REGIONAL FOREST NUTRITION

RESEARCH PROJECT

BIENNIAL REPORT
1978-1980

COLLEGE OF FOREST RESOURCES
UNIVERSITY OF WASHINGTON

November 1980

PARTICIPATING MEMBERS

1978 - 1980

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Boise Cascade Corporation

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FOREWORD

Since the previous Biennial Report, a number of important events have occurred which have had an important bearing on the Regional Forest Nutrition Research Project. We have suffered personal and professional loss in the death of Dr. Ken Turnbull in late May of this year (1980). His wise counsel and dedicated work will be missed by our staff and by all the cooperators. A search for a successor to Ken is underway at the College; however, the replacement issue is clouded by the fact that the University has been required to take significant budget cuts in the past few months. When the College budget is already at a marginal operating level, filling vacant positions is always in jeopardy.

Our other personnel loss occurred when Dr. Bill Atkinson moved from the College to a managerial position with Crown Zellerbach Corporation. Most of you probably have already had contact with him in his new position. We certainly miss his enthusiasm and dedicated service but wish him great success in his new endeavors.

We have made some shifts in personnel assignments to take up some of the workload in the project. I have taken on more direct supervision of the entire program. Dr. Ian Morison came back onto the project during the summer and he and I spent much of the time contacting co-operators and reviewing field work and management possibilities. Dr. Bruce Bare will conduct the economic analysis of forest fertilization and assist Al Becker in the documentation of procedures for data processing. Charley Peterson is continuing the data analysis as well as assuming the responsibilities of mensuration director. Any major decisions regarding present and future RFNRP activities will be made after consultation with the technical advisory committee and biometrics subcommittee as has been done in the past.

The Phase IV program was successfully initiated on schedule and the field crew has put in a very busy summer season virtually completing the new installations. Many cooperators responded to our request for candidate areas and provided field help in the specific locations. We certainly thank them all for this dedicated effort.

Volcanic activity of Mt. St. Helens has implications relative to the Regional Project. As far as we know, no installations have been destroyed, but many did receive varying amounts of ashfall. Many different opinions exist as to the effect of the ashfall on forest growth. A Forest Service grant will enable us to assess quantities of ash on plots which have been affected and we will then relate this information to growth performance over the next several years. The ten years of basic growth information on many of our plots will make a solid base for looking at changes brought on by the ashfall.

We continue to make progress in the evaluation of methods to aid in predicting fertilizer response. Several organizations are using Regional data to refine soil incubation procedures. Phil Ryan, an advanced graduate student at the College, is computerizing all the soils information and reviewing this in relationship to response. We are expanding the work on sulfur-nitrogen interaction through the cooperation of Weyerhaeuser Company and SUDIC (Sulfur Development Institute of Canada).

We hope the information contained in this report will substantially add to your understanding of the role of essential elements in the management of forest lands. Fertilizer application is a management tool which must be used wisely and cost-effectively to be of value in forestry. We continue to dedicate our efforts to providing this basic information. We welcome your questions and your advice in this effort.

Stanley P. Gessel

INTRODUCTION

The Regional Forest Nutrition Research Project (RFNRP) was initiated in 1969 with the primary objective of providing resource managers with more accurate data on the effects of fertilizing and thinning young-growth Douglas-fir and western hemlock forests in the Pacific Northwest.

Based on the needs for additional information which previous forest fertilization research in this region had brought to light, the Northwest Forest Soils Council determined that an intensive field program with regional focus should incorporate the following goals:

1. To establish and maintain a series of fertilizing and thinning field trials on participants' lands in western Washington and western Oregon under various conditions of soils, climate, age, and site;
2. to collect and analyze response data from these plots and report results to subscribers;
3. to conduct supplemental research in related areas such as diagnosis of elemental deficiencies, analysis of the effects of fertilizer application on total ecosystems, effects on wood quality, economics of fertilization and thinning, and mensurational techniques to detect response;
4. to report findings regularly to subscribers and to advise them on fertilization problems and practices;
5. and to cooperate with other programs and research designed to intensify forest management and increase wood production.

