WINTER INJURY

State Forester Forum

Introduction

Frost damage and cold injury most commonly occur when temperatures drop below freezing during the growing season. Actively growing tissue is not frost hardy and is easily injured by temperatures in the 27º to 23º F range (Stathers 1989). Injury can also occur during the winter when warm sunny days are followed by rapidly falling temperatures at night that quickly freeze the thawed tissue.

Damage

The most common form of frost injury occurs when temperatures drop below freezing on clear nights after buds break and new growth begins in the spring. When **late spring frosts** occur, the new growth is killed and turns bright red. It often remains on the tree all year (Figure 1). Older foliage is undamaged. Both terminal and branch growth are severely reduced in the season following injury. Repeated injury of this type results in forked tops and trees with a shrub-like growth form. This is especially true for grand fir. The fullest and best-formed Christmas trees are found in areas where repeated frost injury has pruned the trees (Figure 2). **Early fall frosts** can also kill new growth on seedlings that have produced a second flush of leader growth late in the growing season. Second flushes of height growth are occasionally observed on planted Douglas-fir during wet years and on ponderosa pine treated with Velpar herbicide.

Figure 1. *New growth on grand fir killed by late spring frost. Photo by Dan Miller.*

Figure 2. *Grand fir shaped by repeated pruning by late spring frosts. Note the needle disease on the ponderosa pine in the background. Photo by Dan Miller.*

Repeated browsing by big game can also result in a shrub-like growth form of smaller trees and must be considered when deciding if the site has a frost problem. This is caused by the persistent clipping of

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new growth on leaders and branches. Browse damage is usually restricted to the bottom four to five feet of the tree. Once the trees exceed the height where browsing occurs, leader and branch growth will be normal. On heavily browsed sites, trees may not have any green branches below four to five feet. Looking for this browse line on taller trees will help determine if the shrub-like growth form is caused by frost or browsing. On sites with severe frost problems, branch growth will continue to be slow above the browse line.

Unusually cold weather following spring or fall planting can kill newly planted seedlings. In the spring this happens when frosts occur after the seedlings have lost dormancy and begun to grow. Sometimes only the new flush of growth is killed (Figure 3) but often the entire seedling dies. This can also occur with fall plantings if the cold temperatures exceed the level of frost hardiness in the seedlings. Once planted, the seedlings will soon increase their cold tolerance in response to cooler temperatures on the planting site. There are a few days following planting, however, when the seedlings are still susceptible to injury.

Figure 3. *New growth on Douglas-fir killed by late spring frost. Photo by Dan Miller*

Freezing temperatures during the growing season can also injure seedlings and saplings without the trees exhibiting visible symptoms. These **sublethal frosts** damage cells in the foliage and can result a significant reductions in growth and vigor (Steen and others 1990). Slow growth and yellow foliage of Douglas-fir seedlings and saplings has been observed on frost-prone sites. These sites are often typical frost pockets such as stream bottoms and meadows; however they can also be large relatively flat areas where cold air cannot drain away. These symptoms have also been observed on sites where the topography does not indicate that frost should be a problem but the presence of vegetation such as beargrass (*Xerophyllum tenax*) indicates a cold site. Grossnickle (2000) reported similar discoloration and growth reduction for spruce species on sites where frosts occurred during the growing season. If possible, avoid planting significant amounts of Douglas-fir and other frost sensitive species on frost-prone sites and sites where beargrass or other cold site indicators are present.

Winter desiccation is another form of freezing injury in conifers. It occurs when the above-ground or above-snowline parts of trees are exposed to warm, dry air and sun while the unexposed parts

Figure 4. *Winter desiccation on white pine seedlings. Photo by Dan Miller.*

Figure 5. *Winter desiccation. Only the portion of the seedling above the snow line was affected. The stem below the pencil was still alive. Photo by Dan Miller.*

remain at temperatures near or below freezing (Figures 4, 5). In these situations, excessive water loss from the needles results in the death of some or all of the exposed foliage (Sutinen and others 2001).

