Early Growth and Drought Avoidance in Douglas-fir Seedlings

By Terry D. Heiner
Denis P. Lavender

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Terry C. Heiner
Assistant Professor Biological Sciences
Western New Mexico University

Denis P. Lavender
Professor of Forestry
Oregon State University

CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Methods</td>
<td>1</td>
</tr>
<tr>
<td>Results</td>
<td>2</td>
</tr>
<tr>
<td>Discussion</td>
<td>4</td>
</tr>
<tr>
<td>Conclusion</td>
<td>6</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>6</td>
</tr>
</tbody>
</table>

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Oregon State University
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INTRODUCTION

Although the Douglas-fir region of the northwestern United States and British Columbia is frequently considered to have a common silviculture, obstacles to successful regeneration of the species range from competing vegetation and mammals on the mesic sites to extreme drought and heat on the xeric southerly exposures in northern California and southern Oregon. Recent reports on Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, by Ferrell and Woodard (1), Pharis and Ferrell (8), and Zavitkovski and Ferrell (11, 12) describe studies that demonstrated differences by seed source of response to drought stress of Douglas-fir seedlings under laboratory and greenhouse conditions. Our study was undertaken to determine whether planting stock raised from seed collected from mesic and xeric sites would demonstrate a differential survival under drought stress. And, further, to determine whether such survival differences were correlated with definite seedling parameters.

METHODS

Lots of seeds were collected from five trees growing in a dry area near Medford, Oregon, and from many trees of a young-growth stand in a moist area near Timber in the Oregon Coast Range. The first area supports a scattered stand of mixed Douglas-fir and oak (*Quercus garryana* Doug.) on a 30-percent slope with a southerly exposure. The elevation is about 2,000 feet, and the annual rainfall totals 20 inches. The second area is a slight northerly slope at an elevation of 1,800 feet. The annual rainfall totals 60 inches.

The six lots of seeds were sown in the Oregon Forest Nursery, 6 miles north of Corvallis, in the spring of 1964. In late February, 1966, seedlings were lifted from each population. The largest and smallest 25 percent (by weight) of each group were discarded and 164 seedlings selected randomly from the remaining populations of each of the six seed sources.

During the first week of March, the seedlings were planted in an area 7 by 10 feet in an enclosure designed to permit control of soil moisture. The 164 six-seedling rows each contained one seedling from each seed source positioned randomly. The plants were spaced 3 inches apart in the rows, and the rows were also 3 inches apart. The soil was wetted to field capacity when the seedlings were planted, and then allowed to dry naturally during the growing season. A plastic cover suspended 8 feet above the soil prevented rains from moistening the soil.

In addition, populations of seedlings from each seed source were maintained in the nursery during the experiment. These plants differed from those transplanted to the lysimeter in that the nursery seedlings were not transplanted and were well watered during the growing season. We observed no mortality in the nursery populations.

Activity of terminal and lateral buds and seedling mortality were recorded every week during the growing season. Gravimetric soil moisture determinations were made fortnightly at three soil depths—10, 30, and 60 centimeters. Finally, the experimental populations were harvested in early fall with extreme care to prevent the destruction of fine roots.

After harvest, the following seedling parameters were recorded: seedling fresh weight, depth the roots penetrated, surface area of root system, shoot-root ratio, thickness of needle cuticle, and percentages of potassium and calcium in seedling foliage.
The surface area of the seedling root systems was determined with the titration method of Wilde (10). This procedure is time-consuming, so a sample containing six of the largest and six of the smallest living seedlings of each seed source together with a similar sample of dead seedlings was chosen to represent the seedling populations.

Ratios of shoots to roots were determined for the same plants. The fresh weights of seedling shoots and roots were recorded to the nearest 0.1 gram.

Twenty living seedlings, ten subjected to drought stress and ten from well-watered nursery seed beds, from each seedling population were sampled for determination of needle cuticle thickness. Ten needles were clipped from the distal 1.0 centimeter of current whorl branches of each seedling. Cross sections from the center of each needle were prepared according to standard microtechniques of Johansen (2) and the cuticle thickness was measured under 645x magnification.

Mineral content of current year foliage was determined on composite needle samples harvested from the current whorl of twenty seedlings, ten subjected to drought stress and ten maintained in the nursery, for each seed source. The foliage was dried to constant weight at 70 C, ground in a micro-Wiley mill to pass a 40-mesh screen, digested, and analyzed according to the procedure outlined by Lavender and Carmichael (4).

RESULTS

As noted, the bursting of terminal and lateral buds was tallied at weekly intervals. Figure 1 presents the data describing the terminal bud activity (the lateral bud activity was similar) of the seedling populations.

Percentage of seedling survival is shown for seedlings of the experimental population at monthly intervals for the period of drought stress in Table 1.

Table 1. Survival of Douglas-fir Seedlings under Drought Stress.

<table>
<thead>
<tr>
<th>Seed source</th>
<th>June 1</th>
<th>July 1</th>
<th>August 1</th>
<th>September 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern Oregon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>94</td>
<td>87</td>
<td>64</td>
<td>56&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>2</td>
<td>97</td>
<td>92</td>
<td>81</td>
<td>55&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>77</td>
<td>72</td>
<td>56&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>4</td>
<td>99</td>
<td>97</td>
<td>86</td>
<td>70&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
<tr>
<td>5</td>
<td>96</td>
<td>88</td>
<td>72</td>
<td>58&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Northwest Oregon</td>
<td>87</td>
<td>63</td>
<td>35</td>
<td>16&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Survival percentages with different subscripts (i.e., a, b, c) differ significantly at the 1% level of probability.
Figure 1. Rate and amount of terminal bud burst by seed source and date.

