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Alternate Types of Artificial Shade Increase Survival of Douglas-Fir *(Pseudotsuga menziesii* (Mirb.) Franco) Seedlings in Clearcuts[1]

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*Survival of Douglas-fir (*Pseudotsuga menziesii *(Mirb.) Franco) seedlings on two sites facing south was increased by three artificial shading devices: shadecards to the south of the seedlings, shadecards to the east of the seedlings, and Styrofoam cups inverted around seedling bases. Shadecards placed to the south of the seedlings increased survival the most, but the cups also increased survival and were cheaper. On one site, deer did not browse the seedlings; but on the other site, seedlings with shadecards were browsed less than either the controls or the seedlings with cups.* (Tree Planters' Notes 36(4):7-12; 1985)

In southwest Oregon and northern California, excessive heat has killed many Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) germinants and nursery-grown seedlings on slopes facing south. Heat can be moderated by shelter-wood regeneration (8) but still may be great enough to kill natural germinants (5). Shelterwoods, however, usually cost more than clearcutting and complicate weed control. Also, logging the overstory may kill many established seedlings. Some sites in southwest Oregon may require additional preparation and planting after final overstory removal.

Artificial shade boosts survival of nursery-grown conifers planted on clearcuts facing south. Shade from hand-piled rocks and woody debris increased survival of Douglas-fir and white fir *(Abies concolor* (cord. & Glend.) Lindl. ex Hilde br.) in California (13) and Douglas-fir in Oregon (11), but many seedlings were killed by toppling debris. In northern California, shade from lath fencing increased survival of Douglas-fir germinants, but nursery-grown stock survived well regardless of shade (16). Shade from cedar shingles boosted survival of Douglas-fir and white fir in northern California (1) and of Douglas-fir in southwest Oregon (9).

Large shingles are expensive. Shadecards, a cheaper alternative, have been widely used to protect seedlings on slopes facing south in southwest Oregon. Shadecards are 216- by 280-millimeters (8- by 10-inch) pieces of heavy waxed cardboard stapled to lath stakes, which are then driven into the soil about 7 centimeters (3 inches) south of the seedling (fig. 1).

Hobbs (7) reported that shadecards increase survival of 1+0 Douglas-fir seedlings on slopes facing south, but not on those facing north, east, or west. Shadecards are also effective on flat sites (1). Although shadecards apparently have not decreased survival, data showing increased survival with

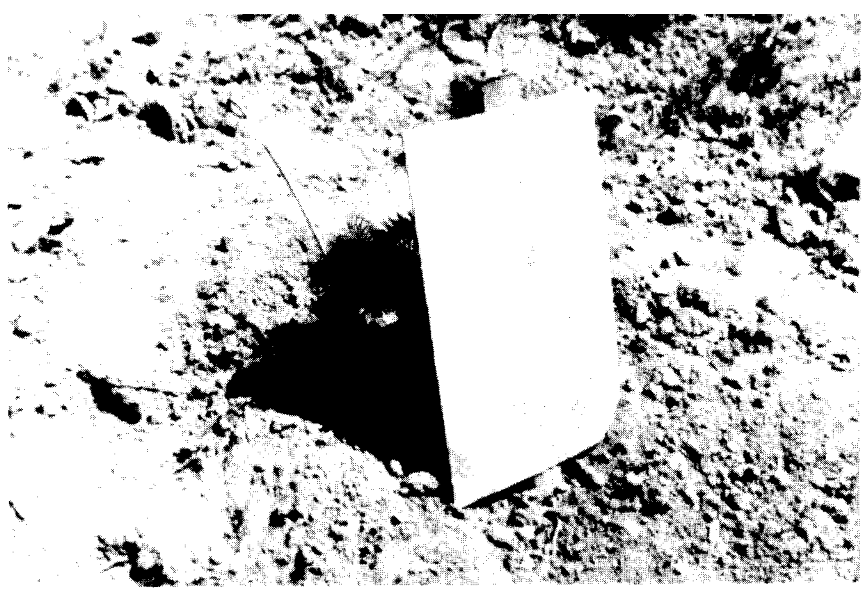

Figure 1—*Seedling with shadecard.*

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shadecards vary considerably (9, 12, 15). Soil characteristics may contribute to this variation, because shade effectiveness apparently increases with coarseness of soil texture (9, 12). Annual and seasonal weather changes may also be important.

