Nursery Practices, Seedling Sizes, and Field Performance[1]

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Abstract.--Highlights are presented from a large cooperative study to determine the combined effects of nursery cultural practices on the initial size and subsequent field performance of 2+0 Douglas-fir seedlings. The study involved seven sources of stock produced in three different nurseries and field plantings made over 3 years on 28 sites in southwestern Oregon. Seedbed density had more effect on the size of seedlings produced and on subsequent 4-year field survival and growth than did variations in irrigation frequency or undercutting and wrenching.

INTRODUCTION

A large cooperative research endeavor to determine the combined effects of nursery cultural practices on the size and subsequent field performance of 2+0 Douglas-fir seedlings has been underway in southwestern Oregon for the last decade.[3] This short report provides nurserymen a preliminary synopsis of field results that, when fully analyzed, will be covered in one or more scientific articles.

OBJECTIVES

Nursery cultural practices used in the production of bareroot stock received renewed emphasis during the 1970's. Wrenching was given particular attention, but various studies were also made on the effects of seedbed density, undercutting, fertilization, and other practices. Much information was produced by these studies, but there remained important gaps in our understanding; namely, (1) There was conflicting evidence on the benefits of wrenching. (2) Most studies had measured the effects of varying a single practice at only one nursery. (3) The longer-term effects of nursery practices on seedling field performance were not known.

A multi-faceted study involving three nurseries, outplantings in 3 years, and subsequent field observations for 4 years was carried out to learn more about the combined effects of nursery practices. The first description of this study was reported at the Nursery Council's meeting in Eureka, California (Jaramillo 1978, Stein 1978), and completed results for one facet of the effort were reported at the Council's meeting in Coeur d'Alene, Idaho (Stein 1984, 1985).

METHODS

The general approach in this investigation was to subject Douglas-fir seedlings to different combinations of nursery cultural practices during their second year in the nursery, measure a sample of the seedlings produced, and subject other samples to greenhouse and outdoor performance tests. The key performance test involved planting rows of seedlings representing each treatment combination on contrasting forest sites. Over a 3-year period, trials were made with seedlings from seven seed sources grown in three nurseries and tested by identical methods.

In four trials, seedlings were produced in 18 combinations of three nursery practices--two moisture regimes, three levels of root disturbance, and three seedbed densities. In two additional trials, fertilization was also varied, and each nursery practice was applied at two levels--16 combinations. One trial had only nine treatment combinations--three levels of root disturbance and three seedbed densities.

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[1]Paper presented at the Combined Western Forest Nursery Council, Forest Nursery Association of British Columbia and Intermountain Forest Nursery Association meeting; 1988 August 8-11; Vernon, British Columbia.
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In each trial, treatment combinations were replicated three times on stock of the same seed source--in most instances, replications were made in seedbeds adjacent to each other. Every treatment combination was randomly assigned to a plot in each bed. Either in the fall of the first season or early spring of the second, all plots were thinned as specified to 10, 15, or 30 seedlings per square foot (108, 161, or 323/sq. m). Later in the spring, one-third of the plots were undercut at 6 inches (15 cm). Another third of the plots, as designated beforehand, was undercut and wrenched at 8-inch (20-cm) depth when seedlings were 8 inches (20 cm) tall, with wrenching repeated at 3-week intervals until September. The remaining third of the plots received the same undercut and wrenching treatment and, in addition, was vertically root-pruned on two sides every 6 weeks. In their second growing season, seedlings were irrigated often enough before June 15 to keep their moisture stress at dawn below 5 bars. In the following 2 months, seedlings in half the plots were allowed to reach stresses up to 12 bars before rewatering. In late summer and autumn, all seedlings were allowed to reach the higher stresses before rewatering.

Samples of seedlings from all treatments were collected in fall and winter for measurement of size and tests of performance, but only those lifted in winter were outplanted on forest sites. To achieve equal sorting of all treatments, only damaged seedlings and obvious runts were culled. Thus, some small-diameter or short seedlings that normally would be culled were included in the sets of sample seedlings.

Seedlings of a single seed source were planted on four clearcuts appropriate in location and elevation for the source. Planting sites were chosen to represent contrasting conditions--generally moderate to severe reforestation situations (fig. 1). Three blocks of test trees were planted on each site; each block contained one row of each treatment. Rows contained 20 trees each. Thus, each treatment combination was represented by 240 trees per seed source--12 rows in three replications at four locations. Trees planted in the third year were protected by plastic mesh tubing. Most outplanting sites were on Bureau of Land Management lands both east and west of Roseburg, Oregon.

Survival and total height of outplanted seedlings were obtained after the first, second, and fourth growing seasons. Also, the size attributes at outplanting were measured for seedlings from all treatment combinations. For purposes of this broad overview, an average was calculated for each irrigation, wrenching, and density level tested on the individual seed source. Treatment averages from all seed sources with the same treatment combinations were then summed and overall averages calculated. Six of the seven seed sources included comparison of two moisture levels, but only five included three levels of root disturbance and seedbed density.

