Ten-Year Response of Western Larch and Douglas-fir Seedlings to Mulch Mats, Sulfometuron, and Shade in Northeast Oregon

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Abstract

This trial investigated the effectiveness of small-scale vegetation management treatments on seedling survival and growth. Treatments included a black mulch mat, a spot application of sulfometuron, and control; in each of these treatments, half the seedlings were shaded. Costs of the treatments were evaluated. Vegetation management and shade improved seedling survival after 4 and 10 yr. After 10 yr, individual seedling and per-area volume growth in the weed control treatments outperformed the control; in some cases, they were diverging. Lowest cost per established seedling was obtained by using sulfometuron without shade.

Introduction

Vegetative competition from grasses, sedges, forbs, shrubs, and hardwood trees can lower conifer seedling survival and growth (Stewart and others 1984; Walstad and Kuch 1987). In reviewing 60 of the longest term studies, Wagner and others (2006) stated that reducing competition with vegetation management substantially increased tree growth for many species and sites worldwide. Managing competing vegetation is essential to plantation establishment, especially in areas of the Western United States where summers are typically hot and dry and humidity and soil moisture are low during the growing season. Reducing competition for soil moisture is critical to seedling performance, particularly during the early years of seedling establishment (Newton 1973).

Although effects of vegetation management on seedling performance of Douglas-fir [*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco] have been studied extensively in western and southwestern Oregon (Hobbs and others 1992), the Rocky Mountain type [*Pseudotsuga menziesii* var. *glauca* (Mirb.) Franco] and western larch [*Larix occidentalis* (Nutt.)] in eastern Oregon have received little attention. Most of the few studies conducted in the inland Northwest have demonstrated that reducing competing vegetation enhances establishment of Douglas-fir and western larch. Boyd (1986), summarizing results of 24 site-preparation trials in the northern Rocky Mountains, reported that vegetation management with herbicides improved the Plantation Growth Index (PGI) up to 5-fold after 6 yr for Douglas-fir and up to 3-fold after 3 yr for western larch, compared with the control treatment [PGI=(survival)(stem volume)]. Dimock and others (1983) reported that stem volume yield of hexazinone-treated 2-0 bare-root Douglas-fir seedlings near Entiat River, WA, increased 650 percent over untreated checks after 6 yr. Graham and others (1995) studied western larch germination in the Northern Rocky Mountains on burned-over ground, natural mineral soil, rotten wood, and duff. They found significant short-term growth improvements of 5–11 percent if organic materials were enriched and competing vegetation was controlled. In a summary of western larch ecology and silviculture in northern Idaho and western Montana, Schmidt and others (1976) stated that naturally regenerated larch grows twice as fast on mineral seedbeds where most of the competing vegetation has been removed than it does on heavily vegetated forest floor, at least for the first 15 yr.

Shading can substantially improve survival of Douglas-fir seedlings on droughty sites in southwestern Oregon (Minore 1971; Hobbs 1982; Helgerson 1990). Survival appeared to be better when shade was placed on the south side of seedlings than when it was on the east side (Helgerson 1990). Strothman (1972) found, however, that shade may not be necessary for Douglas-fir seedling survival on drier, south-facing slopes in the coast range of northern California. Evidence of benefits to Douglas-fir seedling growth from using shadecards has been lacking (Helgerson and others 1992).

Woodland owners and industrial forest land managers in eastern Oregon are planting more Douglas-fir and western larch for economic and forest health reasons (Knight 2007, personal communication). Few, if any, studies of these species on eastside forest sites have evaluated vegetation management options, shading effects on seedling performance, or their associated costs and benefits. The objective of this trial was to examine the effectiveness of small-scale vegetation management treatments and shade on the survival, growth, and costs of plantation-grown western larch and Douglas-fir seedlings.

Methods

Study Areas. The study areas were on the Eastern Oregon University Rebarrow Research Forest and the Oregon State University Obertueffer Research and Education Forest (Obie) near La Grande, OR (45º3´ N, 118º09´ W). On both sites, annual average precipitation is 64–76 cm (25–30 in), deposited largely as snow (Oregon Climate Service 2008). Warm, dry summers are common.