Although clearcutting and planting with shadecards can be a cheaper reforestation method than shelterwood harvesting (9), the shadecards are still expensive. They cost 30 to 40 cents per seedling for materials and installation.

This study was done to determine if shading with Styrofoam cups (fig. 2) would lower costs and increase survival rates compared to shadecards. Another objective was to test whether shadecards placed to the east would, because of additional morning shade, increase survival despite greater afternoon heat. A third objective was to explore the effects of shade on Douglas-fir planted under different conditions on two different sites.

Methods

Bareroot 2+0 Douglas-fir seedlings at two sites were shaded in the following ways: a) with shadecards to the south, b) with shadecards to the east, and c) with 187-millimeter ($6^1/_3$ -ounce) Styrofoam coffee cups inverted around seedling bases. Some seedlings were left unshaded for controls. The shades were installed in a randomized, complete-block design (2), with three replications at the two sites.

Figure 2—*Seedling with Styrofoam cup.*

Before the cups were installed, the bottom of each was removed and the sides were slit. After installation, the rim of each cup was fastened to the soil with three U-shaped pins made from paper clips. Whereas a shadecard shades most of the seedling and a diurnally changing area of soil behind it, an inverted cup continuously shades about 60 millimeters (2.3 inches) of the seedling's base and a much smaller soil area (fig. 1).

Lick Ridge Site. The Lick Ridge site (T. 39 S., R. 2 W., S. 34, Willamette Meridian) is on a south-facing 30-40 percent slope at 883 meters, (2,900 feet) elevation. The soil has characteristics of both a loamy, skeletal Typic Haploxeralf and a fine-loamy, mixed, mesic Typic Haploxeralf. Gravel particles (> 2 millimeters) average 13 percent (SE, 1.33; N = 3) by weight of the surface 80 millimeters. Annual rainfall is about 890 millimeters (35 inches) (4), one-seventh of which (127 millimeters, or 5 inches) falls between May 1 and September 30 (10). Potential direct-beam solar radiation is about 144,000 gram calories per square centimeter between May 1 and September 30 (3).

The site, on Bureau of Land Management holdings, had been withdrawn from the allowable-cut land base because of reforestation problems. A manzanita *(Arctostaphylos patula* Greene) brushfield with scattered ponderosa pine *(Pinus ponderosa* Laws.) dominated the site. The brush was piled with a bulldozer and burned in 1980. The site had been planted as part of a land reclamation effort in 1981 and received 2.25 kilograms/hectare (2 pounds/acre) of atrazine for grass control.

Study seedlings at Lick Ridge were planted February 19, 1982, in cold, clear weather. Each treatment plot held 50 seedlings planted by an experienced crew. Shade cards and cups were installed within 2 weeks of planting. In 1983, germinant brush plants were controlled by hand-pulling within the plots and by application of 2.25 kilograms/hectare (2 pounds/acre) of 2,4-D on the rest of the unit.

Julie Creek site. The Julie Creek site (T. 34 S., R. 9 W., S. 35, Willamette Meridian) faces south with slopes between 40 and 60 percent at an elevation of 944 meters (3100 feet). The soil is a fine-loamy, mixed mesic Ultic Haploxeralf. Gravel particles make up an average of 14 percent (SE = 3.38, N = 3) by weight of the surface 80 millimeters. Average annual rainfall is about 2,032 millimeters (80 inches) (4), one-tenth of which (203 millimeters or 8 inches) falls between May 1 and September 30 (10). During this period, potential directbeam insolation is about 142,000 gram calories/square centimeter (3). Old-growth Douglas-fir with under-story tanoak *(Lithocarpus densiflorus* (Hook & Arn.) Rehd.) and Pacific madrone *(Arbutus menziesii* Pursh) occupied the site. The Douglas-fir was harvested, the brush slashed, and the site burned in 1981. In 1983, tanoak and madrone sprouts in the study plots were controlled with a broadcast application of 1.09 kilograms/ hectare (1.5 pounds/acre) of triclopyr ester.

At Julie Creek, seedlings were planted in warmer weather (May 4-6, 1982) because access roads were previously blocked by snow. Each treatment plot held 40 seedlings planted by an inexperienced crew. Shadecards and cups were installed within 4 weeks of planting.

