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COLLEGE OF FORESTRY-WILDLIFE AND RANGE SCIENCES

GROWTH RESPONSES AND NUTRIENT RELATIONS OF FERTILIZED AND UNFERTILIZED GRAND FIR

by

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INTRODUCTION

Beneficial results from forest land fertilization in other areas (White and Leaf, 1957, Walker and Beacher, 1963) prompted several Idaho experiments involving tree nutrition. One such study, reported earlier (Loewenstein and Pitkin, 1963) dealt with a site supporting planted ponderosa pine *(Pinus ponderosa* Laws) and western white pine *(Pinus monticola* Douglas), as well as naturally occurring grand fir *(Abies grandis* [Dougl.] Lindl.). The grand fir and white pine responded significantly to nitrogen additions; the ponderosa pine did not.

A second Idaho experiment concerned a natural stand of grand fir with some admixture of Douglas fir *(Pseudotsuga menziesii* [Mirb.] Franco.) in the 20 to 30 year old age class. The site, on a gentle north slope, is located on the College of Forestry Experimental Forest (Flat Creek unit). The habitat type (Daubenmire & Daubenmire, 1968) is *Abies grandis-Pachistima myrsinites.* Soil supporting the stand has a pH of 5.5, and a silt loam texture. Moisture percent at the 15 atmosphere point is 9.51; the ⅓ atmosphere point is 35.42. Organic matter in the surface mineral horizon totals 3.4 percent. For the same horizon total nitrogen assayed 0.13 percent, available phosphorus 60 ppm, and exchangeable potassium 260 ppm.

Each treated plot received a combination of nitrogen, phosphorus and potassium fertilizer at the following rates: 300 lb/acre nitrogen as ammonium sulfate, 150 lb/acre phosphorous as treble super phosphate, and 150 lb/acre potassium as muriate of potash. Fertilizer was applied in the spring of the year.

A dramatic growth response as a result of fertilization was recorded by grand fir. Measurement of control and treated plots revealed that significant differences occurred not only in the second year following fertilization, but also in the 2 following years. Because of the excellent results from fertilizer addition in this experiment, a detailed comparison of fertilized and unfertilized trees in regard to growth responses and nutrient content was undertaken. The present paper reports the results of this work.

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[2] Professor and Associate Professor of Forestry, respectively.

PROCEDURE

Four growing seasons after plot fertilization, a tree from the treated area and a tree from the control plot were selected for the detailed growth, nutrient, and wood quality analysis. The trees chosen were among the largest on the plots. Prior to felling, increment borings revealed that the 2 specimens were the same age (25) and that before fertilization, their growth rates were quite similar.

The trees were cut at the ground line (no roots were excavated) and laid on large plastic sheets. Total height growth was recorded, as well as annual growth for the 3 years before fertilization, the year of fertilization, and the 3 following years. The branches were then removed from the stems. Needles produced in the harvest year were separated from older needles and current year branches separated from older branches. Branch and needle samples were oven dried in the laboratory, where the total weight of each component was determined. Following weighing, the material was ground in a Wiley mill and carefully subsampled for nutrient analysis.

In the field, the bark was removed from each stem, and subsequently dried, weighed, ground, and subsampled for nutrient analysis in the laboratory. After bark removal, the stems were cut into 4-foot sections, the diameter at the center of each section being recorded. Volume calculations were made using these data.

A 1-inch thick cross-sectional disk was removed from the sections at the center points. In the laboratory these disks were used to determine the width of spring and summer wood portions of the annual rings, number of cells produced, and the specific gravity of the wood developed in the 3-year period prior to and following the year of fertilization.

The wood from each section was dried and weighed in the laboratory, then ground and subsampled for nutrient analysis. The weight of the disks used in making the determinations described above was taken into account when calculating total nutrient content of the various sections.

Nitrogen in tissues was determined by the Kjeldahl method, phosphorus levels were found using the vanadomolybdophosphoric colormetric method, and potassium was determined by flame photometry. Procedures used were similar to those given by Jackson (1958).