Because of the scope of this program, a cooperative funding approach was used to enlist a broad base of support from regional timber companies, fertilizer manufacturers, and governmental agencies involved with resource management. The College of Forest Resources of the University of Washington administers and executes the project under the direction of Dr. Stanley P. Gessel.

A total of six Douglas-fir and three western hemlock provinces are employed for design purposes. The original research design called for simultaneous establishment of unthinned and thinned fertilizer plots. However, funding levels in 1969 did not permit the full program to proceed, and the cooperators decided to begin with the unthinned plots only. This became known as Phase I, when in 1971, sufficient funds had been generated to incorporate the thinning-fertilizer trials. The latter portion of the program is referred to as Phase II. Two further extentions, Phase III and Phase IV, have established a data base which now totals nearly 1900 permanent sample plots.

<u>Phase I (fertilization only) 1969-1970</u>

Plots established in this phase currently have ten years of growth measurements. Approximately half of the Douglas-fir plots were treated with fertilizer after eight growing seasons, as a part of Phase III. A portion of the hemlock plots have been refertilized, and some of the remainder have been thinned and refertilized, after ten growing seasons as part of Phase IV.

<u>Phase II (fertilization and thinning) 1971-1972</u>

Plots in Phase II have eight years of measurements at this writing. Half of the thinned Douglas-fir plots have been treated with fertilizer to coincide with the Phase I retreatments. In addition, half of the thinned hemlock plots will be refertilized after ten seasons to complete the Phase II re-treatments.

<u>Phase III (fertilization and thinning in young stands, and fertilization in areas of low productivity) 1975</u>

These plots now have four seasons of growth data that are currently being analyzed and combined with the Phase I and Phase II data to improve response estimates.

<u>Phase IV (low stocking and young spaced stands) 1980</u>

Part of the plots established in Phase IV are in areas of low natural stocking to help answer questions in two areas:

1. What is the effect of fertilizer in low- and under-stocked stands?; and
2. Do thinned stands react to fertilizer in the same way as do natural stands of the same stocking?

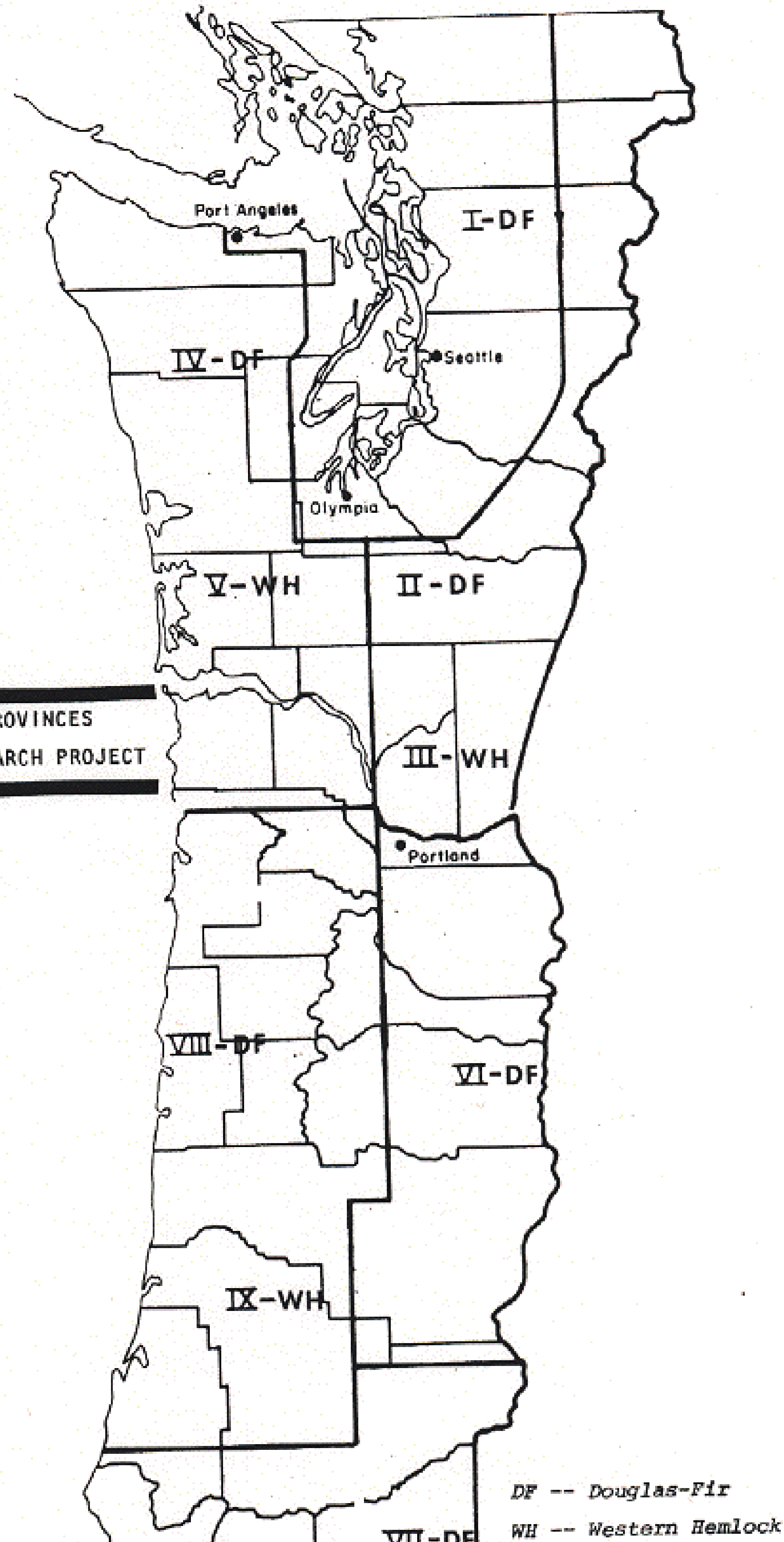
Other plots have been established in young stands that have had some form of stocking control, in order to assess the effect of fertilizer on the type of intensively managed stand that is expected to be increasingly prevalent in the future.