Rebarrow. On Rebarrow, plots were located at 1,616 m (5,300 ft) elevation, facing west on gentle slopes (<5 percent). A few scattered grand fir [*Abies grandis* (Dougl.) Lindl.], Douglas-fir, and western larch (<10 per acre) were in the overstory. The understory was fully occupied by orchard grass [*Dactylis glomerata* (L.)], elk sedge [*Carex geyeri* (Boott)], and pine grass [*Calamagrostis rubescens* (Buckley)], as well as scattered clumps of snowberry [*Symphoricarpos albus* (L.) Blake], willow [*Salix sp* (L.)], grouse huckleberry [*Vaccinium sp* (L.)], oceanspray [*Holodiscus discolor* (Pursh.) Maxim.], and mallow ninebark [*Physocarpus malvaceus* (Greene) Ktze.].

Rebarrow is on the cool end of a warm, dry mixed-conifer type (Emmingham and others 2005). The soil is a moderately deep, well-drained, very stony Kamela silt loam with a site index of 70 for Douglas-fir on a 100-yr basis (Dyksterhuis and High 1985). A few years before planting, the area had been salvage-logged following an outbreak of western spruce budworm [*Choristoneura occidentalis* (Freeman)]. Light amounts of slash covered the site.

Obie. Plots on Obie were located on a warm, dry mixed-conifer type (Emmingham and others 2005) with north to northwest exposures and slopes of <5 percent at an elevation of 1,226 m (4,020 ft). The treatment area was an old pasture, fully occupied and dominated by orchard grass. The soil is a deep, well-drained Lookingglass silt loam (Dyksterhuis and High 1985). The Douglas-fir site index is 95 on a 100-yr basis (Cochran 1979).

Treatments. For each species, 20 5-cm³ (0.31-in³) containerized seedlings were planted on 3.7 m (12 ft) × 3.7 m (12 ft) spacing in 6 plots in each of three treatments: 0.8-m² (9-ft²) black plastic mulch mat, 0.8-m² (9-ft²) spot application of sulfometuron (Oust), and no treatment (control) at each of two sites. A buffer of 7.3 m (24 ft) was left between each plot.

The three treatments were blocked by species, with each treatment randomly located and adjacent to the other treatments. Treatment areas measured 11 m (36 ft) wide × 86 m (282 ft) long. Planting was completed on May 1, 1997, by a contract planting crew. On every other plot in each treatment, seedlings were shaded on the south-southwest side of the seedling with a 20-cm (8-in) × 31-cm (12-in) black mesh Tree Shade card (Terra Tech, Inc., Eugene, OR). According to the manufacturer, they provide about 80 percent shade to the seedling. Black PAK Ground Cover mats (Terra Tech, Inc., Eugene, OR) were purchased in bulk, cut to size, placed over planted seedlings, and secured to the ground by five landscape staples. Sulfometuron was applied over the top of dormant seedlings with a backpack sprayer at a rate of 292 mL ai ha^{-1} (4 oz ai ac^{-1}) with a total spray volume of 183 L ha^{-1} (20 gal ac^{-1}). Installations and applications occurred before seedling budbreak in spring 1997.

Data Collection. Data collection included survival and growth. For Rebarrow, survival was monitored after the growing season in the first, second, third and fourth year. Survival was recorded as the number of live trees at the end of each growing season. Growth information was collected at the end of the third and fourth year. The Rebarrow site was abandoned in subsequent years because of poor survival in all treatments. At Obie, survival was monitored at the end of the growing season in the 1st, 2nd, 3rd, 4th, 5th, 8th and 10th yr. Growth was measured in the 3rd, 4th, 5th, 8th and 10th yr.

Total seedling height and diameter were recorded. Stem volume per seedling was calculated with the formula for a cone [$V = \pi D^2 H/12$, where D=diameter and H=height]. Volume per area calculations assumed 741 trees ha^{-1} (300 trees ac^{-1}) and used treatment means for survival and growth at the end of 10 yr at Obie. Data were recorded before budbreak on eight seedlings per plot in 1997; because of poor survival in some of the plots, however, growth was recorded for all live trees for determining means. Diameters were taken within 2.5 cm (1 in) of the soil surface; heights were measured from the top of the terminal bud. Mean seedling size at the time of planting was 3.1 mm (0.12 in) basal diameter and 25.4 cm (10 in) height for western larch and 2.1 mm (0.08 in) basal diameter and 13.1 cm (5.2 in) height for Douglas-fir (n=144).