RESULTS AND DISCUSSION

Diameter and Height Growth

Fertilization markedly affected diameter growth. For the 3-year period immediately prior to fertilization, the tree from the control plot had an increase in DBH of 0.38 inches; the fertilized tree grew 0.50 inches in diameter during this same period. After fertilization, the three year growth record indicated that the control tree again gained 0.38 inches in diameter, whereas for the same period, the fertilized tree realized a 1.26 inch diameter increment. Fertilization more than doubled diameter growth of the treated specimen.

The effect of nitrogen treatment on height growth of the sample trees was less striking than the effect on diameter growth. During the 3-year period following treatment, height increment of the control tree was 108 percent of that found for the 3-year period before fertilization, the corresponding figure for the fertilized tree was 115 percent. On another site (Loewenstein and Pitkin, 1963), the stimulus to height growth resulting from fertilization was much greater. The fact that in some situations height increment is the growth factor most affected by fertilization and in other situations response is concentrated more in diameter increment has been noted previously, but the reasons for such variation in the type of response are not well documented.

Dry Weight

Striking differences in the dry weight of the fertilized and unfertilized tree are graphically revealed in Figure 1.

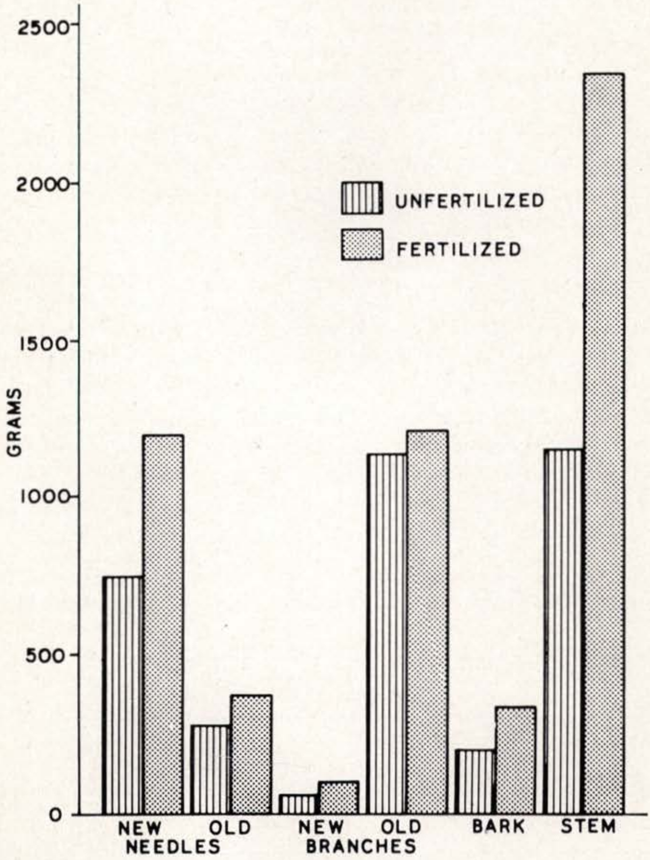

Figure 1. Dry weight of above ground components of fertilized and unfertilized grand fir.

Of particular interest are the data for stemwood, which weighed about twice as much in the fertilized tree than in the control. That this difference is attributable to treatment is evident from a consideration of the following. Calculations based on measurements made on cross-sections from the lower portions of the stems indicate that immediately prior to fertilization cross-sectional areas of the 2 specimens were similar (about 1.5/square inches). Upon harvest, the total cross-sectional area in the lower portion of the fertilized stem was 5.3 square inches; that of the control was only 2.59 square inches. Seventy-three percent of the total cross-sectional area of the fertilized specimen developed in the 3-year period following treatment; the figure for the control is only about 37 percent. As discussed later, fertilization did not strongly influence density of the wood. Thus we may conclude that the fertilizer addition, stimulating diameter growth particularly, was mainly responsible for the great disparity in the weight of the woody portion of the stems.

