SEVENTY-FIVE-YEAR-OLD DOUGLAS-FIR ON HIGH-QUALITY SITE
RESPOND TO NITROGEN FERTILIZER

by

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ABSTRACT

Individually treated, 75-year-old, codominant, Douglas-fir trees growing on a highly productive site II soil responded well to nitrogenous fertilizers. Although the six treatments tested increased average 5-year basal area growth by 17 to 53 percent over control growth, only ammonium nitrate at 300-N dosage increased growth significantly. The six fertilizer treatments did not differ significantly among themselves; response to 300 pounds of nitrogen per acre (336 kg/ha) as urea was as good as that to 600-N (672 kg/ha) or to other elements in combination with 300-N.

Keywords: Douglas-fir, Pseudotsuga menziesii, fertilizer response (forest tree), nitrogen fertilizer response, basal area increment, silviculture.
INTRODUCTION

Fertilization is a practical silvicultural tool. However, to maximize its usefulness, we must know where response can be expected from specific treatments and to what extent growth will be increased. The results obtained after fertilizing codominant trees in a highly productive, 75-year-old stand add important information to our knowledge.

Our study was designed to provide answers to five questions, as they pertain to this site and stand condition: (1) Is growth increased by addition of nitrogen? (2) How does response vary by amount of nitrogen added? (3) Does source of nitrogen make any difference? (4) Does addition of other elements, with nitrogen, affect the response? (5) What is the duration of response? We report 5-year basal area growth of individually treated codominant trees.

STUDY AREA

The study area is on the McCleary Experimental Forest, near McCleary, Washington. It lies on gently sloping ground at an elevation of about 400 feet (122 m). Both climate and soil favor rapid tree growth. A nearby weather station, at Elma, shows an average annual precipitation of 66 inches (168 cm), with 14 inches (36 cm) from April through September. Average annual temperature is 51°F (11°C); average temperature from April through September is 58°F (14°C). The average frost-free growing season is about 185 days. The soils, which are derived from glacial till with some admixture from underlying basalt, are Tebo gravelly loams—both normal and wet phases. Site index averages about 180—site II.

The stand originated after repeated fires and is nearly pure Douglas-fir (fig. 1). It was 74 years old when the fertilizer study was begun in spring 1968. Prior to that, the stand had been thinned four times at 5-year intervals, the most recent being in the summer of 1965. At age 74, there were about 70 trees per acre (173/ha), with an average d.b.h. of 23 inches (58 cm) and a volume of 10,000 cubic feet (753 m³/ha).

1/ Maintained by the Pacific Northwest Forest and Range Experiment Station in cooperation with Simpson Timber Company.
2/ Carl McMurphy, Soil Conservation Service, Olympia, Washington, personal communication. Soil had previously been classified as Olympic loam.
METHODS

FERTILIZER TREATMENTS

We tested seven treatments, including a control (table 1). Based on field tests at other locations, we selected most promising elements, combinations, and application rates. Nitrogen, alone or combined with other elements, was applied to all fertilized trees; this choice was based on considerable existing evidence that insufficient available nitrogen generally limits Douglas-fir growth in the Pacific Northwest.

Each treatment was randomly assigned to 6 trees of the 42 selected codominant Douglas-firs, scattered over a 25-acre (10-ha) area. No study tree was closer

Table 1.--Treatments and corresponding amounts of elements and fertilizers applied

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Element</th>
<th>Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>5/</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treble superphosphate (19.6 percent P, 1 percent S, and 12 percent Ca)</td>
</tr>
<tr>
<td>6/</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treble superphosphate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil sulfur (99 percent S)</td>
</tr>
<tr>
<td>7/</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treble superphosphate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil sulfur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potassium chloride (60 percent K and 0.3 percent Ca)</td>
</tr>
</tbody>
</table>

1/ Pounds per acre x 1.12 = kg/ha.

