Pacific Northwest Forest and Range Experiment Station

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GROWTH RESPONSE OF 35-YEAR-OLD, SITE V DOUGLAS-FIR TO NITROGEN FERTILIZER

by

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ABSTRACT

During the first 4 years following application, addition of 200 to 600 pounds of nitrogen per acre increased height increment 62 percent and d.b.h. increment 79 to 160 percent. Gross basal area increment was greater with heavier fertilizer applications, but severe snowbreakage was also increased. Thus, net production tended to be greatest with the addition of 200 pounds of nitrogen. Indications are that heavier application rates will have a longer lasting beneficial effect.

INTRODUCTION

A nitrogen-fertilizer trial in a 35-year-old, site V Douglas-fir plantation on Wind River Experimental Forest in southwestern Washington clearly illustrates substantial growth response. This interim report assesses the influence of fertilizer during the first 4 years following treatment in terms of basal area growth per acre, snowbreakage, diameter growth, height growth, and cone production. Findings of this study are consistent with those reported by others for low-site conditions[1] and add to an accumulating knowledge of what can be accomplished through forest fertilization.

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[1] Gessel, S. P., et al. The growth behavior of Douglas-fir with nitrogenous fertilizer in western Washington. Univ. Wash. Coll. Forest. Res. Bull. 1. 1965.

The plantation is located at the east edge of the Yacolt Burn in an area that was repeatedly swept by wildfire, the last in 1927. At the start of the study, the trees had sparse, chlorotic foliage and were growing very slowly. In a nearby part of the same plantation, an admixture of red alder had significantly increased nitrogen content of the soil and of Douglas-fir foliage, and increased the rate of Douglas-fir growth.[2/] This led to initiation of the study reported here.

THE STUDY

Treatment

In April 1964, ammonium nitrate was applied to 0.1-acre circular plots at rates of 0, 200, 400, and 600 pounds of nitrogen per acre. Each treatment was applied to three plots, in a completely random design (fig. 1).

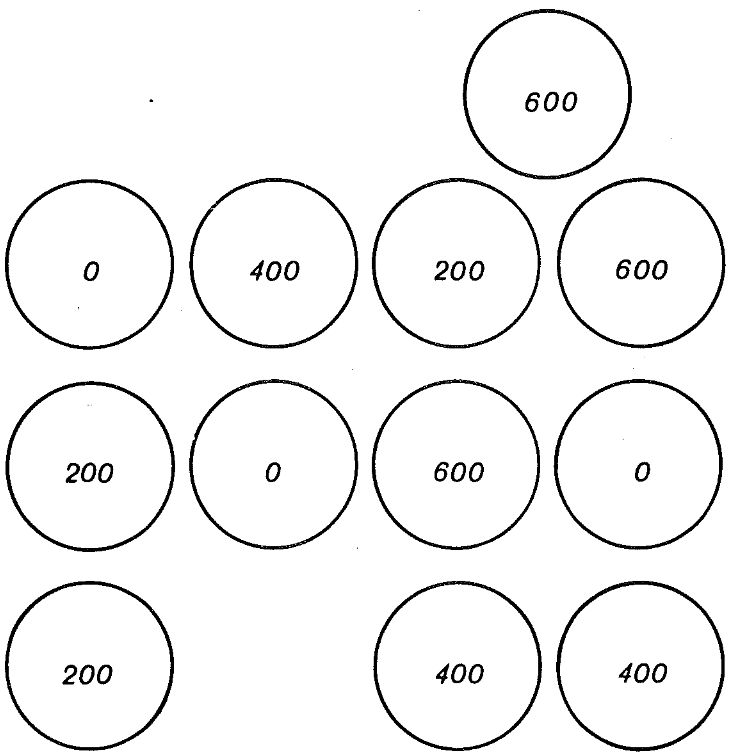

Figure 1.--*Arrangement of plots, identified by pounds of nitrogen fertilizer applied.*

[2/] Tarrant, Robert F. Stand development and soil fertility in a Douglas-fir—red alder plantation. Forest Sci. 7:238-246. 1961.

Pretreatment Condition

Trees had been planted in 1930 at an average spacing of 8 by 8 feet, but actual spacing was quite erratic. Thus, although trees tended to be in rows, there was no clearcut configuration to the spatial arrangement. Basal area on these plots averaged 101 square feet per acre in trees averaging 5.6 inches d.b.h. and 45 feet tall. Site index averaged 87 and ranged from 79 to 96 (height at age 100). Basal area per acre on most of these plots was below normal by McArdle's yield tables,[3/] most likely as the result of incomplete occupancy of the area by trees. Expressed as a percent of normal for the indicated site index of each plot, stocking after the 1963 growing season (and before winter mortality) ranged from 73 to 106 percent of full stocking, averaging 87 percent.