Dry weight of each other component, particularly current year needles and stem bark, was also greater in the fertilized tree than in the untreated specimen.

About 42 percent of the total above ground dry weight of the fertilized tree was in stemwood; the corresponding figure for the control was approximately 32 percent. The proportion of total dry weight in foliage, on the other hand, apparently was not affected by treatment. Foliage accounted for about 28 percent of the above ground dry weight of the tree in both sample trees.

Specific Gravity

Wood from both the fertilized and unfertilized specimens decreased in specific gravity in the 3-year period following fertilization (Table 1). While the small sample size precludes any definitive judgement, it appears that a greater decrease occurred in the bole of the fertilized tree. This result, of course, is not unusual (Larson, 1968). One of the chief concerns voiced in regard to forest fertilization has to do with precisely such effects on wood quality. In the current instance we believe, as did Erickson and Lambert (1958), the great increment in wood fiber resulting from fertilization overshadows any minor influence on specific gravity.

Table 1. Specific gravity of wood from fertilized and unfertilized grand fir.

Location	Specific Gravity			
	Fertilized		Unfertilized	
	A[1]	B[2]	A[1]	B[2]
Lower bole	0.502	0.404	0.468	0.421
Middle bole	0.423	0.370	0.391	0.349
Upper bole	----	0.366	----	0.405

[1] Wood from three-year period immediately prior to fertilization.

[2] Wood from three-year period commencing the year after fertilization.

Spring and Summer Wood Production

Fertilization affected the relationship between springwood and summerwood production. As treatment stimulated production of both, the net change in proportion of summerwood was moderate. Data from the lower portion of the bole are illustrative of the findings. Springwood production of the control tree for the 3 years following the year of treatment was 99.6 percent of that achieved in the three years before treatment; the similar figure for the fertilized tree was 246.7 percent. Summerwood production of the control for the 3-year interval after treatment was 100 percent of the production during the three years before treatment; the similar figure for the fertilized tree was 173.8 percent. Further calculations show that for this lower portion of the bole, the percent of total wood production in control latewood was essentially the same during the 3-year periods immediately before and after the year of treatment. The portion of total wood production in summerwood decreased in the fertilized tree—from 15.1 percent before the year of treatment to 11.2 percent for the 3-year span following the year of treatment.

Number of Cells

The number of cells were counted in 4 transects across the growth rings. Data for the lower bole are representative of trends found. For the 3-year periods immediately preceding and following the year of treatment, the average number of spring and summerwood cells across cross-sectional transects of the control disk varied little. The number of cells in cross-sectional transects from the treated specimen, on the other hand, reflected the influence of fertilization. Average number of cells in the springwood transects rose from 79 prior to treatment to a total of 164 for the 3-year period subsequent to the year of fertilization. Similar figures for summerwood are 25 and 30, respectively.

Nutrient Content

Total nitrogen, phosphorus, and potassium content in above ground portions of trees was strongly affected by fertilization (Table 2). The data illustrate the value of expressing nutrient content on an absolute, as well as on the more common concentration basis. From the standpoint of concentration, there is no difference in the percentage of phosphorus, for example. Because of the much greater weight of the fertilized tree, however, the actual amount of phosphorus in it is much greater than that in the control. A similar situation is illustrated by the data for nitrogen and potassium—little difference in concentration; a large dif-

Table 2. Nitrogen, phosphorus, and potassium content of fertilized and unfertilized grand fir. Values are for whole tree excluding roots.

	Nitrogen		Phosphorus		Potassium	
	%	Grams	%	Grams	%	Grams
Fertilized	0.56	31.1	0.08	4.6	0.41	23.0
Unfertilized	0.53	19.1	0.08	2.9	0.47	16.7

ference in total quantity of these elements in fertilized and unfertilized specimens.

Nutrient percentages in the various tree components are tabulated in Table 3. Regardless of the particular nutrient, differences in concentration between the fertilized and unfertilized specimens are not large. In some instances, (e. g. potassium in new and old needles) the components from the unfertilized tree actually exhibited a higher nutrient percentage than did the components from the fertilized tree. This, in the case of new needles, is probably an example of the "dilution effect," the nutrients in the tree stimulated by fertilization being distributed through a great deal more tissue than in the control.