Data Analysis. A statistical analysis was not performed because of several confounding factors. First, treatments were not laid out in a completely randomized design. Second, a stand of trees at Obie cast some late afternoon shade on two plots in the Douglas-fir mat treatment. Finally, although treatments within a block were relatively close to each other, there may be soil differences between treatment areas that are not accounted for. While the effect of this confounding is unknown and inferences from the data are limited, this trial has value as a case study that can contribute to a limited knowledge base.

Four-Year Results

Rebarrow. *Survival.* The mat and sulfometuron treatments improved survival of western larch seedlings about two-fold compared with the control at 4 yr (table 1). Mats improved Douglas-fir seedling survival by 56 percent, but spot applications of herbicide had no effect on survival compared to control. Shade enhanced survival 2.2-fold in western larch and 2.6-fold in Douglas-fir.

Growth. Herbicide and mats increased volume growth of western larch seedlings by 55 percent and 48 percent, respectively, compared with no treatment. Douglas-fir seedling growth was enhanced with vegetation management even more. Shade did not appear to improve larch or Douglas-fir seedling growth.

Obie. *Survival.* Seedling survival across all treatments at Obie was higher than at Rebarrow (table 1), with larch seedling survival increasing almost 4-fold in the mat and herbicide treatments, compared with the control. Control of competing vegetation was not as effective for Douglas-fir survival, where mats and herbicide increased survival by 44 percent and 220 percent, respectively, in relation to control. Shade improved survival 38 percent and 61 percent for larch and Douglas-fir, respectively, compared to no shade.

Growth. Reducing competing vegetation increased tree volume growth for both western larch and Douglas-fir relative to controls (table 1). Spot treatment with sulfometuron increased larch tree size almost 5-fold, and mats provided an 8-fold increase. Douglas-fir showed much smaller growth improvements with weed control. Although western larch seedlings showed no apparent growth benefit with shade, shaded Douglas-fir seedlings were 2.7 times larger than unshaded.

Ten-Year Results

Rebarrow. Because of poor survival in all treatments, the Rebarrow site was abandoned after the fourth year.

Obie. *Survival***.** Survival of western larch seedlings was 3–4 times greater when competition was controlled than in the control treatment (figure 1). Except for mats without shade, weed control substantially improved Douglas-fir seedling survival through year 10 as well, with the shaded mat and spot herbicide treatments showing survival rates of 63 percent and 78 percent, respectively, compared with 40 percent in the shaded control (figure 1). Shade appeared to have a greater effect on Douglas-fir seedling survival than

Table 1. Treatment comparisons of survival, height, basal diameter, and individual tree volume of Douglas-fir and western larch seedlings at Rebarrow and Obie in year 4.

	Rebarrow					Obie				
	Control	Mat	Sulfometuron	Shade	No shade	Control	Mat	Sulfometuron	Shade	No shade
Western larch										
Survival (%)	16.0	33.0	28.3	29.0	13.0	19.0	75.0	76.0	66.0	48.0
Height (cm)	50.5	57.1	55.1	55.0	55.6	61.7	101.4	96.3	91.5	92.7
Basal diameter (mm)	8.3	9.5	9.8	9.0	9.8	8.5	18.7	15.1	15.8	15.0
Volume (cm³)	9.1	13.5	14.1	11.7	14.0	11.7	92.8	57.5	59.8	54.6
Douglas-fir										
Survival (%)	23.0	36.0	18.0	37.0	14.0	32.0	46.0	71	61.0	38.0
Height	26.5	35.1	40.6	37.7	35.1	37.9	42.0	37.8	46.1	30.6
Basal diameter	5.9	8.6	8.8	8.3	8.3	7.9	9.1	8.4	9.7	7.2

on western larch, increasing survival by 100 percent in the control treatment and almost tripling survival when shade was used with mats. Shade benefits were less dramatic for herbicide-treated seedlings (data not shown).

Growth. Individual unshaded western larch seedlings in the herbicide or mat treatment grew 5 to 6 times larger than seedlings in the control; however, the benefits of weed control were somewhat less for shaded seedlings (figure 2). Individual mean tree volume of Douglas-fir seedlings in the mat treatment with shade was twice as large as that in seedlings in the shaded control or herbicide spot spray treatments (figure 2). Herbicide spot treatment without shade produced a 70-percent increase in seedling size compared to unshaded seedlings in the mat and control treatments. Shade more than doubled the mean individual Douglas-fir tree volume compared with seedlings without shade; however, there was no difference between shaded and unshaded treatments for western larch (figure 3).