Measurements

Diameters of all trees on the central 0.05-acre portion of each plot were measured to the nearest 0.1 inch in April 1964 and in the fall of 1965, 1966, and 1967. Heights of at least seven of these trees, distributed equally over the d.b.h. range, were measured concurrently. In 1967, heights on a total of 14 trees were measured on each plot, and height to the 1963 terminal was measured on all of these which had not been included in the initial measurement.

RESULTS AND DISCUSSION

Basal Area Increment Per Acre

Averaged for each treatment, 4-year gross basal area increment was 68 to 120 percent greater in fertilized stands than in unfertilized stands. Growth in all fertilized stands was significantly better than that in unfertilized stands. However, because of considerable within-treatment variation, growth did not differ significantly among the three fertilizer treatments.

A look at annual increment during this 4-year period gives a little more complete picture of the effect of the different intensities of fertilizer on gross increment (table 1). Unfortunately, we did not make a measurement after the first growing season, so we must use the average for the first 2 years.

Aside from treatment effects, annual gross basal area growth varied considerably during this 4-year period. For example, on the untreated plots, growth in 1966 was nearly twice as great as the average annual growth in 1964-65, whereas growth in 1967 was only about half of that in 1964-65, or one-quarter of the 1966 growth. With such

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[3/] McArdle, Richard E., et al. The yield of Douglas-fir in the Pacific Northwest. U.S. Dep. Agr. Tech. Bull. 201. 1930 (rev. 1961).

Table 1.--*Annual gross basal area increment by treatment and year (average of three observations)*

Treatment[1]	1964-65[2]	1966	1967	4-year total
	---------- Square feet ----------			
0	3.2	6.2	1.6	14.2
200	5.0	9.0	4.9	23.9
400	6.0	11.3	7.0	30.3
600	5.6	11.8	8.2	31.2

1/ Pounds of nitrogen per acre.

2/ Average for 2 years.

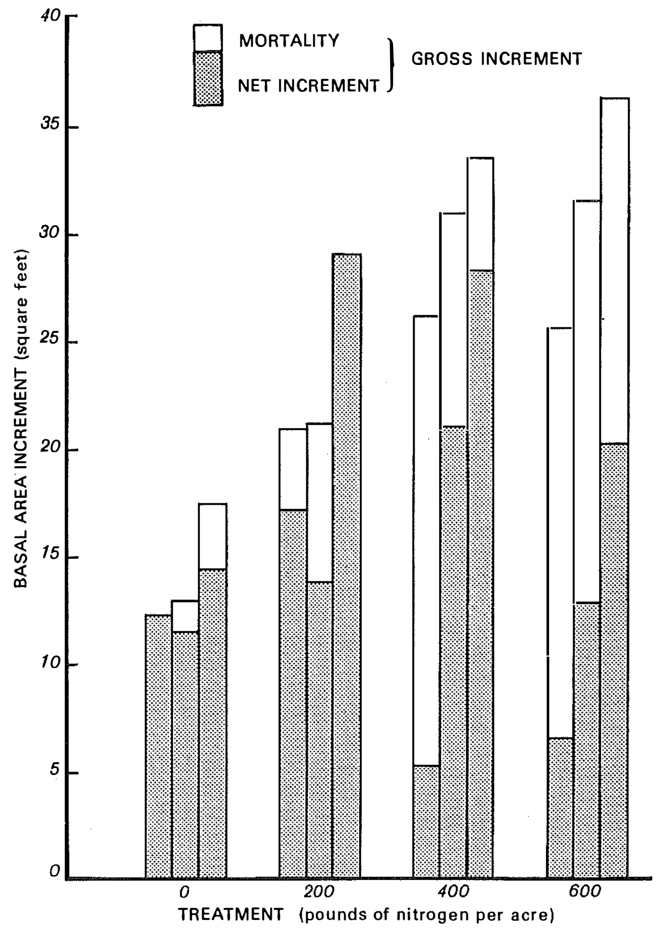
wide differences in growth rate from one year to another, it is quite possible that relative effects of fertilizer treatments were different than if annual growth had been more uniform.