Surviving installations at the time of publication of this report, together with the number of growing seasons after-treatment which they will have accumulated by June 30, 1980 are as follows:

Date of establishment	Type of installation	Number of installations	Growth Seasons after treatment, June 30, 1980
1969	Phase I	39DF, 10WH	10
1970	Phase I	44DF, 12WH	9
1971	Phase II	9DF, 7WH	8
1972	Phase II	26DF, 1WH	7
1973	B. L. M.	6DF	6
1975	Phase III	23DF, 6WH	4
1975	Willamette National Forest	4DF	4
1976	Mt. Hood National Forest	1DF	3
1977	Siskiyou National Forest	8DF	2
1977	B. L. M.	6DF	2
1977	Phase III Regen.	2DF	2
1977	Phase III Intensive hemlock	1WH	2
1977	Old Growth	1DF	2
1978	Colville National Forest	4DF	1
1978	Melamine	2DF	1
1980	Weyerhaeuser Contract	3DF	0
1980	Phase IV	27DF, 8WH	0

Total = 250 installations

DOUGLAS-FIR AND WESTERN HEMLOCK PROVINCES
OF REGIONAL FOREST NUTRITION RESEARCH PROJECT



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I REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE *TOTAL* STAND FOR *UNTHINNED* DOUGLAS-FIR, EIGHT YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

The primary objective of this project has been to attain a regional estimate of mean response according to relevant stand variables such as age, site index, etc. Response, measured as an increase in growth rate due to fertilizer application, can be thought of as:

RESPONSE = [Unthinned Fertilized Total Stand Growth Rate] minus [Growth Rate as in Unthinned Unfertilized Total Stand]

Analysis of response is based on 392 plots of 1/10-acre or larger, comprised of at least 80% Douglas-fir type stands. This data base covers breast-height age classes 10 through 50, and 50-year site index classes 1 through 4. All increment figures are gross p.a.i. (periodic annual increment) spanning 8 growing seasons, with the exception of response duration which is comprised of 4 consecutive growth periods of 2 years each. Minimum d.b.h. (diameter at breast height) is 1.55 inches. The distribution of plots along with tables of raw data are located in Appendix A.

