Forests for Tomorrow Adaptive Management Initiative

Synthesis of Information on Selected Topics & Clarification of Key Uncertainties

EXCERPT:
Management of Pine Grass Competition

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The Forests for Tomorrow (FFT) program was established by the BC Government in 2005 in response to the devastating impact of major fires and the mountain pine beetle (MPB) epidemic on the forest land base of the Province. The program is aimed at improving the future timber supply and protecting other forest values through the re-establishment of young forests on lands that would otherwise remain underproductive.

The mountain pine beetle epidemic had affected over 10 million hectares of forest land by 2008 and is expected to expand further. This loss in forest cover is unprecedented in both scale and complexity. Many forest types have been affected across a range of ecological conditions from the dry Chilcotin to moist sub-boreal and high elevation zones. These twin factors of scale and complexity have, in turn, created numerous uncertainties for forest managers. Adaptive management strategies have been proposed as one approach for dealing with these uncertainties.

An adaptive management workshop held on June 26, 2008 under the FFT program for key staff engaged in restoring forest cover to the mountain pine beetle area raised a range of uncertainties or questions from participants. This is one of the topics for which our team was asked to review and summarize information in the existing literature.

Executive Summary

Much of the background (and references therein) is condensed from Simard et al. (2003); Heineman et al. (2003) (Appendix 1), BC Forest Practices Branch (1997), and a BC Ministry of Forests website: http://www.myacquire.com/spvegman/expertsystem/siteID.asp

Pine grass (*Calamagrostis rubsecens*) is a major competitor with conifer seedlings in the southern and central Interior, especially in the IDF and is one of several factors that make the dry, grassy Douglas-fir (*Pseudotsuga menziesii* (var. *glauca*) forests in interior British Columbia difficult to regenerate. There is concern that pinegrass will flourish in the increased light under stands killed by mountain pine beetle and make it difficult to successfully underplant these stands.

Pinegrass is an efficient competitor for soil water, partly because its growth peaks early in the growing season, well before conifer growth. Competition is most pronounced on drought-prone sites where roots compete for moisture which is the most critical factor for survival and early growth of planted tree seedlings. The grass increases the severity of summer drought and frost and reduces soil temperatures thereby contributing to poor seedling performance. On moister sites trees can establish through pine grass and competition is not as significant.

Pinegrass cover increases quickly and dramatically in response to greater light provided by harvested openings greater than one tree length in diameter. Following clearcutting, dense stands of pinegrass can develop within 2–4 years. Lightly disturbed areas can be completely invaded after one season. Severely disturbed areas are usually invaded after 4–5 years. The grass is increasing under the light levels found under dead pine stands but it is not clear how much competition occurs and how competition develops over time.

Solutions involve identifying where pinegrass is a severe competitor, and then removing pine grass and/or establishing seedlings before pinegrass invasion. Decisions about how to remove pinegrass then depend on the slope and amount of overstory retained. In the open, mechanical treatments (with ripper plows or disc trenchers) can control pinegrass for 3–4 years and, if intensive enough, increase Douglas-fir survival and growth. For lodgepole pine sites, only medium-impact mechanical site preparation is necessary where natural regeneration is expected. Chemical treatments to create planting spots about 150 cm in diameter are also options. On steep slopes, chemical treatments are usually better than mechanical treatments.

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Mechanical removal of forest floor material, particularly on steep slopes, improves pine growth but can result in short-term negative effects on nutrient availability, the ECM community and soil physical properties. Under dead stands, treatments with herbicides or manual screefing are the most relevant options to explore. Other potentially useful approaches are early establishment of seedlings before the grass responses to increased light levels and using larger planting stock.

The Issue

Pine grass (*Calamagrostis rubsecens* Buckl.) is a major competitor with conifer seedlings in the southern and central Interior, especially in the IDF and is one of several factors that make the dry, grassy Douglas-fir (*Pseudotsuga menziesii* (var. *glauca* (Beissn.) Franco) forests in interior British Columbia difficult to regenerate. There is concern that pinegrass will flourish in the increased light under stands killed by mountain pine beetle and make it difficult to successfully underplant these stands.