Area volume yields of western larch were 15 times greater in the herbicide treatment than in the control (figure 4). The mat treatment response was even higher, yielding 21 times the yield of the control. Seedlings grown with mats provided about 40 percent more volume per area than those treated with herbicides. Area volume yields of Douglas-fir in the shaded mat treatment grew more than twice as much as in the shaded herbicide treatment and nine times as much as in the unshaded mat and control treatments (figure 4). Douglas-fir seedlings in the shaded herbicide treatment grew 48 percent more volume per area than shaded controls.

Cost analysis. In both species, cost was lowest in the unshaded herbicide treatment, followed closely by the shaded herbicide treatment (table 2). Although shading generally improved seedling survival, this advantage was not enough to offset the added cost of shade cards, except in the control and mat treatments for Douglas-fir. (There was only a $0.02/seeding benefit for shaded trees in the larch mat treatment). Mats were a lower cost alternative than no treatment for larch because of the large difference in survival rates between the treatments.

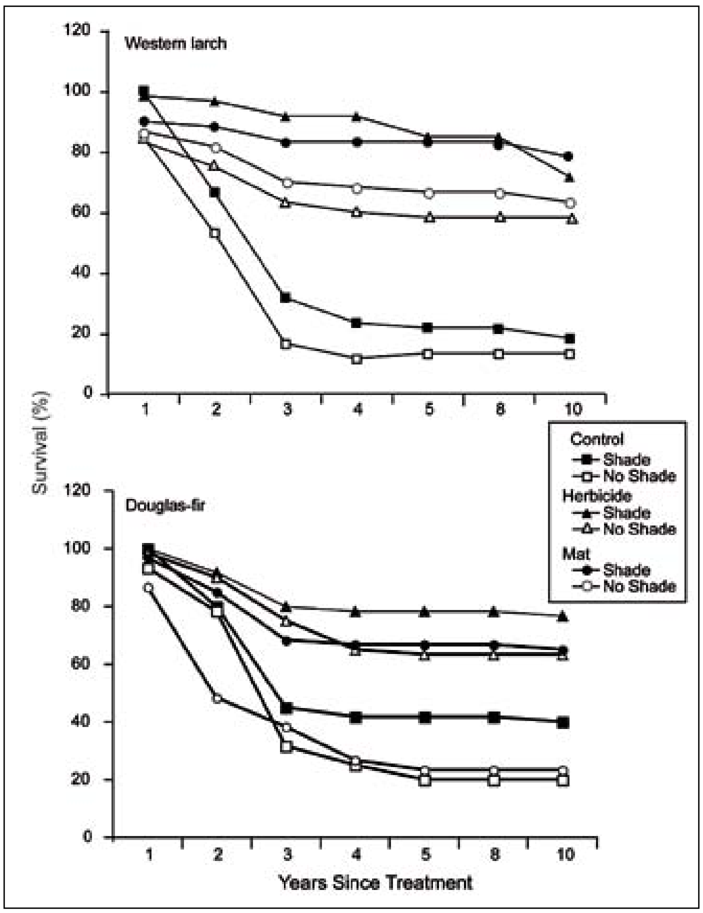

Figure 1. Mean survival by treatment for western larch and Douglas-fir 10 yr after planting.