Table 3. Percentage of Nitrogen, Phosphorus, and Potassium in above ground components of fertilized and unfertilized grand fir.

Component	Nitrogen (%)		Phosphorous (%)		Potassium (%)	
	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.
Needles						
New	1.29	1.18	0.19	0.19	0.90	1.09
Old	1.00	1.06	0.14	0.15	0.58	0.81
Branches						
New	0.98	0.88	0.18	0.15	0.86	0.92
Old	0.52	0.43	0.08	0.06	0.42	0.34
Bark	0.52	0.50	0.10	0.07	0.50	0.48
Stem	0.11	0.08	0.01	0.01	0.10	0.08

The highest concentrations of the 3 elements were generally found in the foliage, but new branches also contained relatively high percentages. Data for stems represent the average for the entire bole. There were, however, appreciable differences between concentration of elements in cross-section samples from the lower bole and the upper bole. These differences presumably reflect the fact that the samples from the upper bole were largely sapwood, whereas the lower cross-sectional samples contained appreciable amounts of heartwood. Additionally, the upper sample from the fertilized tree consisted almost entirely of wood formed since the year of treatment. Thus, for example, this section contained 0.7 percent nitrogen, compared to an average of 0.11 for the entire bole.

A comparison of the quantity of nitrogen, phosphorus and potassium contained in the various above ground components of the fertilized and unfertilized trees is presented in Figures 2, 3, and 4. In contrast to the data concerning percentage values (Table 3), large differences between fertilized and unfertilized trees in actual nutrient content are apparent. Four growing seasons after treatment, current year (new) needles from the fertilized tree contained 15.45 grams of nitrogen, 2.28 grams of phosphorus, and 10.78 grams of potassium. The corresponding figures for the unfertilized tree were 8.78 grams of nitrogen, 1.41 grams of phosphorus, and 8.11 grams of potassium. Although the magnitude of difference was not as large as in the case of current year needles, total nitrogen and phosphorus content of older needles from the fertilized specimen was appreciably greater than that of the control. Potassium content of older needles from the unfertilized tree was slightly greater than the content of that element in older needles of the treated sapling. It is of particular interest to note that the nitrogen, phosphorus, and potassium content of the stemwood of the fertilized tree was more than 2½ times that of the control.

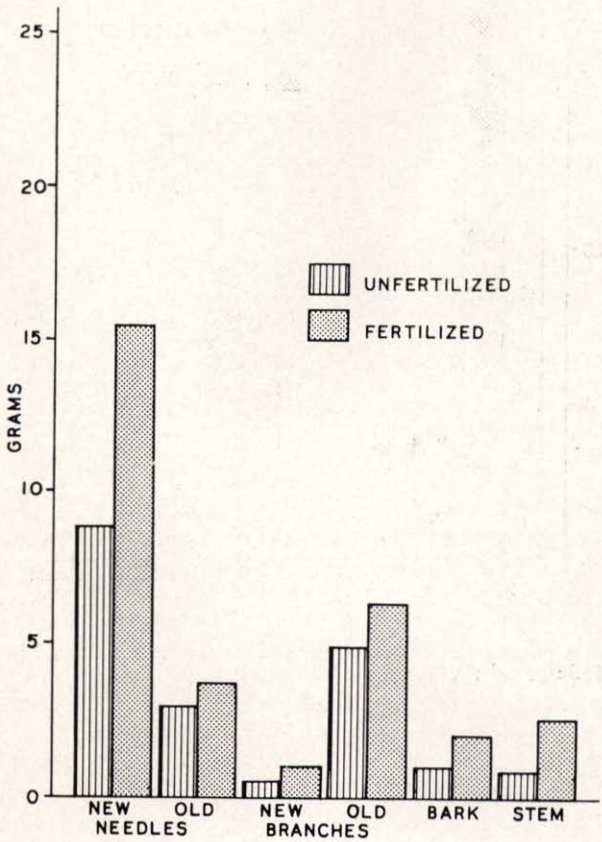

Figure 2. Total nitrogen in above ground components of fertilized and unfertilized grand fir.