RESULTS

Seedling Size

Seedlings tested for field performance were generally of medium length, sturdy, and well-balanced. Top lengths of seedlings averaged 10.1 inches (25.7 cm), and means ranged from 8.0 to 12.8 inches (20.4 to 32.5 cm) among the seven

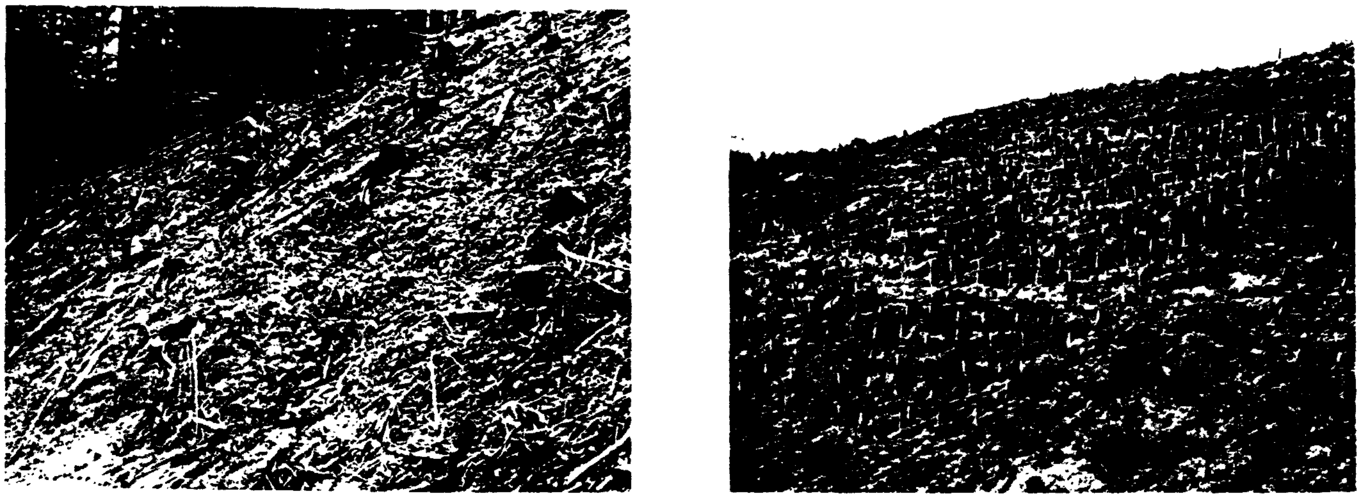

Figure 1.--Seedlings were planted on contrasting sites in geographic locations appropriate to the seed source. Sites included: (LEFT) a steep, unburned north slope at 2,800 feet (850 m) in the Cascade Mountains east of Sutherlin, Oregon, and (RIGHT) a freshly burned south slope reclaimed from evergreen brush at 1,700 feet (520 m) in the Siskiyou Mountains south of Riddle, Oregon.

seed sources. Stem diameters averaged 0.19 inches (4.9 mm), and source means ranged from 0.16 to 0.23 inches (4.0 to 5.9 mm). Total dry weights of seedlings averaged 7.4 gm, with source means ranging from 5.5 to 9.6 gm. Top-root ratios averaged 1.83 and ranged from 1.47 to 2.34 among the seed source means.

The combinations of cultural practices under which seedlings were produced influenced some of their physical attributes but had little influence on others. Additional irrigation produced seedlings that averaged 0.3 inch (0.8 cm) taller, the same diameter and weight, and slightly different in top-root ratio, 1.87 versus 1.80, than those irrigated with less frequency. Seedlings undercut and wrenched after reaching a specified target height averaged 0.4 inch (1.1 cm) taller than those undercut early in the season; their stem diameters averaged slightly less, however, 0.20 versus 0.21 inches (5.1 versus 5.3 mm). Average dry weight and top-root ratio were almost equal for seedlings subjected to undercutting, undercutting and wrenching, and undercutting and wrenching plus root pruning treatments.

Seedbed density had no effect on average top length of seedlings but influenced their average stem diameter and total dry weight. Among the seed sources tested at three densities, stem diameters averaged 0.23, 0.20, and 0.18 inches (5.7, 5.2, and 4.6 mm), respectively, for the least dense to the most dense seedbeds. Total dry weights averaged 9.2, 7.3, and 5.5 gm per seedling from the least dense to the most dense seedbeds, and top-root ratios were 1.73, 1.83, and 1.93.

Field Performance

Two-thirds of the seedlings planted in the field were alive at the end of 4 years. The average survival among the seven seed sources (and the different geographic areas they represented) ranged from 38 to 83 percent and among the 28 locations at which the seedlings were planted from 14 to 92 percent. Survival in midseason of the first year averaged 96 percent or more for all seed sources except one, demonstrating that healthy seedlings had been planted on all but the four locations receiving stock of this source. Midseason survival was 75 percent for the seed source affected by root rot in the nursery. This source also averaged the lowest survival by the fourth year (38 percent) and had the lowest average (14 percent) for any single field location. Low survival at another field location resulted from planting an area where grass and other competition was already established.