2/ Trees fertilized with treble superphosphate received additional, but small, amounts of S and Ca (7.6 and 9.2 pounds per acre, respectively).
than 90 feet (27 m) to another. All were undamaged and apparently healthy.\textsuperscript{3} Fertilizer was evenly distributed over a 0.1-acre (0.04-ha) area surrounding each designated tree; thus, both the subject trees and their nearest neighbors were treated.

Application was made on April 9 and 10, 1968, during sunny weather on moist soil. During the 7 days after fertilization, skies were overcast and about 1.6 inches (4.1 cm) of rain were measured at nearby Elma. Thus, weather conditions were unlikely to have led to gaseous losses of N as have been reported for urea applications during dry, hot weather.\textsuperscript{4}

**MEASUREMENTS AND ANALYSES**

To measure growth and response, two to six cores were extracted from each tree 5 years after treatment. These, along with d.b.h. and bark thickness measurements taken at the same time, provided the basis for measuring pretreatment growth and subsequent response.\textsuperscript{5} The core-length from cambium to each annual ring, through that formed 8 years before treatment, was measured and recorded to the nearest 0.02 inch (0.05 cm). These measurements were then converted to overbark basal area in each year and to annual basal area growth. From this we computed periodic basal area growth for (1) the two 4-year periods prior to fertilization and (2) the 5-year periods both after and before treatment.

The effect of treatment on 5-year basal area growth was determined by analyses of covariance. Differences in mean posttreatment growth were tested for statistical significance at the 5-percent probability level using Scheffe's test.\textsuperscript{6}

**RESULTS**

**FIVE-YEAR PERIODIC GROWTH**

We believed that response of trees to treatment might be affected by their competitive status, especially since some of them had been released, to varying degrees, by the thinning two to three growing seasons before fertilization. Our cores showed that radial growth was declining on some and improving on others. Therefore, we decided to use this change in growth rate as an index of pretreatment competitive status and calculated the ratio of growth during the most recent 4 years to that during the previous 4 years. Although ratios varied from 0.82 to 1.68, posttreatment growth of trees was not significantly correlated with our index of competitive status.

\textsuperscript{3} Subsequently, three of the study trees, each treated differently, were accidentally cut. Thus, three of the seven treatments were left with only five trees.


\textsuperscript{5} We initially took two cores per tree, from opposite ends of an average diameter. Annual d.b.h. measurements with a diameter tape were used to judge reliability of these cores for determining past growth. If the two sets of measurements did not reasonably agree, additional cores were taken to improve accuracy.

Posttreatment growth was significantly correlated with pretreatment basal area and, more strongly, with pretreatment growth rate (fig. 2). Therefore, to separate effects of treatment from effects of different pretreatment growth rates, data were adjusted by covariance analysis to a common pretreatment growth rate (0.0396 square foot (0.00368 m²) per tree per year).

Figure 2.--Periodic annual basal area growth during 5-year periods before and after treatment.
There evidently was a response to added nitrogen; growth with all six fertilizer treatments averaged greater than growth without fertilizer (table 2). Adjusted means for fertilizer treatments were 17 to 53 percent greater than that without fertilizer; however, differences among fertilizer treatments were non-significant. The only significant increase was for ammonium nitrate--53 percent over the control. Although ammonium nitrate appeared superior to urea as a source of nitrogen, this difference was not statistically significant. Response to 600 pounds (672 kg/ha) of nitrogen was no better than response to 300 pounds (336 kg/ha); thus, the optimum level of nitrogen might have been more or less than 300 pounds. Likewise, no additional growth was gained by supplying other elements along with nitrogen.