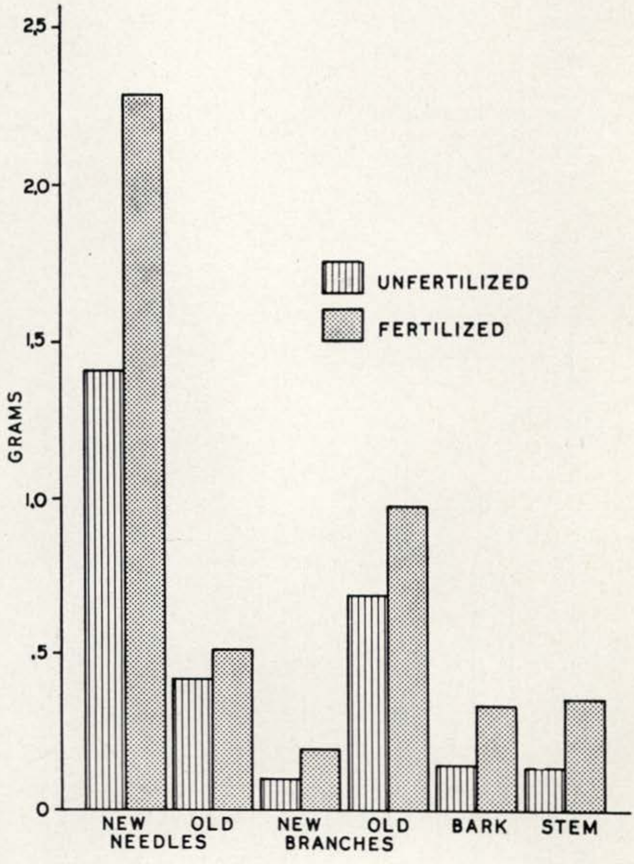

Figure 3. Total phosphorus in above ground components of fertilized and unfertilized grand fir.

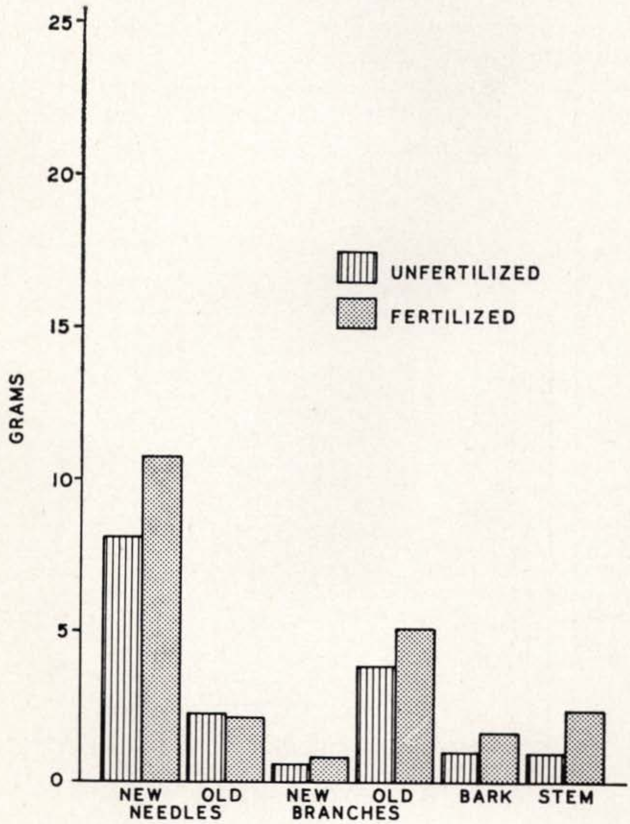

Figure 4. Total potassium in above ground components of fertilized and unfertilized grand fir.