Results of Analysis

1. Gross P.A.I. of Total Basal Area: The average response across the data ranges of age, site, and basal area was about 18% to 200 pounds of nitrogen and about 24% to 400 pounds of nitrogen. Response is significantly related to site index, initial basal area, and level of N-application. The smoothed estimates of growth rate are presented in Table 1, with smoothed response estimates given in Table 2. Response to fertilizer is greatest in lower site classes and in the lower range of basal area. The interaction of basal area and nitrogen dosage produces an apparent response trend across age in Table 2 due to the fact that basal area varies by age class (age itself was not significantly related to response).

2. Gross P.A.I. of Total Volume: Results of the volume increment analysis show a mean response of 42 cubic feet per acre per year to 200 pounds of nitrogen across the range of data. This response represents a 13% increase over the estimated increment of untreated stands.

Stands receiving an application of 400 pounds of nitrogen per acre demonstrate a total stand response of 57 cubic feet per acre per year across the range of data, an increase of approximately 17% over the estimated growth rate of the unfertilized stands.

The standard error associated with the response estimates is 14% of response for the 400-lb level of fertilizer application, and 19% of response for the 200-lb application. That is, actual mean response to fertilizer may differ from 42 cu ft/ac/yr (200 lb-N) or from 57 cu ft/ac yr (400 lb-N) by ± 8 cu ft/ac/yr.

Table 1.

Estimated mean 8-year gross total basal area growth for unthinned Douglas-fir (sq ft/ac/yr; min. d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
10	0	12.6	12.7	12.7	-
	200	14.0	14.6	15.2	-
	400	14.3	14.8	15.3	-
20	0	7.8	7.9	8.0	8.0
	200	8.3	8.9	9.5	10.1
	400	8.8	9.3	9.7	10.2
30	0	6.2	6.2	6.2	6.1
	200	6.4	7.0	7.6	8.1
	400	7.0	7.4	7.8	8.2
40	0	5.4	5.2	5.1	4.9
	200	5.6	6.0	6.4	6.8
	400	6.2	6.4	6.7	6.9
50	0	4.5	4.3	4.0	3.7
	200	4.7	5.1	5.3	5.6
	400	5.3	5.5	5.6	5.7

Table 2.

Estimated mean response of 8-year gross total basal area growth for unthinned Douglas-fir (sq ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.
10	200	1.4	1.9	2.5	-
	400	1.7	2.1	2.5	-
20	200	0.4	1.0	1.5	2.1
	400	1.0	1.4	1.7	2.2
30	200	0.3	0.8	1.4	2.0
	400	0.9	1.2	1.6	2.0
40	200	0.2	0.8	1.3	1.9
	400	0.8	1.2	1.6	2.0
50	200	0.2	0.8	1.3	1.9
	400	0.8	1.2	1.6	2.0

There was no statistically significant effect (95% confidence level) of age, initial basal area, number of stems, or site index on volume response. Although response varied significantly across site index for the first 4 years, this interaction has not been statistically significant (95% confidence level) for the 6-year and 8-year (current) analyses. However, response estimates are given for each site class for ease of comparison with past RFNRP reports:

Dosage \ Site Class	I	II	III	IV	Mean
200-lb N	28	38	48	59	42
400-lb N	39	52	65	79	57

The smoothed volume increment estimates for the total stand are summarized in Table 3. An example of smoothed growth trends for untreated stands is given in Figure 1.

Table 3.

