with mild winters punctuated by a few deeply cold nights, are bad for the tops of plant but good for the roots. You can't win.

Trees suffering root damage may grow the following spring but show small leaves. The flowers may wilt soon after bloom. Death of the tree may be rapid following leaf-out, especially if warm temperatures prevail, or tree death may take a couple of years. Each year the tree becomes weaker and weaker and finally succumbs, perhaps to some pest or disease. If root damage is slight the tree may recover without your notice.

TACTICS for reducing the kinds of damage above include winter mulches and piling fluffy snow or other insulation over plants. This is common practice with rose bushes. Snow is a great insulator. Look at the following table of data from Wisconsin.

Table 5. Fluffy snow has great insulation value; compacted snow has little insulation value.

When the air temperature is -14° F, other important temperatures are:

Location	Temperature (° F)
At snow surface	-1° F
Under 3 inches of snow	16° F
Under 6 inches of snow	22° F

CLASS 5: UNKNOWN CAUSES

Pruning wounds

Pruning wounds made in the fall or winter interfere with hardening of the tissue directly around them. We don't understand all the science behind this, but it is surely a hormonal interplay, probably with ethylene stimulating the production of auxins and cytokinens for healing and these interfering with abscisic acid-mediated hardening. So don't prune in the fall with the possible exception of remedial pruning on plants that bleed heavily if pruned in spring, such as walnut, maple, and birch.

CLASS 6: MECHANICAL DAMAGE

Mechanical damage was not discussed above since it is relatively straight-forward. The weight of snow, particularly heavy wet snow and ice can force branches down, sometimes breaking them completely off the plant, sometimes only cracking their crotches.

Remove broken branches or their stubs during spring pruning if you can wait. Broken branches often tear the bark about which you can do little. Clean up the wound and hope it heals well.

Remedy cracked crotches by tying the two branches together to relieve strain on the cracked area. This will help the area heal when cambium activity begins in spring.

TACTICS for aiding plants with potential mechanical damage include gently shaking off the snow to relieve the weight strain on the branch. Do this only if temperatures are above freezing; if they are below that point leave the snow on them and let it melt naturally as the temperatures rise. Shaking frozen branches could cause them to snap off.

Branches noted to be heavily weighted and drooping during a storm can be propped up with forked sticks to help support the weight.

Winter damaged trees should not be pruned back hard following the damaging winter. You may be removing wood that was only slightly damaged and so decreasing the foliage canopy that would normally supply carbohydrates to the plant. Instead, wait a year for any damaged tissue to show itself, then prune sparingly. Hard-pruned trees often do not make it, while those not pruned will.

Stop watering in mid-August to help trees harden-off for cold weather. If water is available in the fall, water evergreens thoroughly after leaves of deciduous trees have fallen. Fall watering helps trees tolerate drying winter conditions. Many Montana wells have high salt levels that actually can desiccate trees and shrubs. Test water from questionable sources to ensure suitable quality for irrigation.

References

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