The 2+0 bareroot seedlings planted at both sites were grown at the USDA Forest Service J. H. Stone Nursery near Medford, Oregon. The Lick Ridge seedlings were lifted January 19, 1982, and the Julie Creek seedlings were lifted January 4 and 5, 1982. The vigor of seedlings from each lot was measured by stress-testing (6). Seedling heights and root collar diameters were measured after planting and at the end of the first two growing seasons. Treatment differences were tested with analyses of variance and the Ryan-Einot-Gabriel-Welsch multiple F-test (14). Survival and browsing means were transformed with the arc-sin conversion (2). The means for each location were compared by analysis of variance, according to the place-by-treatment interaction.

Results and Discussion

Effects on Survival. At Lick Ridge, survival of the shaded seedlings was near 100 percent for the first and second year. Survival of the control seedlings was significantly lower within each year ($P<0.05$) and dropped from 94 percent in 1982 to 89 percent in 1983. At Julie Creek, overall seedling survival was lower than at Lick Ridge, but the difference between shaded seedlings and the controls was greater, differing significantly in 1982 and 1983. At both sites, seedlings with south-placed shadecards survived best, and most of the mortality occurred in the first growing season (table 1).

On both sites, the survival of seedlings shaded with cups was about the same as those shaded with south-placed shadecards. This result suggests that shading the base of seedlings is as effective as shading a larger area on the seedlings. Some cups blew away and had to be reinstalled; otherwise, more seedlings shaded with cups might have survived. All shadecards stayed in place. In general, shadecards placed on the east side increased survival on both sites, but not as much as shadecards placed on the south side or cups. Unshaded control seedlings that died showed no heat lesions.

In stress tests, Lick Ridge seedlings ranked "excellent" (3 percent mortality of stressed seedlings), and Julie Creek seedlings ranked "good" (10 percent mortality of stressed seedlings). The Lick Ridge

Table 1—*Percentage survival of seedlings, planted at Lick Ridge and Julie Creek sites, during their first (1982) and second (1983) growing seasons*[1]

Site	Control	Shade card East	Shade card South	Styrofoam Cup
Lick Ridge				
1982	94a	99b	100b	99ab
1983	89a	97ab	100b	99ab
Julie Creek				
1982	72a	85b	94b	89b
1983	69a	82b	89b	85b

[1]Means within a row followed by the same letter do not differ at $p = 0.05$.

was 4.58 millimeters (SE = 0.31) and that of live seedlings was 4.95 millimeters (SE = 0.08). At Julie Creek, the average diameter of dead seedlings was 4.20 millimeters (SE = 0.19) and that of live seedlings was 4.11 millimeters (SE = 0.13). After 2 years, some live seedlings in control plots at Julie Creek had planting diameters under 3 millimeters, and some dead seedlings had planting diameters over 7 millimeters.

seedlings broke bud quickly and uniformly in the spring; the Julie Creek seedlings broke bud more slowly, some not until late June. Results from Julie Creek showed a higher mortality rate for control seedlings and a relatively higher survival rate for shaded seedlings. Because soil gravel content was almost the same at the two sites, probable causes for the increased mortality were poorer quality seedlings (longer in storage), hotter planting conditions, and inexperienced planters. This theory supports Strothman's (16) suggestion that high survival is partly due to excellent planting stock and careful planting, regardless of shading intensity.

Some foresters suggest that small-diameter seedlings may be more susceptible to heat damage than large-diameter seedlings. In this study, however, live and dead seedlings in the control plots within each study area did not vary greatly in size at the end of the first year. In the first year, the average diameter of dead seedlings at Lick Ridge

Table 2—*Seedling sizes at Lick Ridge (all live seedlings) and Julie Creek (all live unbrowsed seedlings)*[1]

