)W TO RECOGNIZE FROST DAMAGE IN FOREST TREES

. . . and what to do about it

Forestry Extension

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The cold weather in December 1972 injured or killed seedlings and trees in the Pacific Northwest. Severe cold spells are relatively rare in the Pacific Northwest and many foresters are not familiar with the symptoms and consequences of frost injury.

Unfortunately, the extent of frost damage often is not readily apparent and the question remains: Is the seedling going to have a reasonable chance to survive after outplanting in the field?

What Is Involved in Frost Injury?

Frost injury is caused by the killing of cells in a plant by temperatures at or below freezing. If large amounts of tissue are killed, the plant will die. Extent and degree of frost injury depends on many factors and predicting exactly when frost damage is going to occur is difficult. However, we can establish some general guidelines to show when and where to expect frost damage.

Seasonal changes in frost sensitivity

Woody plants of the temperate zones undergo a distinct seasonal change in their ability to withstand cold. As a general rule, they are damaged easily by temperatures of 32° F or just below during the growing season but can stand much lower temperatures without damage during the dormant season. Acquisition and loss of frost resistance do not occur at the same date each year. Hardening and dehardening of plants are influenced by a combination of environmental factors, primarily temperature, light, and moisture. Because weather changes somewhat from year to year, the combination of these factors changes too, and thus causes forward or backward shifts of the periods when plants acquire or lose frost resistance.

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Species

Susceptibility to frost damage varies considerably among tree species. Frost resistance of common forest trees in Oregon may be rated as high for lodgepole pine, ponderosa pine, incense cedar, Engelmann spruce, and the true firs; medium for the coastal variety of Douglas-fir, western hemlock, and western red cedar; and low for Sitka spruce.

Trees often used in Christmas tree plantations but not native to Oregon also show different degrees of susceptibility to frost injury. Susceptibility is low for Scots pine, black pine, and Colorado fir. It is high for Monterey pine and the redwoods.

However, sensitivity to frost is by no means uniform within a species and particularly in those with a wide range of distribution. As a general rule, provenances or races from high elevations and higher latitudes are more frost resistant than those from low elevations and lower latitudes. Date of bud set can be used as a general indicator of fall frost hardiness. Provenances that set winter buds early tend to suffer less from fall and winter frost than those that form winter buds late in the season.

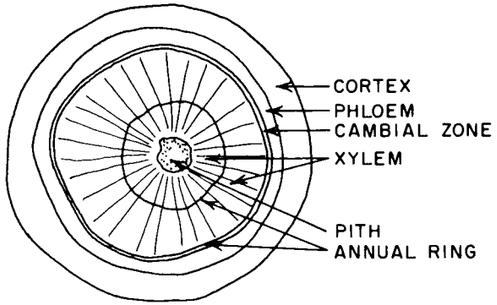
And finally, great variability in regard to frost susceptibility may exist within a population of trees from the same seed source. Indications are that such variability is very pronounced in Douglas-fir and that it can be reduced considerably by selection for frost-resistant individuals.

Individual trees

Age is an important factor in frost injury. Generally, trees become less prone to frost injury as they grow older. Regardless of the age of a tree, new tissues are more easily injured by frost than older tissues.

Frost tolerance varies also between parts of a tree. Leaves are generally the most hardy and roots the least hardy organs. Stems, branches, and buds occupy an intermediate position in regard to hardiness.

Even within the same plant organ, frost resistance may vary. For instance, basal parts of stems often are injured at temperatures that do not cause injury in the upper parts of stems. Within a stem,



CROSS SECTION THROUGH STEM OF 2-YEAR OLD DOUGLAS-FIR

cells of the phloem and cambium are more sensitive to frost than cells of the cortex or the xylem. To complicate matters even further, the annual cycle of hardening and dehardening is not synchronized for all parts of the tree. In some species, leaves reach their peak of frost resistance from 4 to 6 weeks later than stems, and from 2 to 4 weeks later than buds.

Identification of Frost Injury in Seedlings

Identification of frost injury is most important in nursery stock to be used in the current planting season. Correct assessment of whether or not seedlings are too damaged for outplanting can prevent costly losses. Positive identification of frost injury often is possible within a few days after exposure of trees to frost but may require weeks in some cases.

Leaves

Frost injury to leaves is easy to recognize. Injured foliage usually loses its normal green color very rapidly, that is from 24 to 72 hours after exposure to above freezing temperatures. It acquires a purplish or sometimes a dull grey hue. If leaf tissues have been killed completely, foliage will lose the purplish, bluish, or grey hue and turn brown within two or three weeks. If leaves have been only partially killed, only that portion of the leaves will turn color. Partial injury is very common in needles of conifers. Partially injured needles often will remain for one or even two seasons before they are shed.