The treatment-year interaction for this first 4 years was not quite significant, but there are indications that a trend may be developing. Growth in the third year, 1966, averaged by treatments, varied from 180 to 211 percent of the average for the first 2 years and showed no clear relationship to treatment. On the other hand, growth in the fourth year varied from 50 to 146 percent of the average for the first 2 years, and showed a very clear trend of increasing relative growth with increasing amounts of fertilizer. This changing trend may be associated primarily with poor growing conditions in the fourth year,[4] as exemplified by the unfertilized plots. Conversely, it may indicate that, whereas all fertilizer treatments tested had virtually the same initial effect on gross increment, the longevity of the effect increases with increasing intensity of fertilizer application.

Substantial mortality was associated with the heavier fertilizer intensities. Thus, net basal area increment over the 4-year period tended to be greatest in stands receiving 200 pounds of nitrogen per acre (fig. 2).

4/ Growing conditions refer to both environment and physiological condition of trees.

Figure 2.--*Effect of fertilizer on 4-year basal area increment (three observations per treatment), 1964-67.*



Snowbreakage

Total number of trees suffering severe storm damage since the time of fertilizer application differed significantly among treatments, with the moderately and heavily fertilized stands incurring about three times as much damage as the unfertilized and lightly fertilized stands.

Breakage during the first winter following treatment was generally quite severe but was also quite erratic and did not differ significantly among treatments. Similar damage occurred the winter preceding treatment. Breakage during the second winter, on the other hand, did differ significantly among treatments and increased as fertilizer intensity increased.

Thus, moderate and heavy fertilizer application apparently increased amount of storm breakage, with much of the impact being delayed until the second winter following treatment. Kreutzer[5/] similarly

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5/ Kreutzer, K. Ernährungszustand und Volumenzuwachs von Kiefernbeständen neuer Düngungsversuche in Bayern. Forstwissenschaftliches Centralblatt 86:28-53. 1967.

observed that, as the weight of needles increased with improvement in nitrogen nutrition, the danger of snowbreakage simultaneously became greater.

Virtually all of this snowbreakage was very severe. Most trees which have survived thus far have most of their crowns broken out and stand a very slim chance of recovery, but many linger on. Fertilizer has apparently somewhat hastened their death (table 2).

Table 2.--*Number of trees damaged since time of treatment (sum of three plots per treatment)*

Treatment[1/]	Damaged trees			Percent dead
	Total	Dead	Live	
0	7	2	5	29
200	10	5	5	50
400	29	20	9	69
600	32	21	11	66

[1/] Pounds of nitrogen per acre.

Only 6 percent of the damaged trees were among the largest 200 trees per acre. Thirty-one percent were among the second largest 200 trees per acre. In most cases, the damaged trees would probably not have amounted to much anyway, although most currently had ample growing space. Also, the loss of these trees generally did not offer much release to leave trees.

D.b.h. Growth

We are interested in the effect of fertilizer on growth of the individual trees as well as growth per acre. Basal area growth per acre may give a misleading impression of the effect of various fertilizer intensities on growth of the individual trees because the severe storm damage on moderately and heavily fertilized plots took substantial areas temporarily out of production. For this reason, d.b.h. growth of undamaged surviving trees was analyzed separately.

Plottings of 4-year d.b.h. growth over starting d.b.h. showed the relationship to be linear. Regressions fitted to the data show that, in all treatments, growth was virtually proportional to tree size; an 8-inch tree grew twice as much as a 4-inch tree (fig. 3). On the