Red belt is a type of winter desiccation that occurs in bands or belts at specific elevations. The primary symptom is the reddening of needles during the winter or early spring. These needles are shed during the following summer. Red belt may be caused by warm Chinook winds that rapidly warm and dry foliage along an interface between warm and cold air. It may also be caused by the rapid freezing of warmed needles when the freezing level suddenly changes. Injury results in a growth reduction the following spring. Favor a high proportion of larch in the species mix on sites affected with severe or reoccurring injury (Bella and Navratil 1987).

Identification of Cold and Frost-prone Sites

There are several causes of frost during the growing season. It can occur when unusually cold air masses move into the area as part of the ever changing weather pattern. Most commonly, however, frosts occur on calm clear nights when heat radiates up into the atmosphere cooling the ground surface. Under these conditions, frosts occur at ground level while the air temperature above the ground remains above freezing. The occurrence of this type of frost is impeded by cloud cover or overstory vegetation cover. A canopy cover of at least 50% is generally required to significantly reduce these frost hazards (Steen and others 1990). The risk of radiation frost is greater on sites where the air is drier and cooler at sunset (Stathers 1989).

Heavy timber cutting on upper slopes can create frost problems at lower elevations. These harvests remove the overstory trees that provide thermal cover and permit the air near the ground to cool rapidly. This cold air is denser than the warmer air above it. Because of this density difference, the cold air flows down hill and accumulates in low-lying areas such as creek bottoms and meadows, creating frost pockets, often where none had existed previously. Frosts can occur on these sites even if they have overstory vegetation cover. Mid to upper slopes remain frost free longer because the cold air drains away.

Topography of the site can be used to identify potential frost pockets prior to logging or ordering seedlings (Stathers 1989). Low spots where cold air can collect and large, open flat areas are frost prone since the cold air cannot drain away and pools up on site (Figure 6). North aspects have a slightly higher risk of frost than other aspects. The risk of frost also increases at higher elevation. Exposed, windy sites are less frost-prone than sheltered sites.

Existing vegetation may also provide indications of frost problems. The presence of cold site species such as beargrass, false huckleberry *(Menziesia ferruginea*), Labrador tea (*Ledum glandulosum),* or the shrub-like or bushy growth form of existing conifers are good indications of sites with severe frost problems. The presence of conifer species such as subalpine fir, Engelmann spruce, and lodgepole pine that commonly occur on colder sites are also good indicators of frost problems that may occur after harvest.

Figure 6. *Frost pocket. Note the absence of seedlings in the draw bottom. Winter desiccation injury occurred on newly planted seedlings in the foreground. Photo by Dan Miller.*

Removing an overstory of frost resistant species can expose advance regeneration of more susceptible species to injury. For example, grand fir often regenerates in the shade of lodgepole pine overstories on frost-prone sites. Cutting the overstory increases the probability of frost damage to the grand fir (Figure 7).

Management Recommendations

Regeneration losses due to frost damage can be reduced or avoided by:

- Identifying frost-prone sites prior to harvest
- Favoring the regeneration of more frost-resistant species
- Selecting site preparation and vegetation management treatments that reduce frost risk
- Selecting a harvest method that provides more frost protection

Frost-resistant Species

Frost pockets where cold air generated upslope collects in low areas are best treated by selecting frost-resistant species for regeneration or for crop

Figure 7. *Frost susceptible grand fir regenerating under an overstory of lodgepole pine on a frost-prone site. Photo by Dan Miller.*

trees during thinning operations. Milo Larson, a former Silviculturist on the Palouse Ranger District, made extensive observations on frost injury to seedlings (Larson 1977). As a result of this work and other observations, he ranked Idaho conifers by their observed resistance to frost injury (Larson 1978). Table 1 includes a ranking of apparent resistance of unhardened new growth to frost damage. Cochran and Berntsen (1973) found that lodgepole pine germinants were significantly more frost resistant than ponderosa pine germinants. Therefore, prescriptions favoring the natural regeneration of lodgepole pine over ponderosa pine should be more successful on sites prone to late spring frosts. Also, ponderosa pine appears to be more susceptible to needle diseases on frost-prone sites. However this may be due more to the periods of cool temperatures and higher humidity that also occur on these sites than to the occurrence of frost.