Variations in the cultural practices under which seedlings were produced had only minor influences on their field survival. Survival for seedlings produced under moderate moisture regimes averaged 4 percent higher than for those produced under abundant moisture regimes. Survival for seedlings that were only undercut averaged just 3 percent lower than those subjected to undercutting plus wrenching or wrenching and side pruning. Seedlings produced at the highest seedbed density averaged 6 percent lower survival than those produced at the lowest density.

Seedlings averaged 28.4 inches (72 cm) in total height 4 years after outplanting. As might be expected, there were large differences among sources (and the geographic areas they represented) in average total height--from 17.6 to 52.5 inches (45 to 133 cm). Among all 28 locations, average total height ranged from 11.7 to 63.9 inches (30 to 162 cm). There was as much as a two to one difference in total height among locations planted with seedlings of the same source. Heavy browsing by deer caused seedlings at one location to be substantially shorter than elsewhere.

Only the density at which seedlings were grown had a material effect on their total height in the field 4 years later. Average total height varied 0.4 inch (1 cm) or less for seedlings produced under the two moisture regimes or the three root disturbance treatments. Average total height was 1.8 inches (4.5 cm) greater for seedlings produced at the lowest seedbed density than for those produced at the highest density and intermediate for seedlings from medium density beds.

Stem diameters, measured at 12 inches (30 cm) above ground level, averaged nearly 0.4 inches (9.8 mm) 4 years after outplanting. There were large differences in average stem diameter among seed sources and the geographic areas they represented, ranging from 0.2 to 0.7 inches (5.6 to 18.4 mm). For individual locations, the range was even greater, from 0.15 to 0.88 inches (3.7 to 22.4 mm). Again, the cultural effect of seedbed density was more evident 4 years after outplanting than were the effects of moisture regime or level of root disturbance, but all treatment differences among average diameters were small, .04 inches (1 mm) or less.

DISCUSSION

The seedlings outplanted in this study varied substantially in size, but on the average, they met the quality standards considered desirable for Douglas-fir planting stock--top length over 8 inches (20 cm), stem diameter 0.12 inches (3 mm) or larger, and good balance between tops and roots. Top-root ratio was low, averaging 1.83 with a range of 1.31 to 2.43 among treatments. Wrenching regimes were timed to produce good-sized, balanced seedlings, and this objective was achieved. When outplanted, the primary physical differences among seedlings of different treatments were differences in stem diameter and weight attributable to the densities at which they were produced.

Four years after outplanting, differences in survival and growth of seedlings reflected primarily the initial size effects attributable to seedbed density. Heavier seedlings, resulting from lower seedbed densities, tended to survive and grow better in the field. The effects reflect relatively small differences in density of the seedbeds--a target difference of 10, 15, and 30 seedlings per square foot (108, 161, or 323/sq. m) at the start of the second season. The lowest density at harvest was near 10 per square foot (108/sq. m) but actually closer to 25 than 30 per square foot (269 than 323/sq. m) at the highest density. Studies have shown that large seedlings do better than small seedlings on favorable sites, and within the limits of the seedling sizes tested, results of this study indicate that larger seedlings also tend to do better on sites where moisture stresses are moderate to severe.

Despite large differences in the climates and soils in which seedlings were produced and field tested, the same combinations of cultural practices had similar effects. This is an important finding for it improves the predictability of seedling performance--when seedlings treated the same way in different nurseries respond the same way, not necessarily in magnitude but in direction of the response. Among the range of cultural practices tested, evidence from this study indicates that seedbed density is a more critical determinant of seedling size and future performance than are more frequent watering or more root disturbance from wrenching.

LITERATURE CITED

Jaramillo, Annabelle. 1978. An integrated study of nursery stock conditioning: oscilloscope readings and cold hardiness. p. B106-B116. In: Gustafson, Robert W., ed. Proceedings, Western Forest Nursery Council and Intermountain Nurseryman's Association Combined Nurseryman's Conference and Seed Processing Workshop; 1978 August 7-11; Eureka, California. San Francisco, CA: USDA Forest Service.

Stein, William I. 1978. An integrated study of nursery stock conditioning: preliminary observations on stock performance. p. B96-B105. In: Gustafson, Robert W., ed. Proceedings, Western Forest Nursery Council and Intermountain Nurseryman's Association Combined Nurseryman's Conference and Seed Processing Workshop; 1978 August 7-11; Eureka, California. San Francisco, CA: USDA Forest Service.

Stein, William I. 1984. Wrenching Douglas-fir seedlings in August: immediate but no lasting effects. Res. Pap. PNW-317, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Stein, William I. 1985. Effects of wrenching Douglas-fir seedlings in August. p. 122-125. In: Proceedings: Western Forest Nursery Council-Intermountain Nurseryman's Association combined meeting; 1984 August 14-16; Coeur d'Alene, Idaho. Gen. Tech. Rep. INT-185, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Landis, Thomas D. 1988. tech coord. Proceedings, combined meeting of the Western Forest Nursery Associations; 1988 August 8-11; Vernon, British Columbia, Gen. Tech. Rep. RM-167, Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 227;.