Table 2.--Effect of treatment on periodic annual basal area growth per tree (treatment averages)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>5-year p.a.i. Before</th>
<th>5-year p.a.i. After</th>
<th>Ratio (^{1f})</th>
<th>Adjusted p.a.i.</th>
<th>Increase (^{2f})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.0364</td>
<td>0.0346</td>
<td>0.95</td>
<td>0.0384</td>
<td>0</td>
</tr>
<tr>
<td>300-N, P, S</td>
<td>0.0374</td>
<td>0.0424</td>
<td>1.13</td>
<td>0.0450</td>
<td>17</td>
</tr>
<tr>
<td>600-N</td>
<td>0.0426</td>
<td>0.0502</td>
<td>1.18</td>
<td>0.0468</td>
<td>22</td>
</tr>
<tr>
<td>300-N, P</td>
<td>0.0473</td>
<td>0.0585</td>
<td>1.24</td>
<td>0.0496</td>
<td>29</td>
</tr>
<tr>
<td>300-N</td>
<td>0.0430</td>
<td>0.0542</td>
<td>1.26</td>
<td>0.0503</td>
<td>31</td>
</tr>
<tr>
<td>300-N, P, K, S</td>
<td>0.0378</td>
<td>0.0500</td>
<td>1.32</td>
<td>0.0522</td>
<td>36</td>
</tr>
<tr>
<td>300-N (AN)</td>
<td>0.0323</td>
<td>0.0503</td>
<td>1.56</td>
<td>0.0589</td>
<td>53</td>
</tr>
</tbody>
</table>

\(^{1f}\) After:before.
\(^{2f}\) Square feet x 0.0929 = square meters.

TRENDS IN GROWTH OVER TIME

Trends over time show when response began and peaked; they suggest how long response may last. Trends also indicate possible relationships between response and differences in pretreatment growth patterns. The trends shown are generally supported by the individual-tree growth upon which these averages are based; the greatest variation around these trends was with the NPS treatment. Differences in trends were not statistically tested.

There was an immediate response in 1968 to all fertilizer treatments; in each year thereafter, growth was better for all fertilizer treatments than for the control (fig. 3). However, differences in pretreatment growth patterns cast
Figure 3.--Trends in adjusted growth over time, relative to control growth.
doubt upon the exact effect of treatment. By chance, trees fertilized with ammonium nitrate not only tended to have the lowest average pretreatment growth rate, but also had a steadily improving growth rate prior to fertilizer treatment. This was presumably a response to the 1965 thinning and could be responsible, in part, for ammonium nitrate giving the greatest apparent increase in growth.

Response to most treatments peaked in the second year following treatment. Otherwise, trends are quite erratic and cannot be readily explained. Fertilizer effects will probably continue after this 5-year observation period; however, there is no clear indication that the effectiveness of one treatment will last longer than that of another.

DISCUSSION AND CONCLUSIONS

Our index of competitive status was not a significant variable. This lack of statistical significance does not necessarily mean that such factors as recency and amount of release received in thinnings do not affect the tree's response to fertilizer; for example, the growth trend with the ammonium nitrate treatment strongly suggests an interaction of the thinning and fertilizing treatments. Thus, caution should be exercised when interpreting the apparent differences in effectiveness of fertilizer treatments, especially in thinned stands.

Our study results suggest the following conclusions:

1. Nitrogenous fertilizers increased basal area growth of these codominant Douglas-fir.

2. Ammonium nitrate appears superior to urea as a source of nitrogen, but this superiority may, in part, be due to pretreatment growth trends. Our conclusion is provisional.

3. Response to 300 pounds of nitrogen per acre (336 kg/ha) as urea was at least as good as that to 600-N or to other elements in combination with 300-N.

4. Response to all fertilizer treatments will continue for longer than this 5-year observation period; a future reevaluation is necessary.

On this highly productive site, fertilizing increased basal area growth of mature trees by an average of about 30 percent. Increases in cross-sectional area growth at higher levels on the stem and in volume growth may be a little less.2/

We must now relate these responses to expectations with operational fertilization. Would broadcast application of fertilizer increase basal area growth per acre as much as it increased growth of these trees? We are testing this in a followup trial by comparing the effect of ammonium nitrate and urea on this same experimental forest. We anticipate that total stand response will be similar in magnitude to that of individually treated codominant trees.

Increased growth by fertilizing mature stands such as this has an obvious economic significance; a large proportion of this growth is merchantable and has a high unit value. Moreover, this growth can soon be removed in harvest.