Reduction of Summer Frost Injury to Seedlings in the Southern Interior: Project 3.02

SUMMARY

Four site preparation treatments—herbicide, herbicide plus shade cards, shading, and scalping plus rippling—were compared with a control to test their effects in preventing summer frost damage to seedlings in the IDFDk, MSxk, and ESSFxc subzones in the southern interior. The species studied were Douglas-fir and lodgepole pine at the IDFDk site, and Engelmann spruce and lodgepole pine at the MSxk and ESSFxc sites.

The frequency of severe summer frosts (less than 4°C) during the growing season was found to be moderate to high on all three sites, occurring when seedlings, undergoing bud burst and stem elongation, are most susceptible to injury. Although lodgepole pine seedlings experience no summer frost injury on these sites, Engelmann spruce and Douglas-fir are damaged in most years on the sites.

Mechanical site preparation treatments that remove the grass canopy and organic layer were found to reduce both the frequency and intensity of summer frost on the sites. The herbicide and shade card treatments, which removed the grass canopy but not the organic layers, experienced similar amounts of frost damage as did the grass surface. The authors note that these results apply only to sites where the seedlings and the surrounding vegetation are of similar height, since low temperatures occur not on the ground, but up into the canopy (for example, 10–15 cm above the ground in a pinegrass canopy, at a similar height to that of the seedlings). In a taller canopy, the minimum temperature may occur well above the seedlings, and thus the vegetation may reduce frost damage to them.

INTRODUCTION

The effects of site preparation on seedling survival and growth were studied over a 4-year period (1986–1989), in three clearcuts in the IDFDk, MSxk, and ESSFxc subzones near Kamloops. These sites, chosen to represent dry, grass-dominated clearcuts in the southern interior, are described in FRDA Memos 162, 166, 167, and 177.

At the beginning of the project, the primary causes of failure of regeneration were considered to be soil moisture deficits in summer, low soil temperatures in spring, and possibly root collar damage as a result of high temperatures in summer. During the past five growing seasons, our research has shown that soil moisture deficits did reduce seedling growth, but soil temperature had no discernible effect and root collar damage was not observed. In the spring and early summer of 1986 and 1987, Douglas-fir and Engelmann spruce seedlings were damaged by frost. The climate stations were then modified to monitor air temperature at 15 cm above the ground (a better measure of the temperature a seedling is exposed to than the conventional measure of air temperature at 1.5 m), and all seedlings were surveyed for frost damage in each growing season.

TREATMENTS

In 1986 and 1987, four treatments were compared with a control (C1, no site preparation): herbicide (HRB), herbicide plus shade cards (SHD), scalping (SCP), and scalping plus rippling (RIP). The treatments were applied uniformly to strips 12 x 3 m. Herbicide (30 mL glyphosate/gal 100 m²) was applied in the herbicide treatments 2 or 3 times during the growing season to eliminate competing vegetation (predominantly pinegrass at the IDFDk and MSxk sites, and pinegrass and bluejoint at the ESSFxc site). This was done during the first 2 years following planting; after this no attempt was made to control competing vegetation. Scalping with a front-mounted blade removed the surface organic layer. Rippling to a depth of 30–50 cm was done using two rear-mounted ripper-shanks with drags, along paths 30–40 cm apart.

In 1987 and 1988 at the IDFDk site, research was done on ripped trenches (TRH) formed using dual ripper-shanks with heavy steel drags. The trenches were 20-30 cm deep and 40-60 cm wide at the top, and were shaped by hand using a spade to create an even cross-section. At the IDFDk site in 1988, the herbicide and herbicide with shade card treatments were replaced by an additional trenching treatment (TRS), as above, except that the trenches were made in scalped strips 3 m wide. At the other two sites, a ripped trench in grass was used in the 1988 planting.