Table 2 summarizes the data describing the mean maximum root length of the living and dead seedlings of each seed source. Statistical analyses of these data showed that only the difference between the root lengths of living plants grown from seed of southern Oregon seed source five and those of the living plants of the northwest Oregon seed source was significant and then only at the 5 percent level of probability. A further analysis of lengths of roots by date of mortality demonstrated no significant difference between dates.

Figure 2 presents the mean soil moisture contents at each sample depth during the summer. Table 3 presents seedling survival and mortality data segregated by root length at time of harvest. Thirty centimeters is the least depth sampled at which there was at least some available moisture during the entire growing season.

Table 2. Mean Root Lengths, by Seed Source in Centimeters.

<table>
<thead>
<tr>
<th>Plant condition</th>
<th>Seed source</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N. W. Ore.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live</td>
<td>38.46</td>
<td>35.53</td>
<td>39.77</td>
<td>36.21</td>
<td>42.67</td>
<td>31.33</td>
<td></td>
</tr>
<tr>
<td>Dead</td>
<td>23.05</td>
<td>21.85</td>
<td>23.49</td>
<td>23.87</td>
<td>23.04</td>
<td>22.41</td>
<td></td>
</tr>
</tbody>
</table>
The determinations of the shoot-root ratios of the surviving seedlings were subjected to statistical evaluation. The analyses demonstrated no correlation between shoot-root ratios and mortality, and no significant difference between shoot-root ratios of plants of the six seed sources.

Neither the chemical analyses of the nondroughted plants nor those of seedlings that survived the drought stress yielded calcium-potassium ratios that were correlated with seedling survival.

Finally, no differences in cuticle thickness could be demonstrated among seedlings of the several seed sources whether or not the plants had been exposed to the drought stress.

DISCUSSION

Experiments with controlled environments have demonstrated that Douglas-fir seedlings that have their chilling requirement satisfied initiate bud growth in response to rising temperature in the spring. The data in Figure 1 demonstrate that seedlings from all the southern Oregon seed sources had a much earlier and more complete bud burst than did those plants grown from northwest Oregon seed. The early growth of the southern plants probably reflects an adaptation to spring rains. In contrast, the northwest Oregon plants normally have plentiful moisture until early summer. No selection for early growth has taken place here; in fact, early growth could be a disadvantage in areas with late frosts.

The data in Table 1 show clearly that the seedlings of the mesic seed source demonstrated the lowest survival throughout the experimental period. A comparison of the data of Table 1 with the bud-burst data in Figure 1 shows a strong correlation between early bud burst and
seedling survival. All seedlings in all populations that had no bud activity died, but those that initiated bud activity early in all populations generally survived the drought stress.

The seedling root systems were excavated carefully to ensure harvest of the intact roots. Although at least part of the roots of dead seedlings may have been destroyed by saprophytes before harvest, the lack of reduction in root length with earlier dates of mortality is evidence that they were not.

The data in Tables 2 and 3 and in Figure 2 indicate that seedling survival was dependent largely upon the ability of the root system to penetrate below a depth of 30 centimeters (the use of this criterion in Table 3 is admittedly arbitrary, because the limits of available soil moisture were not defined accurately by the sampling procedure). Although some root growth may occur in any month of the year, the period of greatest activity is generally in the weeks immediately before bud growth. Because seedlings that initiated bud growth early also initiated the surge of root growth early, the correlation between early bud burst and survival noted probably reflects a correlation between early root growth and survival.

The data in Table 2 and the results of the determinations of root surface area demonstrate little difference among the surviving seedlings of all seed sources in their ability to produce roots. The differences in survival of the seedlings of the tested seed sources, then, is related to the proportion of each study population capable of early, vigorous root growth. Both these data and the lack of correlation of the shoot-root ratios and seedling mortality are at variance with the data of Lavender and Overton (6). These workers found that seedlings grown from seed collected in xeric areas had significantly longer roots and lower shoot-root ratios than did seedlings of the present northwest Oregon source when all plants were grown under controlled conditions.

The relatively constant cuticle thickness of all populations tested confirms the earlier work of Tucker (9), who found no significant difference in the cuticle thickness of needles of seedlings grown from southern Oregon seed or from the present northwest Oregon seed source when the plants were grown under any of several environments.

Table 3. Relation Between Final Seedling Root Length and Seedling Survival.

<table>
<thead>
<tr>
<th>Seed source</th>
<th>Roots &gt; 30 cm</th>
<th>Roots &lt; 30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alive</td>
<td>Dead</td>
</tr>
<tr>
<td>S. Oregon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td>N.W. Oregon</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

1Percentage of seedling population.
Finally, the lack of correlation of the seedling calcium-potassium ratios with seedling survival may be at variance with the results of Kral (3), who found that drought resistance in Douglas-fir was associated with a high calcium-potassium ratio in the foliage. Because the principal survival mechanism identified in the present study—vigorou early root growth—is really a drought-avoidance rather than a drought-resistance mechanism and because Kral found a much greater correlation between provenances than within populations, the two studies may not be contradictory.

CONCLUSIONS

Douglas-fir seedlings with the capacity for early, vigorous growth of roots and shoots demonstrate superior survival potential under drought stress. Although this capacity may not ensure survival in areas with prolonged, severe drought, this parameter should be considered when planting stock is selected for reforestation of droughty sites that do not have early frosts.

The trees of any given seed-production area vary widely in date of flushing (7). Collection of seed from early-flushing trees of a given seed-production area, or, better still, controlled crosses between early-flushing trees, should yield seed that will produce seedlings both well adapted to the area and with high potential for survival on southerly exposures.

LITERATURE CITED