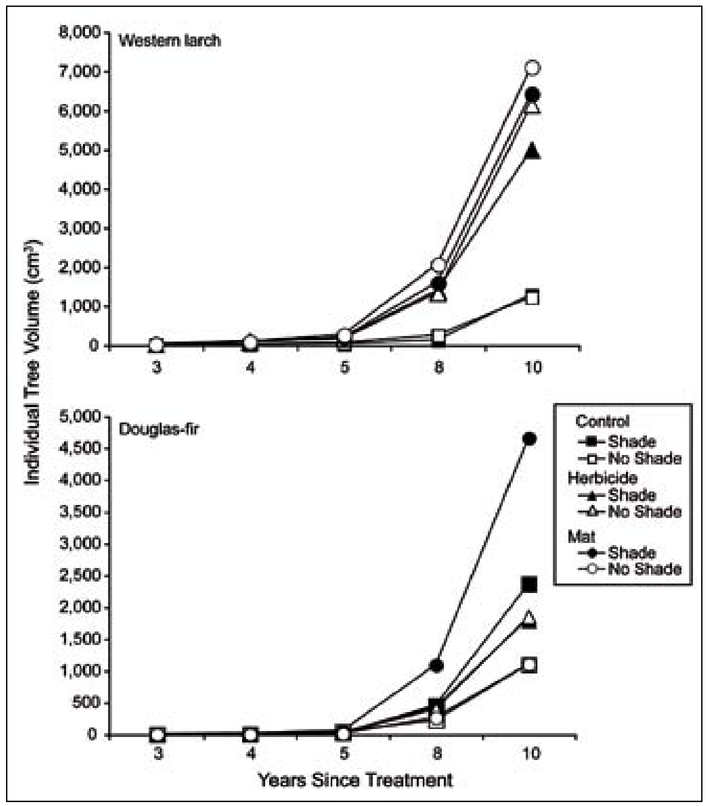

Figure 2. Mean individual tree growth at Obie by treatment for western larch and Douglas-fir through the first 10 yr after planting.

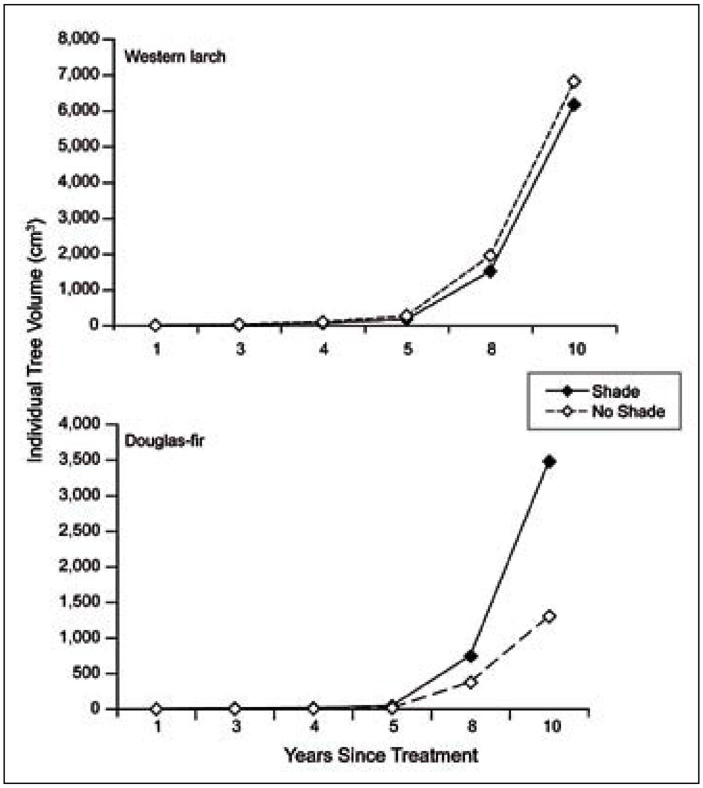

Figure 3. Mean individual tree volume at Obie for western larch and Douglas-fir, with and without shade, through the first 10 yr after planting.

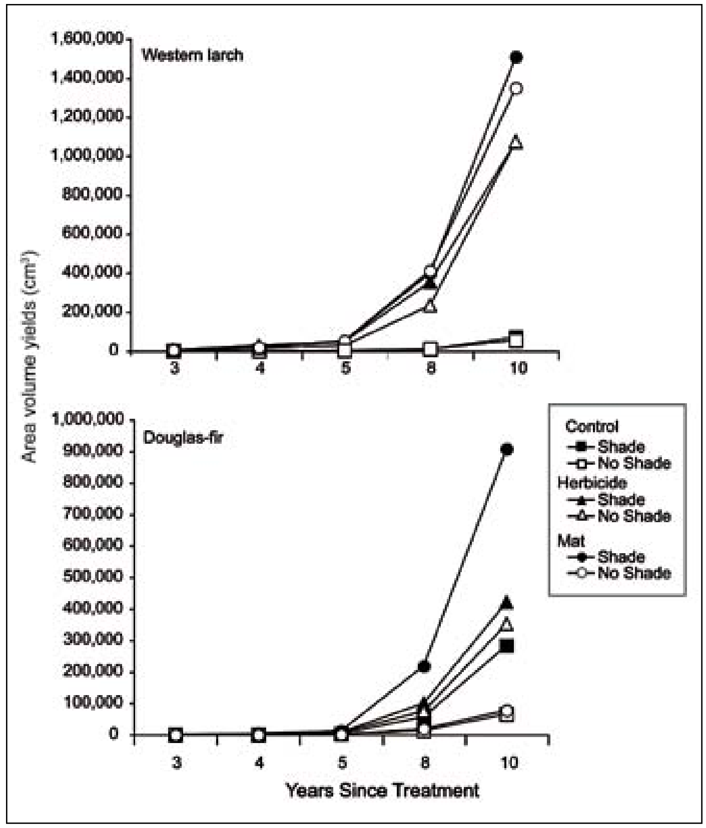

Figure 4. Mean per acre volume growth by treatment at Obie for western larch and Douglas-fir through the first 10 yr after planting.