Seedlings (1+0 plug stock) were planted in each year of the study. Descriptions of the experimental design can be found in the FRDA Memos noted above. The seedlings assessed for frost damage were the same ones used in the growth and survival experiments. The species were Douglas-fir and lodgepole pine at the IDFDk site, and Engelmann spruce and lodgepole pine at the MSxk and ESSFxc sites.
DEFINITION OF FROST INCIDENCE

Frost occurs when air temperatures drop below 0°C. In summer, this typically happens on clear, windless nights. The drop in air temperature is caused by ground cools by longwave radiation, in turn cooling the layer of air in contact with the surface. As cold air is denser than warm air, cold air will tend to flow downhill and fill depressions. This drainage intensifies frost in depressions but reduces frost intensity on slopes.

DEFINITION OF FROST INJURY AND SUMMER FROST

When conifer seedlings are fully hardened they can withstand temperatures much lower than any experienced during summer. During bud burst and stem elongation, however, the actively growing tissues have little frost resistance. Because we know little about the critical temperatures for Douglas-fir, Engelmann spruce, or lodgepole pine, we have used an air temperature of less than -4°C to indicate a severe summer frost, where injury to Engelmann spruce or Douglas-fir is likely. It should also be noted that frost injury depends on more than a critical temperature and the minimum air temperature. The rate of cooling, the duration of the frost, the rate of warming, and the intensity of sunshine following a frost night all affect the severity of frost injury.

SYMPTOMS OF SUMMER FROST INJURY

The symptoms that we have observed in both Engelmann spruce and Douglas-fir following severe summer frosts are consistent and distinctive. Within a few days, the current year's leader and lateral shoots lose turgor and will wilt to form "hooks" or "crosiers." These then develop a purplish hue and dry out over a few weeks. It is possible to identify summer frost injury in tall because the dried shoots remain hooked, and it is usually obvious that the damage occurred before the shoots had completely elongated.

MEASUREMENT OF AIR TEMPERATURE AND SUMMER FROST INJURY

A temperature sensor in the open will give readings higher than the air temperature on a sunny day and lower than the air temperature on a cloudless night. For this reason air temperature is measured in a Stevenson screen at weather stations. The errors can be very large for any sensors larger than a few tenths of a millimetre in diameter. To make accurate temperature measurements near the ground, we used a simple radiation shield consisting of two aluminum plates. Hourly mean air temperatures were collected continuously at the three sites at 15 cm above the ground surface over the control and scalped treatments. In 1989, intensive measurements were made on a few nights with arrays of thermometers made from very fine (0.001-inch) wires. This allowed us to determine the profiles of temperature in and above the scalps, trenches, and grass canopies at the IDFDk site. We also measured changes in temperature across the edge between the grass and scalped surfaces.

Frost injury was measured in late summer when the symptoms were still obvious. It was separated into two classes: frost injury, for seedlings showing any symptoms; and severe frost injury, for seedlings with 50% or more of the lateral shoots or the leader killed. All seedlings in the replicated plots were observed.

FREQUENCY AND INTENSITY OF FROST

Figures 1, 2, and 3 show the frequency of severe frost (less than -4°C) measured at 15 cm above the ground in the grass canopy at the Fehr Mountain (IDFDk), Paska Lake (MSxk), and Tsintsunko Lake (ESSFxcl) sites, respectively. At the IDFDk and ESSFxcl sites, severe frosts occur frequently during the growing season, with the ESSFxcl site experiencing the more severe frosts of the two. The MSxk site has fewer severe frosts than the other sites. It is on a gentle slope, and cold air drainage reduces frost incidence and severity. An operational planting at the base of the slope has been severely damaged by frost. There is no reason to expect that the other two sites are particularly frost prone. It appears that frosts of sufficient severity to cause damage to susceptible seedlings occur in most years in the southern interior in the IDFDk, MSxk, and ESSFxcl.

EFFECTS OF SITE PREPARATION ON FREQUENCY AND INTENSITY OF FROST

Figure 4 shows the hourly mean air temperatures during a severe frost at the IDFDk site in 1987. Seedlings had just begun shoot elongation when this frost occurred. The figure shows clearly the expected difference between air temperature at screen height and seedling height. During the day, the air in the grass canopy is warmer by about 4°C than the air at 1.5 m; at night, it is colder by a similar amount. The figure also shows that the air above the scalped treatment is about 3°C warmer than that above the grass during the frost. Similar temperature rises have been measured above the rippd treatment and in the trenches. This warming has a dramatic effect on the frequency of severe frost during the growing season. For instance, at the Fehr Mountain (IDFDk) site in 1987, six severe frosts were observed in the grass canopy, but only two in the scalped treatment. The mechanical site preparation treatments decrease both the frequency and intensity of summer frost at all three sites.