Basic Biology

Pinegrass is an efficient competitor for soil water, partly because its growth peaks early in the growing season, well before conifer growth (Nicholson 1989). Pinegrass continues to photosynthesize at reduced levels even when it is under moisture stress, which also provides it with a growth advantage over conifer seedlings and allows it to use an even greater share of soil water (Vogel 1985, cited by Haeussler et al. 1990).

Pine grass competition is most pronounced on drought-prone sites where roots compete for moisture which is the most critical factor for survival and early growth of planted tree seedlings (Örlander et al. 1998). Spittlehouse and Goldstein (1989) suggest that newly planted seedlings require about 4 weeks during which soil water potential does not drop below -0.1 MPa. Particularly in drier areas, such as the dry IDF, the grass increases the severity of summer drought and frost and reduces soil temperatures thereby contributing to poor seedling performance (Peterson and Maxwell 1987; Nicholson 1989; Stathers 1989; Fleming et al. 1998).

Following clearcutting, seedlings are able to establish in pine grass dominated understory throughout the IDF, but the probability of successful establishment increases with increasing moisture.

Pinegrass cover increases quickly and dramatically in response to greater light provided by harvested openings greater than one tree length in diameter. It spreads in response to light, medium soil disturbance associated with mechanical site preparation or prescribed fires (Hauessler et al. 1990, Huggard et al. 2005). The increased light levels and ground disturbance allow a continuous mat of pinegrass to develop from the loose open turf that occurs under forest stands. Treatments that favour the development of the pinegrass complex include:

- openings created by natural disturbances, clearcutting, group selection logging, or partial canopy removal
- removal of other non-crop vegetation (e.g., deciduous trees and shrubs)
- low to medium ground disturbance during logging
- low- to medium-impact mechanical site preparation (MSP)
- fires
- fertilization of conifers with nitrogen.

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Following clearcutting, dense stands of pinegrass can develop within 2–4 years. Lightly disturbed areas can be completely invaded after one season. Severely disturbed areas are usually invaded after 4–5 years. Pine grass may diminish over time. At Opax, for example pine grass is no longer dominant on some sites and other species have established (Huggard et al. 2005).

Typical Treatments for Pinegrass

Usually, where pinegrass is thought to be a strong competitor it is removed to reduce moisture stress and increase soil temperatures early in the spring. Complete removal of pinegrass during site preparation is more beneficial than partial removal. Silviculture treatments that remove pinegrass with or without the forest floor in 1- to 3-m patches have been shown to inhibit the regrowth of pinegrass, and can influence soil water availability in the dry IDF and improve conifer performance (Nicholson 1989; Fleming et al. 1998). Removal of forest floor can sometimes have some negative effects on other soil properties (see section on ‘complicating factors’ below).

The pinegrass complex can be set back by creating plantable spots using mechanical treatments, manual screefing, or chemical broadcast or spot applications. High impact fires can also destroy the shallow roots and reduce pinegrass. Seeding disturbed sites with domestic grass/legume mixes can lead to the competitive exclusion of reduce pinegrass.

Appropriate treatments depend on if the overstory has been removed or not and the slope of the site. When overstories are removed, treatments usually involve disc trenchers and plow rippers, but these machines will not be suitable if pine grass needs to be treated under dead canopies of pine. Slope also affects appropriate treatments. Although mechanical and chemical treatments have improved short-term seedling microclimate, survival, and growth on flat sites (Nicholson 1989; Fleming et al. 1998), little is known about appropriate site preparation methods for steep slopes. The site preparation tools commonly used on flat pinegrass sites, such as disc trenchers and ripper plows (Newsome 1998), are not suitable on slopes steeper than 35%. In contrast, lower impact tools, such as screefers, excavators, mulch mats, and ground foliar chemical application, may be more appropriate on steep slopes.