Table 2. Year 10 established seedling cost by treatment at Obie.

	Control		Herb		Mats	
	Shade	No shade	Shade	No shade	Shade	No shade
Cost per acre ($)[1]	291	177	339	225	624	510
Western larch						
Established seedlings per acre[2]	55	45	215	175	235	190
Cost per seedling ($)	5.29	3.93	1.58	1.29	2.66	2.68
Douglas-fir						
Established seedlings per acre	120	60	230	190	195	70

[1] Cost assumptions (in 1997 dollars):
- 300 trees planted ac^{-1}.
- Douglas-fir and western larch seedlings: $240 per 1000.
- Planting: $0.35 $seedling^{-1}$.
- Sulfometuron herbicide: $3.25 ac^{-1}.
- Herbicide application: $45.00 ac^{-1}.
- Mats: bulk mats $186 ac^{-1}, application $75.00 ac^{-1}, staples $12.00 ac^{-1}, cutting mats $60.00 ac^{-1}.
- Tree shades: shade card $45.00 ac^{-1}, wickets $30.00 ac^{-1}, installation $37.50 ac^{-1}.

[2] Established seedlings per acre at year 10 = (300)(percent survival).

Discussion

The results presented here are consistent with other spot-treatment vegetation control studies in the region (Barber 1984; Oester and others 1995). Barber (1984) tested 1-m^2 (11-ft^2) site-preparation spot treatments with atrazine and hand scalps of 0.15 m^2 (1.6 ft^2) on a grassy site near Cle Elum, WA. First year 2-0 Douglas-fir survival was improved about 5-fold and predawn moisture stress of seedlings dropped by 4.5-fold after atrazine treatment, compared with the control. Oester and others (1995) found that 2-0 ponderosa pine trees faced with grass competition survived 250 percent better and were 350 percent larger than control trees 5 yr after hexazinone treatment. This study found the same trends: after 10 yr, spot herbicide applications doubled survival of Douglas-fir seedlings, and small mulch mats doubled Douglas-fir tree growth. The sulfometuron spot spray or mat improved western larch survival 3–4-fold and tree growth 6–8-fold.

The long-term seedling survival and growth improvements with sulfometuron for western larch on the Obie site suggest that this low-cost, one time treatment could be an effective choice for woodland owners looking for reasonable boosts in performance for a relatively small investment. Mats could be an alternative for woodland owners who want comparable performance, but would rather not use herbicides; however, the cost will be higher (table 2). For the most part, the same can be said for Douglas-fir; however, there are two differences. First, if black mulch mats are used to establish Douglas-fir on open sites, a shade card is essential to prevent high seedling mortality, which will increase cost. Second, although the sulfometuron treatment controlled weeds enough to improve Douglas-fir survival, it did not benefit growth after 10 yr at Obie. The retarded growth of Douglas-fir with sulfometuron is not uncommon and could have been caused by the higher application rate [293 ml ai ha^{-1} (4 oz a.i. ac^{-1})] used in this trial (Justice 2007, personal communication). Those owners who want to use an herbicide treatment and prevent growth setbacks should consider using an alternative to sulfometuron or consulting a herbicide specialist for recommendations.

If mulch mats are preferred and cost is not an issue, a larger mat may be used to improve growth response. In a 5-yr study in the coast range of northern California, comparing large and small mulch mats, a small scalp and control, McDonald and others (1994) found that mean diameter of Douglas-fir seedlings grown with large mats [9.3 m^2 (100 ft^2)] was significantly greater than that of the control and scalp treatments.