Site Preparation Treatments

Site preparation treatments designed to improve planter access and control competing vegetation also can effectively reduce the risk of growing season frost (Stathers 1989). Treatments that effectively reduce the risk of frost damage include:

- Killing and if possible removing dense grass cover. A low dense canopy of grass produces a frost-prone environment for seedlings.

- Leaving sparse, short herbaceous or shrub canopies. This may conflict with moisture-preserving objectives, however.
- Exposing mineral soil by scalping, trenching and mounding. Scalps must be larger than small hand scalps on level ground but small scalps may be effective on sloping terrain.
- Ripping that breaks up and removes vegetation cover and incorporates surface organic matter.
- Planting in microsites such as next to large heat-holding stumps and logs.
- Avoiding low-lying planting spots.
- Leaving slash cover that provides at least 50% shade for seedlings.

There is no effective site preparation treatment for deep frost pockets with a continuous supply of cold air from higher elevations. To be successful, these sites must be regenerated with frost-resistant species (Table 1).

Harvest Methods

When designing harvest units on frost-prone sites, create openings on the bottom of the unit to allow cold air to flow out. Orient leave strips to minimize cold air dams caused by dense timber that trap cold air within harvest units (Figure 8).

Shelterwood harvests may be required in frost-prone areas where site preparation treatments cannot be relied on to provide adequate protection and frost resistant species cannot be regenerated. In order to be effective, the harvest should leave at least 50% canopy cover to reduce the probability of on-site frost formation. It may be difficult to protect frost pockets where cold air continuously flows onto the site. To be effective, the shelterwood must remain in place until the regeneration

Species	Frost Resistance	Preference for Use on Frost-prone Sites
Lodgepole pine	Highly resistant	Preferred
Ponderosa pine	Highly resistant	Preferred
Subalpine fir	Resistant	Preferred
Western white pine	Moderately resistant	Acceptable
Western larch	Moderately resistant (2)	Acceptable
Western redcedar	Moderately resistant (1)	Acceptable
Engelmann spruce	Sensitive (3)	Acceptable
Douglas-fir	Sensitive	Not Recommended
Grand fir	Highly sensitive	Not Recommended
Western hemlock	Highly sensitive	Not Recommended

(1) Containerized western redcedar has been shown to be very sensitive to fall frosts in the year it is planted (Miller and Schaefer (1994).
(2) Larch has shown susceptibility to late spring frost during the year planted.
(3) Engelmann spruce is susceptible to growth loss from late spring frosts but will survive and become established in frost pockets.

Table 1. Resistance of Idaho conifers to late spring frost damage (Larson 1978, Emmingham 1985).

Figure 8. *Cold air dam created by solid wall of timber across the lower edge of the harvest unit. Photo by Dan Miller.*

is tall enough to be above the frost zone that forms close to the ground.

For a thorough discussion of frost and harvest methods refer to “Summer Frost in Young Forest Plantations” (Stathers 1989) and “Prescribing Shelterwoods in the Cascade and Siskiyou Mountains of Oregon: Considering Topography, Density and Species” (Emmingham 1985).

Pre-commercial Thinning

On cold sites where cold air is generated on site and cannot drain away and higher elevation subalpine habitat types the occurrence of frosts are reduced or prevented by an overstory canopy that holds heat in during clear nights. A canopy cover of at least 50% is generally required to significantly reduce these frost hazards (Steen and others 1990). On these sites, thinning should be delayed until the openings created will not contribute to frost damage. The more the stand is opened, the greater is the risk of frost damage. Two light thinnings may be required to accomplish this, especially on extremely cold sites.