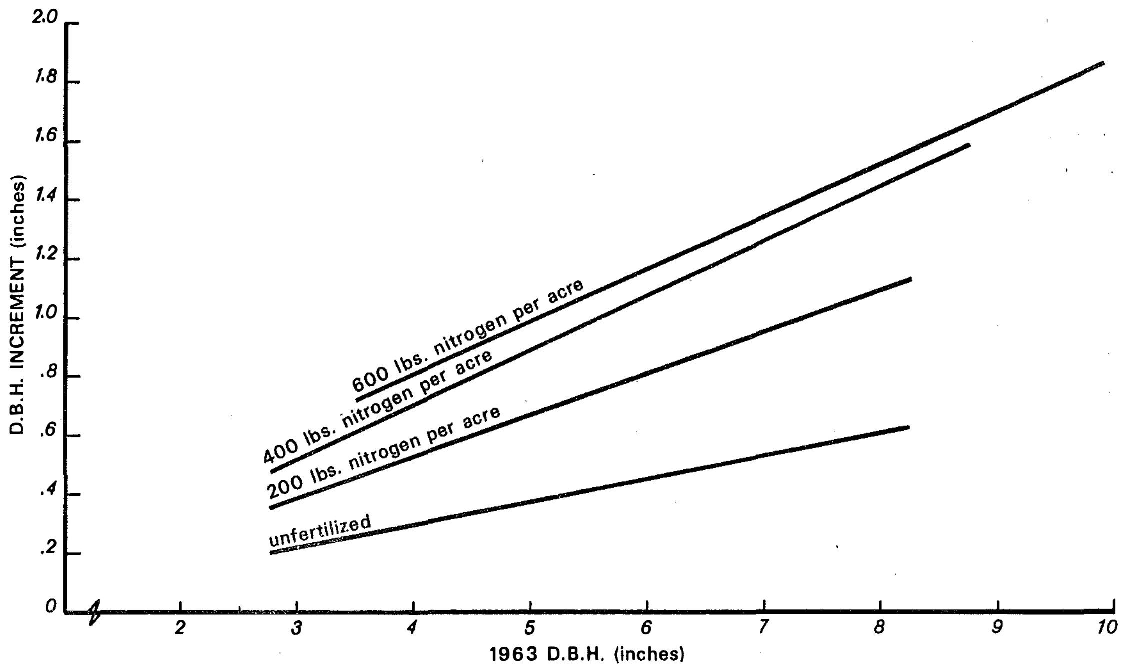

Figure 3.--*Effect of fertilizer on 4-year d.b.h. increment, 1964-67.*

average, d.b.h. growth of trees in fertilized stands was 79 to 160 percent greater than in unfertilized stands. Growth was significantly better in all fertilized stands than in unfertilized, and growth in moderately and heavily fertilized stands was significantly better than that in lightly fertilized stands. Growth on plots receiving 600 pounds nitrogen per acre was <u>not</u> significantly better than that on plots receiving 400 pounds nitrogen. Differences in growth among treatments tend to increase with time, but the interaction between year and treatment is not currently significant.

Most of the increase in growth rate is probably attributable directly to fertilization. However, since there was considerable natural thinning (mortality) in the moderately and heavily fertilized stands, a few trees were released and likely grew more than had this storm damage not occurred.

Height Growth and Change in Site Index

Average height growth of the nine tallest trees measured per plot (approximate dominant and codominant component) differed significantly between fertilized and unfertilized stands, but not among fertilizer treatments. Average growth in fertilized stands was 62 percent greater than that in the unfertilized stand--8.1 versus 5.0 feet.

As a result of this increased height growth, apparent site quality was greatly improved by fertilization but did not differ significantly among fertilizer treatments. Based on 1963 height and 1964-67 height growth of the nine tallest trees measured per plot, average improvement in site index on fertilized plots was 55--from site index 88+ to 144- (height at age 100). The corresponding improvement on unfertilized plots was 6--from 84 to 90.

Cone Production

Cone production was nil on all plots in all years except 1966. In that year, cone production was clearly better in the fertilized stands than in the unfertilized. There were no clear differences among the fertilizer treatments. Cones were produced only on trees larger than about 7 inches d.b.h. (i.e., about the largest 30 percent of the trees).

CONCLUSIONS

Application of 200 to 600 pounds of nitrogen per acre substantially improved both d.b.h. and height increment, and thus growth per acre (table 3). Height increment was significantly better in fertilized

Table 3.--*Effect of fertilizer on 4-year basal area, d.b.h., and height increment, 1964-67*

Treatment[1/]	Gross basal area increment	D.b.h. increment	Height increment
	Square feet	Inches	Feet
0	14.2	0.42	5.0
200	23.9 |	.73	7.7 |
400	30.3 | *	1.06 |	8.7 | *
600	31.2 |	1.10 | *	8.0 |

1/ Pounds of nitrogen per acre.

* Values connected by vertical line are not significantly different.

stands than in unfertilized, but did not differ significantly among fertilizer treatments. D.b.h. increment, on the other hand, also differed significantly between stands receiving 200 and 400 pounds of nitrogen per acre, but not between those receiving 400 and 600 pounds.

Thus far, little has been gained by applying as much as 600 pounds of nitrogen per acre. The relative advantages of 200 versus 400 pounds per acre are not so clear. Whereas trees grew substantially more with the latter, incidence of storm damage, a common occurrence in this area, was increased. Thus, at least on a short-term basis, increase in net production per acre tended to be greatest with 200 pounds per acre. However, there are indications that this trend may change over time, and the study will be continued to determine such changes.