EFFECTS OF SITE PREPARATION ON FROST INJURY

Figures 5, 6, and 7 show the percentage of Douglas-fir or Engelmann spruce seedlings (planted in 1987) with symptoms of severe frost injury, for each of the various treatments at the IDFDk, MSxk, and ESSFxcl sites, respectively. Lodgepole pine showed no symptoms of frost injury at any of the sites and is not included in these figures. At all three sites and in both years there was much less frost injury in the mechanical site preparation treatments. Frost injury was usually highest in the control treatment; lesser but similar amounts of injury resulted in the herbicide and shade card treatments. That frost injury occurred in both years indicates that it is not restricted to the first year after planting. Seedlings planted in 1988 showed similar trends.

INTERPRETATION

These results show that severe frosts are common in the southern Interior in summer, occurring when the seedlings are most susceptible to frost injury during bud burst and stem elongation. The results also show, however, that even on sites with severe frost, mechanical site preparation decreases frost frequency and intensity, in turn significantly decreasing seedling injury. The insulating layer of grass and organic matter limits the heat being conducted into the soil during the day. Consequently, daytime soil temperatures are usually several degrees cooler below a grass-covered or herbicide-treated surface than below a scalped surface. At night, heat is lost from the mineral soil of the mechanical site preparation treatments, and it warms the layer of air near the surface. The grass and organic matter that prevented much heat from being stored in the soil also prevent what little heat was stored from warming the air above
the surface. As shown in Figure 4, this results in air temperatures being colder above the insulated mineral surface during a frost, than above a bare mineral surface. The herbicide and shade card treatments, which removed the grass canopy but not the organic layers, had similar amounts of frost injury as did the grass surface.

These results cannot be extrapolated to sites with other vegetation such as poplar or rhododendron. They apply only to sites where the seedlings and the other vegetation are of similar height. The reason is that the lowest temperatures in a canopy do not occur at the ground surface, but well up into the canopy. Measurements have

**FIGURE 1.** Total number of nights in each month with air temperatures below -4°C at the Fehr Mountain (IDFdk) site in the summers of 1987, 1988, and 1989. Hourly mean temperatures were measured with shielded thermometers at a height of 15 cm in the grass canopy.

**FIGURE 3.** Total number of nights in each month with air temperatures below -4°C at the Tsitsunko Lake (ESSFxc) site in the summers of 1987, 1988, and 1989. Hourly mean temperatures were measured with shielded thermometers at a height of 15 cm in the grass canopy.

**FIGURE 2.** Total number of nights in each month with air temperatures below -4°C at the Paskaw Lake (MSxk) site in the summers of 1988 and 1989. Hourly mean temperatures were measured with shielded thermometers at a height of 15 cm in the grass canopy.

**FIGURE 4.** A typical daily trend in air temperatures for a clear day with low windspeeds during the night. Although the trend is typical, this is one of the most severe summer frosts experienced at the Fehr Mountain (IDFdk) site during the study (occurring on June 23, 1987).
CONCLUSIONS

- Severe frosts are common during the summer in the southern Interior on IDF, MS, and ESSF sites.
- Mechanical site preparation treatments that remove the grass canopy and organic layer reduce both frost intensity and frequency at seedling height.
- Lodgepole pine seedlings are not susceptible to summer frost injury.
- Engelmann spruce and Douglas-fir seedlings are damaged by summer frost in most years on these sites.
- The reductions in frost intensity brought about by mechanical site preparation (2-3°C) are sufficient to reduce summer frost injury significantly in Engelmann spruce and Douglas-fir on grass-covered sites.
- It is not yet known how small scalped and ripping treatments can be made before they lose their ability to reduce frost injury.

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