Mechanical

While low- to medium-impact mechanical disturbance can increase pinegrass competition, intense mechanical site preparation retards pinegrass growth and provides 3–4 years of control. Dense pinegrass communities can increase the incidence and severity of summer radiation frost so mechanical treatments may be used to reduce pinegrass cover on frost-prone sites.

On Douglas-fir sites, intense mechanical disturbance is recommended. Ripper plow or disc trencher can control pinegrass for 3–4 years and increase Douglas-fir survival and growth. Patch scarifiers can remove pinegrass and expose 50 to 150 cm patches of mineral soil. Patch scarifiers have produced noticeable improvements in survival and growth of Douglas-fir at Opax and in the Cariboo Forest Region (Huggard et al. 2005, Vyse et al. 2006).

For lodgepole pine sites, only medium-impact mechanical site preparation is necessary where natural regeneration is expected. Any mechanical treatment that produces a continuous furrow (e.g., disc trencher, ripper, or ripper plow) is recommended for sites to be planted with lodgepole pine. Patch scarification has improved lodgepole pine survival compared to unprepared sites. Severe disturbance should be avoided on clearcuts with abundant lodgepole pine cones to minimize pine overstocking. A moderate pinegrass cover can help prevent pine overstocking.

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Screefing

Patch scarification by planters (removing 30 cm diameter areas of surface grass) usually favours pinegrass and does not improve successful regeneration of seedlings. However, deep scalping, which removes the root mat, may help.

Prescribed Fire

Low- to medium-impact burning can cause a rapid increase in pinegrass after one growing season and is, therefore, rarely used.

Chemical

Herbicides provide the best pinegrass control option, and may be the only effective treatment option on steep slopes, soils that compact easily, or other sites where machines cannot be used. On hot, dry sites, dead vegetation may act as an effective mulch, but may cause problems on frostprone sites. Glyphosate trials in various biogeoclimatic zones (including the IDFdk, MSxk, and ICHmk1) consistently indicate good control of pinegrass for 2–3 growing seasons. Several trials indicate that glyphosate controls pinegrass when applied in the growing season, preferred times to apply glyphosate are May to June and later in August.

Limited research indicates that hexazinone effectively controls pinegrass but data are lacking on the length of control in B.C. forests.

Seeding

Seeding with domestic grasses following MSP can eliminate pinegrass. Since these domestic grasses can also be competitive, they may have to be grazed to minimize competition with crop trees.

Livestock Grazing

Although cattle graze pine grass, particularly early in the season, the effectiveness of using grazing for controlling pine grass has not been confirmed. Similarly sheep will graze pine grass. Livestock grazing tends to be for shorter duration than required for effective control. Repeated treatments of grazing may be effective, but may not be practical from an operational perspective

Complicating Factors

Long-term studies and modelling efforts have demonstrated that forest floor removal can have important effects on forest productivity (Skinner et al. 1989). Removal of the forest floor during harvesting and site preparation treatments can negatively affect both the quantity of nutrients and their availability. Forest floor materials contain large amounts of nutrients, and also provide habitat for organisms that convert those nutrients to forms available for uptake by conifers. IDF soils generally have medium to rich nutrient status due to the predominance of base-rich bedrock and low rates of leaching (Lloyd et al. 1990). The potential for scalping treatments to have long-term effects on overall nutrient content, on both gentle and steep slopes, is likely related to the size and depth of the scalps. Small scalps that remove only forest floor down to the mineral soil are likely to have little long-term effect because surface mineral horizons are relatively nutrient-rich in the IDF. Treatments that produce large, deep scalps (i.e., that remove surface mineral horizons) have greater potential to affect long-term productivity, but are not commonly applied in the southern interior IDF, except where they occur as landings and skid trails. On steep slopes, deep screefs have the potential to increase erosion hazard because of reduced soil structural stability. With medium- to fine-textured soils, any type of screefing on steep slopes can result in surface erosion following high-intensity rainstorms. Hope (1991) demonstrated on dry Douglas-fir sites, that scalping resulted in a reduction of 40% total N, 20% extractable P, and <10% extractable S in the forest floor and mineral soil. After 3

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years, the scalping treatment resulted in reductions of most foliar nutrients, particularly B, and after 5 years the imposed nutrient deficiencies resulted in a decline in seedling growth (T.A. Black, unpublished data, in Simard et al. 2003).