Fertilization did not appear to have a great effect on the distribution of the elements within the trees. In this regard, the data for nitrogen are graphed in Figure 5. Because trends were very similar to that of nitrogen, specific information concerning phosphorus and potassium is not presented. About 50 percent of the nitrogen in the above ground portion of the fertilized trees was contained in new needles; 46 percent of the total nitrogen was found in new needles of the control tree. For older needles, the comparative figures are 15 and 12 percent, respectively, for treated and untreated specimens. The disparity in the figures for current and older needles is explained largely by the fact that the latter component had a much lower dry weight than the former (Figure 1). Concentration of nitrogen in older tissue was also somewhat lower than in current year tissue (Table 3). The older branches contained more of the above ground nitrogen in the trees than did the current year twigs, the bark, and the stemwood combined.

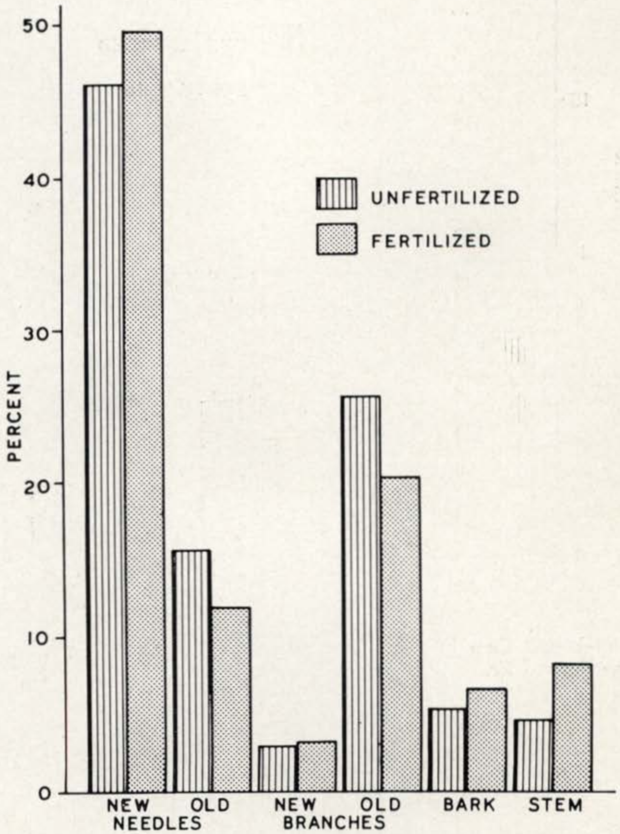

Figure 5. Distribution of nitrogen among components of fertilized and unfertilized grand fir. Percentages refer to that portion of the total nitrogen in above ground tissue which was found in each component.

SUMMARY

Growth responses and nutrient relations of two 25-year-old grand fir trees—one from a plot fertilized with 300 lb/acre nitrogen, 150 lb/acre phosphorus, and 150 lb/acre potassium; the other from a control plot, were examined in detail 4 years after treatment. Previous plot measurements had indicated significant increment gains from the fertilizer application.

Fertilization more than doubled diameter growth during the 3-year period following the year of treatment, in comparison to that achieved for a similar period immediately prior to treatment. Although fertilization appeared to also stimulate height growth, the effect on this parameter was not nearly as pronounced.

Dry weight of all above ground components increased as a result of treatment. The effect was particularly evident in the case of stemwood, the bole of the fertilized specimens weighing twice that of the control.

Factors associated with wood quality (percent summerwood, specific gravity) appeared to be adversely affected by fertilization, but only moderately. These adverse effects were overshadowed by the great gain in fiber.

No large increases in concentration of nitrogen, phosphorus, or potassium in the various components resulted from fertilization. Because of the greater amount of dry matter in the treated specimen, however, large increases occurred in the actual quantity of the three nutrients contained in the tissues. Content of the elements in the stemwood of the fertilized tree, for example, was 2½ times that of the control.

About half of the total nitrogen, phosphorus, and potassium found in the above ground portions of both the fertilized and the control tree was located in current year needles.

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