Useful Links

USFS Region 1 Field Guide

USFS Region 1 Management Guide

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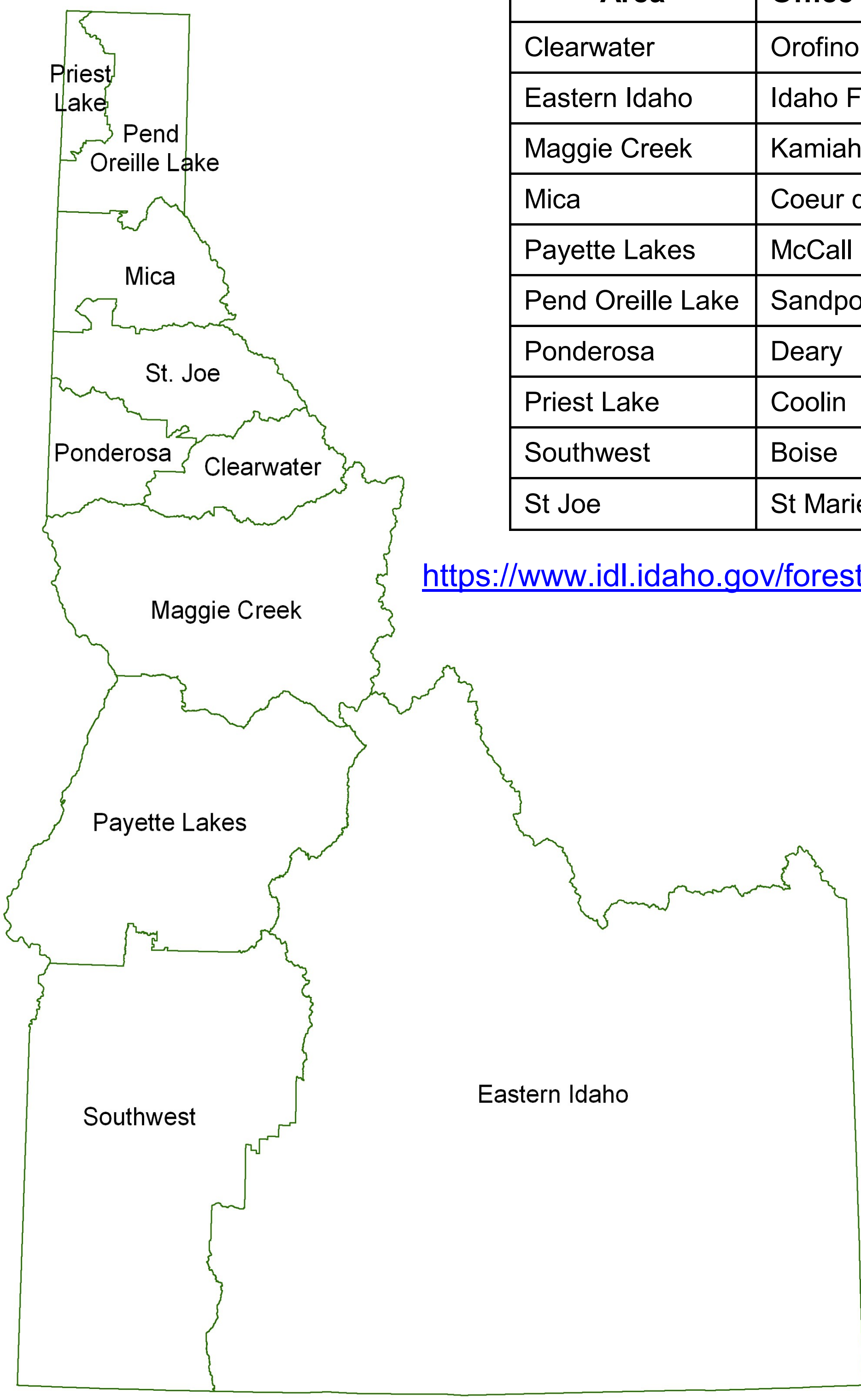

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