Effects of pine grass removal on soil productivity can also occur though impacts on soil organisms. The forest floor and mineral soil are home to a variety of microorganisms, including ectomycorrhizal (ECM) fungi, which play important roles in forming and maintaining soil structure, improving uptake of soil water and nutrients, and maintaining the health of the plant–soil system (Perry et al. 1989). Protecting rhizosphere microorganisms is particularly critical in dry, cold environments (Smith and Read 1997), such as in the dry Interior Douglas-fir (IDF) Biogeoclimatic Subzone in interior British Columbia (Lloyd et al. 1990). The inoculum of ECM fungi tend to be concentrated in the forest floor (Harvey et al. 1979), and this layer can be removed in the mechanical treatment. Thus, it is not surprising that the diversity of ectomycorrhizae was lower in mechanical patches than in chemical patches. Although glyphosate inhibits growth of ECM fungi in pure culture (Chakravarty and Chatarpaul 1990; Kaps and Kuhns 1987), it does not appear to inhibit colonization of trees by ECM fungi in the field (Chakravarty and Chatarpaul 1990; Sidhu and Chakravarty 1990; Schoenholtz et al. 1987). It may also be used as a food source (Hurd et al. 2001). In Simard et al's (2003) study, glyphosate treatment enhanced mycorrhizal diversity, most likely by reducing pinegrass competition and stimulating pine growth. Heineman et al. (2003) also found that both mechanical and chemical site preparation treatments caused short-lived increases in richness (number of species) and diversity (a measure of the relative abundance of individual species) of ectomycorrhizal species at Murray Creek. However, 28 months after planting, ectomycorrhizal diversity was significantly reduced from untreated control levels in the mechanical treatment but not in the chemical treatment. Some grass species can inhibit ECM formation on conifer seedlings (Amaranthus and Perry 1987; Timbal et al. 1990).

Other factors besides pine grass may limit seedling establishment. These include summer drought, summer frost, winter temperature extremes, inadequate seed supply, seed predation and poor quality planting stock (Newsome 1998).

Presence of pinegrass is not always a detriment. Pinegrass can provide several benefits to crop trees including:

- reducing soil surface erosion
- contributing organic matter to surface soil layers
- recycling nutrients that might otherwise be lost to leaching
- excluding more competitive species
- reducing or preventing overstocking of lodgepole pine.

Recommended Approaches

Solutions involve identifying where pinegrass is a severe competitor, and then removing pine grass and/or establishing seedlings before pinegrass invasion. Decisions about how to remove pinegrass then depend on the slope and amount of overstory retained.

Identifying areas where pinegrass is a severe competitor

Pinegrass is a severe competitor on drier sites where openings have been created by natural disturbances, clearcutting, group selection logging, or partial canopy removal. When considering underplanting of stands killed by mountain pine beetle, effects of increased light

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through the dead overstory need to be considered. Increased light seems to have allowed dramatic increases in pine grass in some areas of Prince George (Dow pers comm.), and in some open areas in Kamloops, but not under partial cuts in Opax (Huggard et al. 2005, Vyse pers. comm.). Evaluations should be site specific. .

Where pinegrass is deemed a potential problem then remove pinegrass

For Open Sites on Steep slopes: Results suggest that mid-elevation, steep (>35%), dry, grassy sites in interior British Columbia should be prepared for Douglas-fir or lodgepole pine seedling regeneration by removing pinegrass in large (>150 cm diameter) patches using ground foliar application of glyphosate. This contrasts with earlier research on flat sites, where it was necessary to remove the forest floor along with pinegrass in large patches to reduce damaging frosts and increase seedling survival.