Site, seedling size, and year	Control	Shadecard East	Shadecard South	Styrofoam cup
Lick Ridge				
Diameter (mm)				
Planting	4.9	4.8	4.9	4.9
1982	7.9	6.8	6.9	6.9
1983	13.6a	11.4b	12.4ab	12.2ab
Height (mm)				
Planting	246	237	243	246
1982	334	303	312	309
1983	512	464	484	489
Volume (mm^3)				
Planting[2]	6,387	6,185	6,296	6,165
1982	24,896	15,849	16,965	16,851
1983	117,719a	72,356b	86,647b	88,138ab
Julie Creek				
Diameter (mm)				
Planting	4.0	3.7	4.1	4.4
1982	5.3	5.5	5.5	5.8
1983	7.6	8.0	7.1	8.2
Height (mm)				
Planting	271	260	256	286
1982	294	282	283	313
1983	329	321	299	354
Volume (mm^3)				
Planting[2]	5,228	4,215	5,109	6,396
1982	8,823	9,437	9,575	11,692
1983	21,636	25,499	17,724	30,707

[1]Treatment means in a row with different letters differ at $P < 0.05$, as indicated by ANOVA with previous size as a covariate when appropriate.
[2]Volume = D^2H.

Effects on Growth. After 2 years, the unshaded seedlings at Lick Ridge had the largest diameters and volumes, and the seedlings in the east shade were the smallest. Tests of statistical significance indicated overlap between the treatments (table 2). The greater growth of the unshaded seedlings concurs with results in Strothman's (16) study.

Overall, seedling growth was greater at Lick Ridge. Tests of location means show that the Lick Ridge seedlings were larger ($P<0.05$) than the Julie Creek seedlings in diameter and height at planting. After 2 years, the Lick Ridge seedlings were larger than the unbrowsed Julie Creek seedlings in diameter, height, and volume. The ratio of growth to planting size was greater ($P<0.05$) at Lick Ridge than at Julie Creek.

Probably the larger size of Lick Ridge seedlings at planting did not affect their overall greater survival. Findings in this study showed that the size of live and dead seedlings did not vary greatly.

Effects on Deer Browsing. Lick Ridge seedlings showed no evidence of deer browsing, but shadecards apparently reduced deer browsing at Julie Creek. Most browsing occurred during the first growing season. Shadecards may therefore increase survival by reducing deer browsing (table 3). The only significant relationship between browsing and survival was in the controls at Julie Creek (table 4).

Table 3—*Percentage unbrowsed seedlings at Julie Creek*[1]

Growing season	Unshaded control	Shadecard East	Shadecard South	Styrofoam cup
1982	69a	92b	93b	75b
1983	68a	90b	92b	71a

[1]Values in a row followed by different letters differ significantly ($P = 0.05$).

Table 4—*Effect of browsing on mortality of seedlings at Julie Creek*

Seedling treatment	No. of seedlings Unbrowsed	No. of seedlings Browsed
Controls		
Dead	28	5
Alive	55	32
Shaded seedlings		
Dead	66	8
Alive	327	79

Note that about half of the unbrowsed, unshaded controls died, compared to only 5 of the 32 browsed, unshaded controls. Browsing probably does not increase survival; a more plausible explanation is that the unbrowsed seedlings were less healthy or less palatable. Shade may increase survival of poorer-quality seedlings most. The unbrowsed, unshaded seedlings at Julie Creek had the lowest survival rate, whereas the unbrowsed, shaded seedlings had a high survival rate.

Cost-Effectiveness. Cardboard and lath shadecards weigh about 200 grams (0.44 pound) and cost about 20 cents each. Cost of installation is about 20 cents. Styrofoam coffee cups weigh about 2.2 grams (0.005 pounds) each and cost about 2 cents. Estimated installation cost is 5 to 10 cents each. Subsequent observations indicate that installing the cups over the seedlings by punching out the bottoms but not slitting the sides will prevent their blowing away and thus will eliminate the need for pins. Although south-placed shadecards are slightly more effective in boosting survival, cups are less expensive. Although the three shading methods increased survival at Lick Ridge significantly, they are not cost-effective, given the 89-percent survival rate of the unshaded controls.

Conclusions

Initial survival and growth of Douglas-fir may depend more on seedling quality, planting conditions, or both, than on shade treatment or expected rainfall. This theory is supported by the better survival, growth, and stress test results of seedlings planted at the drier site, Lick Ridge. Artificial shade had greater effects on the survival rate of poorer quality seedlings and seedlings planted under adverse conditions than on better quality seedlings and those planted under optimal conditions. If shade is necessary, inverted Styrofoam cups are nearly as effective as shadecards and are much less expensive. Shadecards may reduce deer browsing during the first 2 years of seedling growth.

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