Increasing the area of a competition-free zone around seedlings has been shown to improve conifer growth in a number of species and locations (Jaramillo 1988; Mason and Kilongo 1999; Rose and others 2006; Wagner and Robinson 2006), with site productivity and species influencing the optimal area of weed control around seedlings (Richardson and others 1996; Wagner and Robinson 2006). After 10 years at Obie, the two small area weed control treatments apparently gave seedlings enough additional site resources to start them on a growth trajectory greater than that of the control and diverging from the latter with time. Rose and others (2006) found that Douglas-fir growth response on a coastal site in Oregon to a 1.49-m^2 (15.5-ft^2) spot application of herbicide was about 65 percent of the tree growth potentially obtainable with total vegetation control, after 12 yr. Based on the trends presented here, potentially greater growth improvements could be achieved with more intensive vegetation control.

On the open sites in this study, shaded seedlings in general showed greater survival than unshaded seedlings, which is consistent with other studies (Lewis and others 1978; Hobbs 1982; Helgerson 1990; Helgerson and others 1992). Shade cards lower surface soil temperature and reduce soil surface evaporation and soil water loss, increasing soil moisture available for seedling use (Flint and Childs 1987). This trial indicates that shade may improve growth of Douglas-fir seedlings; however, the lack of statistical analysis limits inferences, and more rigorous study is needed. Shade did not improve growth of western larch, possibly due in part to its high intolerance to shade (Schmidt and Shearer 1990). The high mortality observed with unshaded Douglas-fir seedlings in the mat treatment likely resulted from elevated temperatures around the seedling caused by the high heat absorption properties of black mulch mats. Other mortality causes, such as animal damage from voles, were not observed to differ between shaded and unshaded seedlings. Western larch did not show similar survival trends with mats.

Other stock types or sites may show different trends from those in this study. Hobbs (1982) found that shade cards improved survival of Douglas-fir bareroot seedlings on south-facing slopes in southwest Oregon. He suggested, however, that stocktype selection may be as important as shadecards on those soils and that any gains in survival or growth from shadecards may depend strongly on site characteristics.

The lower survival of both western larch and Douglas-fir in the first 4 yr at Rebarrow was probably due to harsher site conditions at Rebarrow. The soils at Rebarrow are shallower and have higher rock content, less ash, and a lower soil–water-holding capacity than those at Obie (Dyksterhuis and High 1985). The aspect at Obie is more northerly, and Rebarrow supports a low-growing shrub community, in addition to grasses, that does not occur at Obie. Shrubs remove moisture at lower depths in the soil profile, effectively reducing available soil moisture for seedlings and increasing competition (Newton 1973). Light browsing by wild ungulates was observed at Rebarrow but not Obie. Finally, although precipitation was not monitored on site, precipitation amounts in LaGrande, OR, during the study averaged 10 percent lower than the 1971–2000 annual average of 444.5 mm (17.5 in) (Oregon Climate Service 2008). Three of the first 4 yr and 7 of the 10 yr of the study were below average in annual precipitation. The combined effect of these factors was likely responsible for the higher mortality on Rebarrow in spite of weed control efforts. Higher survival might have been achieved at Rebarrow by applying a higher level of competition control, planting well-balanced seedlings with large root systems, and protecting seedlings from animal damage. Site differences can have big effects on the level of response to and success of vegetation management treatments. The difference in seedling performance between these two sites when similar vegetation management treatments were applied is a good lesson that a "one size fits all" approach should be avoided.

Cost analysis indicates that shade cards are justified economically only for Douglas-fir seedlings planted with no vegetation management or when used in conjunction with mats. Less expensive sources of shade would improve the cost benefits of shade in the other options.

Although the no-treatment option was initially less expensive than the herbicide spot spray, survival fell short by up to 198 seedlings ha^{-1} (80 ac^{-1}), and cost per established seedling was more. Additional dollars would be needed for interplanting and weed control to bring stocking up, causing an even higher per-unit cost to meet management goals, including, in this case, achieving Oregon's Forest Practices Act minimum requirement of 125 trees ac^{-1}. Not only does the "cheap" way increase the real total cost, but also time on the production cycle is lost and the investment must be carried longer—and time is money (Talbert 2008).

Summary

Small, tree-centered spot vegetation management treatments of sulfometuron or plastic mulch mats have the potential to improve survival and growth of Douglas-fir and western larch seedlings on similar sites in northeast Oregon. Western larch appears to perform particularly well through the first 10 yr with small, one-time reductions in competition. More intensive weed control may show better responses. Shading seedlings generally improved survival; however, the added cost of shade cards was not financially feasible except where Douglas-fir was planted without weed control or when black plastic mulch mats are used. Less expensive shade alternatives may prove more cost effective. More research is needed to gain a better understanding of these relationships.

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