On steep slopes, chemical treatments are usually better than mechanical treatments, but permits for chemical treatments require considerable paperwork . Mechanical removal of forest floor material improves pine growth, but can result in short-term negative effects on nutrient availability, the ECM community and soil physical properties. Mechanical treatments also run the risk of site degradation through compaction or operator error. There are many other advantages to chemical vs. mechanical treatments: they are cheaper, easier, and safer to apply; they improve the possibility of using advance regeneration; and they are visually less intrusive. Conversely, there is greater social opposition to the use of herbicides in general, but soil disturbance is also a concern, especially on steep slopes where erosion potential is high. Compared with patch treatments, broadcast herbicide treatments do not appear necessary for improved survival or growth of lodgepole pine on grassy sites and may have negative implications for range and wildlife values (Simard et al. 1998) as well as nutrient leaching (Nilsson and Örlander 1999). Thus, on steep slopes, large chemical patches that retain the forest floor are best for relieving the multiple environmental stressors. Ground foliar chemical application has resulted in good control of pinegrass and improved conifer performance, even where frost risk is high (Nicholson 1989).

For Open Sites on Flatter areas: On flat areas (less than 30% slope), chemical control is also likely effective but mechanical treatments will likely have less impact on soil nutrients than on steep slopes, and are thus a sound alternative. Mechanical and boot screefing in small patches is sometimes sufficient, particularly if trees are planted early before pine grass competition responds to the increased light.

If overstories are completely removed then mechanical treatments can be done with machines. For Douglas-fir sites, intense mechanical disturbance is recommended. The ripper plow or disc trencher can control pinegrass for 3–4 years and increase Douglas-fir survival and growth. For lodgepole pine sites, only medium-impact mechanical site preparation is necessary where natural regeneration is expected. Any mechanical treatment that produces a continuous furrow (e.g., disc trencher, ripper, or ripper plow) is recommended for sites to be planted with lodgepole pine. Severe disturbance should be avoided on clearcuts with abundant lodgepole pine cones to minimize pine overstocking. A moderate pinegrass cover can help prevent pine overstocking.

Under more closed canopies and where underplanting occurs under dead pine: Chemical treatment of patch scarification or screefing in large (>150 cm diameter) patches would be the best alternatives. Again, mechanical treatments have the advantage of less paperwork than chemical treatments. Patch scarification has improved lodgepole pine survival compared to unprepared sites.

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Other Considerations

Any treatment of pine grass should be done considering other possible factors important to regeneration and tree growth and other resources. Several practices should be considered in concert to reduce erosion and minimize impacts on soil flora and fauna and minimize costs. Early planting may allow trees to establish before grasses flush and eliminate the need for site preparation.

Key Uncertainties

The issue is how best to reduce pine grass competition under canopies and to identify areas where that competition is severe enough to need intervention. Treatments with herbicides or manual screefing are the most relevant options to explore. In some areas the need for treatment should be assessed by also trying early establishment of seedlings before the grass responses to increased light levels. Potential for trying larger stock also is an option.

Short-Term Learning

All the treatments noted under key uncertainties are suitable for replicated, short duration experiments that will achieve results over a few years. Experiments should have controls (untreated sites), and one or more treatments, replicated at least three times. Seedling survival, growth (diameter and height), should be recorded yearly after treatment.

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Appendix 1: Details of Local (BC) Results:

Both the studies in this Appendix concern sites that were clearcut and then left for some years before reforestation was attempted … the worst case for pine grass. Vyse et al. (2006) is the only study where there is pine grass in understory, but even there some site prep was used; Huggard et al (2005) report on planting in openings at Opax where small patch site prep was highly successful in reducing pine grass.

1) Simard et al. (2003) planted lodgepole pine in pinegrass controls and small (90 × 90 cm) and large (180 × 90 cm) patches where (i) only pinegrass was removed using glyphosate or (ii) both pinegrass and the forest floor were removed using an excavator. Treatments were replicated three times in east- and west-facing clearcuts and effects were followed for 9 years.