Killing of leaf tissue is almost instantaneous. Newly killed leaves cannot be distinguished visually from uninjured leaves and color change in injured leaves may not occur for several days if temperatures remain below freezing. Nevertheless, the possibility exists to identify damage. Freezing of plant cells ruptures the membranes within those cells. Certain electrical properties of the membranes (electrical impedance) are altered when membranes are damaged. Electrical impedance can be measured with special equipment and therefore damaged tissue can be detected within minutes after it has thawed out. However, such equipment is not generally available and thus field foresters will have to rely primarily on visual symptoms for detection of frost damage.

Stems

Injury to stems is more difficult to determine than to needles, because stems seldom show visually recognizable signs of damage on the outside. Whether or not tissues of the stem were injured can be established by slicing open the stem. Injured stems show various degrees of browning. However, this kind of examination usually does not permit us to identify whether one or several kinds of tissue in the stem have been injured. To do that with any degree of certainty requires examination with a microscope.

If the phloem has been injured, bark will feel mushy and can be peeled off the stem easily. If the frost occurred without a snow cover, the first place to look for this kind of damage is close to the ground. If seedlings were covered partially by snow, the place to look is just above the snow line. Air just above bare ground or just above the surface of the snow reaches the lowest temperatures and is the place where frost injury is most likely to occur first.

Another indication of damage to the stem is shedding of needles. If only needles are damaged,

they will usually remain on the branches for a considerable length of time, that is several months. If both needle and stem tissues have been damaged, needles will begin to drop after two to three weeks. A third possibility is that needles will be shed even though they were not killed by frost. In this case, loss of needles appears to be associated with injury to the needle trace and cortical tissues of the stem.

Buds

Injury to buds is not immediately apparent externally. Injured buds begin to take on a dried-up appearance or start to shrivel about 4 to 6 weeks after occurrence of the injury. However, injury to buds can be checked a few days after exposure to freezing temperatures by cutting open the bud. If the bud has been damaged, tissues inside the bud will show light brown to almost black brown color, depending on the severity of injury.

Roots

Little information is available on freezing damage to roots. Foliage of seedlings whose roots have been killed by freezing will dry gradually when roots have thawed and temperatures rise above freezing.

The entire plant

A simple procedure may be used to assess the impact of frost injury on the plant as a whole. Pot the seedlings, water them well, and put in a place kept at room temperature under natural or artificial light. If seedlings have been damaged severely, they will soon turn brown or dry up.

If economic considerations (sale or purchase of large quantities of seedlings or investment in large planting operations) require more precise measurement of damage to seedlings, laboratory tests can be conducted. A pressure chamber apparatus may be used to detect seedlings with damaged roots or stems. If frost-damaged seedlings are placed under high transpirational stress (warm temperatures, low humidity, rapid air movement) internal plant moisture stress will be well above 20 atmospheres, even with adequate moisture available to the roots. Such seedlings would be a poor risk for planting.

What to Do with Frost-Injured Seedlings?

If seedlings have been injured by frost while still in seedbeds, a decision has to be made whether or not seedlings should be lifted. If damage is extensive, seedlings should be left in seedbeds. Later those that turn out to be uninjured can be used as transplants, or lifted in the next season.

In the event that damage is less extensive and seedlings are being lifted, plants should be culled rigorously. Seedlings with visible damage to more than one-third of the upper-half of the crown should be discarded. Use of frost-injured seedlings, even if damage appears to be light, always presents a risk, especially when seedlings have to be stored for more than a week before planting. Frost injury results in reduced vigor of seedlings and injured tissue provides an easy entryway for pathogens.

If bare-rooted seedlings were exposed to freezing temperatures while in storage, chance of severe injury is high. Such seedlings should be discarded outright or lined out in trenches until usable and unusable seedlings can be separated.

Prevention of Frost Injury

The risk of frost injury to seedlings in nursery beds can be reduced by overhead irrigation of seedlings when temperatures start to drop below freezing or by putting a cover over seedlings. However, covers cease to provide adequate protection once air temperatures drop below 10° to 15° F and sprinkler systems usually can not be kept in operation at such low temperatures.

Seedlings grown in containers should be placed in such a manner as to provide some insulation around the containers. Recent experience has shown that containerized seedlings are particularly prone to suffer from damage to roots if they are grown outside without adequate protection.

Frost injury in plantations and pole-sized stands

Direct frost injury (outright killing of tissues by low temperatures) also is common in saplings and pole-sized trees. Trees in this category are able to heal out frost injury quite effectively unless frosts are uncommonly severe. The cold spell in November 1955 was such an occasion. The frost killed many trees up to 40 years of age and caused reduced growth for as long as 5 to 6 years in injured trees that survived.

A common type of frost injury in young plantations is the so-called frost drying. It results from dessication of tissues when the soil is frozen and the tree becomes unable to replace moisture lost by transpiration. This type of "winter drought" can result in high mortality in plantations.

Dessication also may occur in stands 40 years and older, but seldom leads to the death of the tree. Part of the foliage turns red. Because the reddening of foliage usually is restricted to a well-defined belt across southern and southwestern slopes, foresters talk about a "red belt." A "red belt" causes foresters a lot of apprehension, but stands normally recover from it.

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