Two-year pine survival was 78% in the control and >97% in large patches. All patch treatments improved pine growth, but it was greatest in large chemical patches during the initial 6 years and in both large patch treatments thereafter. Seedlings grew larger following any site preparation treatment than with no treatment. Seedlings were larger in large patches than in small patches. Seedlings were larger where the forest floor was retained than where it was removed along with pinegrass in the short term, but this forest floor effect was no longer apparent after 1995. Although seedlings grew larger following removal of pinegrass using either mechanical or chemical treatments, there was no added benefit of removing the forest floor along with pinegrass.

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Removal of the forest floor reduced foliar and soil nutrients, increased bulk density and soil water availability, decreased porosity and aggregate stability, and reduced ectomycorrhizal diversity and richness. These changes were not observed in chemical patches. Mechanical removal of the forest floor, either in large or small patches, resulted in significant decreases in foliar Al, B, and Mn concentrations compared with the control or chemical patches, where forest floor was left intact ($p < 0.05$). Planned contrasts also showed that mechanical forest floor removal significantly reduced foliar Fe compared with the control ($p < 0.05$). Foliar Al, B, Mn, and Fe concentrations were 43, 15, 48, and 18% lower in the mechanical patches than in the control, respectively. Foliar N and S were slightly lower (by 7 and 4%, respectively) in the chemical patches than in the control ($p < 0.05$). None of the other foliar nutrients were significantly affected by site preparation 5 years after the treatment application.

Mechanical site preparation treatments that removed the forest floor in small or large patches significantly reduced mineral soil N concentration and capital compared with the control after 5 years ($p < 0.05$). Concentrations of C, NH4-N, and NO3-N were also substantially reduced by mechanical site preparation, but differences between the treatments were not significant ($p > 0.05$). Conversely, the mechanical treatments resulted in greater mineral soil cation exchange capacity, exchangeable Ca2+, exchangeable Mg2+, and pH compared with the control ($p < 0.05$). In contrast with the mechanical treatments, the chemical treatments had no significant effect on mineral soil nutrients ($p < 0.05$).

In Simard et al.'s study, all treatments that removed patches of pine grass increased soil temperatures and reduced frost relative to controls, but more so in the large patches than in the small ones. All site preparation treatments increased average daily soil temperature as well as minimum (nighttime) air temperature at seedling height.

None of the site preparation treatments consistently reduced the number of days where soil water potentials fell below –0.1 MPa, and the chemical treatments actually resulted in a greater number of stressful days (< –0.1 MPa) in most years.

Those results are consistent with those of other studies of grass interference and conifer establishment on dry, harsh sites in mid-latitude regions where a reduction in soil water availability was the primary mechanism of grass competition (references in Simard et al 2003). In this study, early survival of lodgepole pine seedlings in the undisturbed pinegrass community appeared to be reduced by inadequate water uptake, which probably resulted from low soil water availability (particularly in the droughty year of planting), low night-time air temperatures, and slow pine root egress.

Simard et al.'s results also agree with results from Heineman et al. 2003 (below) who studied the effects of site preparation on water availability in the seedling root zone at Fehr Mountain and Murray Creek, BC. Mechanical site preparation treatments that removed the forest floor resulted in short-term reductions in soil and/or foliar nutrient concentrations. However, 11 years after treatments were applied at Fehr Mountain, lodgepole pine showed no evidence of deficiencies. Likewise, pine at Murray Creek showed no evidence of deficiencies 5 years after treatment.

2) Heineman et al.'s (2003) review reported that one year after the scalping treatment was applied at Fehr Mountain, total soil nitrogen (N) content was reduced to 60% of the untreated control, extractable phosphorous (P) to about 80% of the control, and extractable potassium (K) and sulphur (S) to 85–90% of the control. The effect on exchangeable cations was small and presumably biologically insignificant. When comparisons were made among biogeoclimatic zones within the Kamloops Forest Region, the effect of forest floor removal on soil nutrient status was less in the IDF zone, where the forest floor is relatively thin, than in either the Montane Spruce (MS) or Engelmann Spruce–Subalpine Fir (ESSF) zones (Hope 1991). For Douglas-fir and lodgepole pine at Fehr Mountain, concentrations of most foliar nutrients had decreased somewhat in the scalping treatment

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compared with the untreated control after 3 years, and boron (B) was reduced to possible deficiency levels. However, the presence of B is highly variable year-to-year, and depends on variations in weather conditions (R. Brockley, pers. comm., 2000). Nitrogen was somewhat deficient in both the control and treatments. By the time lodgepole pine seedlings were 11 years old, significant differences in foliar nutrient levels between treatments remained. Foliar aluminum (Al) and manganese (Mn) concentrations were significantly lower in the scalping treatment than in the control, but were still well above deficiency levels. Foliar sulphur (S) levels were low enough in both the control and scalping treatment to suggest a possible deficiency (G. Hope, unpublished data). Douglas-fir at Fehr Mountain was not sampled at age 11 because of low survival rates (due to frost). At Murray Creek, the effects of scalping and chemical site preparation treatments on soil and lodgepole pine foliar nutrient concentrations were assessed 5 years after site preparation. The removal of forest floor materials in both large and small patches significantly reduced total soil carbon (C) and N capital in comparison with the untreated control, whereas chemical treatments did not reduce quantities significantly. Nutrient levels were affected only within the screefed patches and not across the entire treatment plot, however, because forest floor materials were displaced but not removed from the site. Removal of the forest floor in large and small patches resulted in significant decreases in foliar Al, B, and Mn compared with the control.

Mechanical and chemical treatments improved water availability equally well at Fehr Mountain, maintaining potentials above -0.1 MPa throughout the growing season. For both Douglas-fir and lodgepole pine, increases in the availability of root-zone water improved stomatal conductance, which is known to be positively correlated with photosynthetic rates and growth rates. At Murray Creek, soils were measurably drier on east than on west aspects, a result that was attributed to the east aspect having 100 m lower elevation, steeper slope, and coarser soils than the west aspect. Soil water potential was commonly higher in large mechanical and chemical patches than in the control, suggesting that those treatments had greater potential for increasing water availability to seedlings. However, none of the site preparation treatments consistently reduced the number of days where water potentials fell below -0.1 MPa, and the chemical treatments appeared to increase the number of days with moisture stress. Chemical and mechanical treatments increased soil water availability equally well by reducing the presence of pinegrass, and nighttime air temperature at seedling height also increased as a result of both types of treatment. Removal of forest floor materials in mechanical treatments resulted in short-term reductions in soil and foliar nutrient concentrations at both Fehr Mountain and Murray Creek, but there was no evidence of long-term deficiencies. At Murray Creek, however, ectomycorrhizal diversity was significantly lower in the mechanical treatment than the untreated control 28 months after planting.

2) Vyse et al. (2006) examined the effects of partial cutting on seedling growth of three conifer species at a very dry, hot interior Douglas-fir site near Kamloops, British Columbia. Douglas-fir, lodgepole pine, and ponderosa pine seedlings were planted in mechanically (with a backhoe) prepared 50 cm × 50 cm patches under different canopy conditions created by harvesting 60% of the original stand volume. The prepared areas were selected to represent canopy closures from open to closed, slopes from 0 to 60%, and all aspects. After six years, survival of Douglas-fir, lodgepole pine and ponderosa pine was 78%, 76% and 70%, respectively. Light level had a strong influence on survival and condition and the screefing treatment seemed to be effective at allowing trees to establish before pine grass competition. All species survived well in the most open conditions which was where there was the greatest understory grass, herb and shrub abundance. As well as noting that partial cutting can allow enough light for seedling growth, they also note that preparing small, vegetation-free planting spots is sufficient to achieve adequate understory stocking.

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