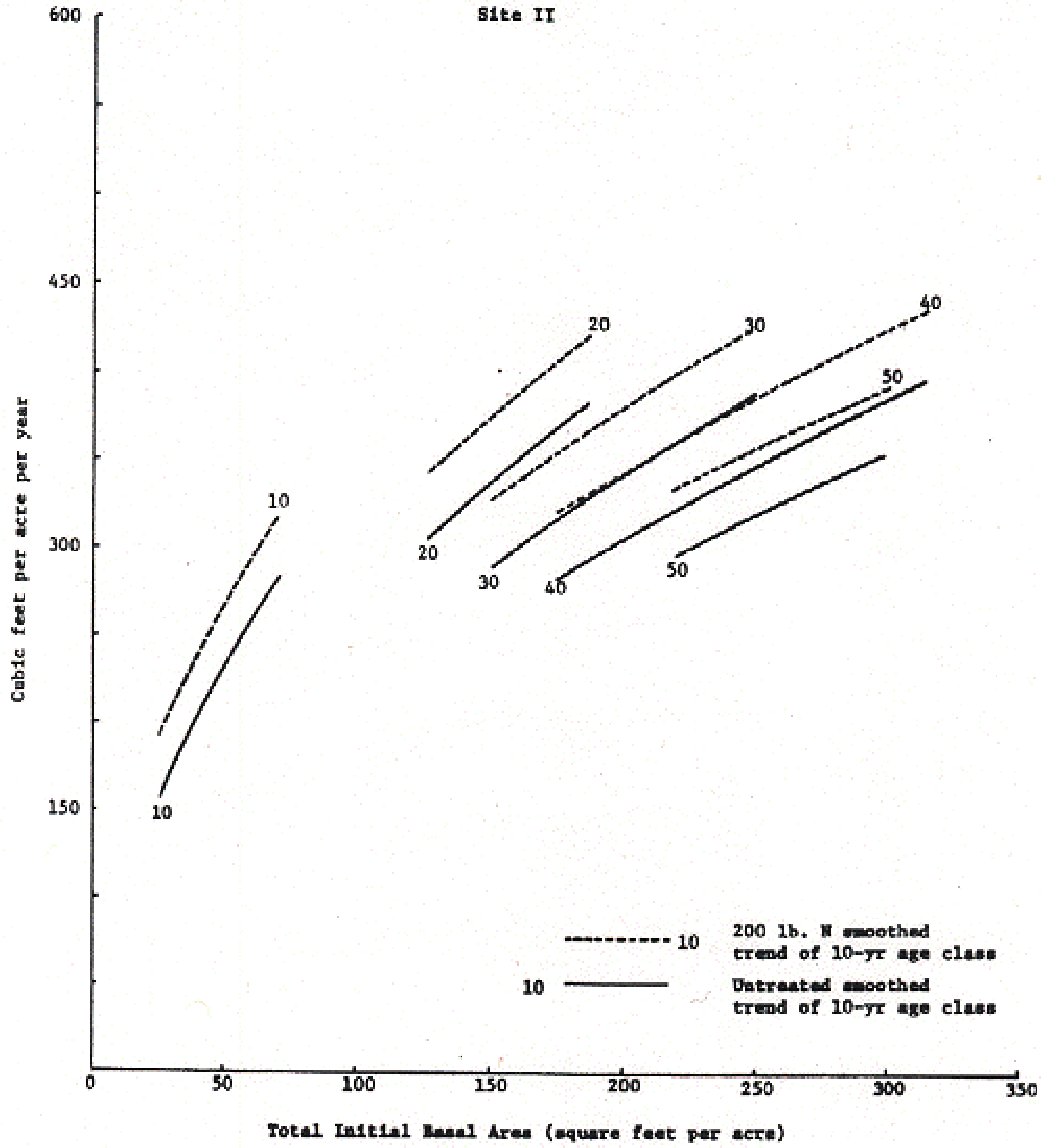
Estimated mean 8-year gross total volume growth for unthinned Douglas-fir (cu ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	284.0	254.9	224.4	-
	200	311.6	292.8	272.7	-
	400	322.7	306.9	289.7	-
20	0	398.3	350.2	301.1	250.7
	200	425.9	388.1	349.3	309.3
	400	436.9	402.2	366.4	329.3
30	0	408.7	357.0	304.5	251.1
	200	436.3	394.9	352.7	309.7
	400	447.4	408.9	369.8	329.7
40	0	396.9	345.5	293.5	240.9
	200	424.5	383.4	341.8	299.5
	400	435.6	397.5	358.8	319.5
50	0	380.3	330.4	280.0	229.1
	200	407.9	368.3	328.2	287.7
	400	419.0	382.3	345.3	307.7

Figure 1.

TREATMENT: 0 and 200 lbs. N per acre
Estimated trends of 8-year gross total volume growth
for unthinned Douglas-fir.

Site II



II REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE *MERCHANTABLE* STAND FOR *UNTHINNED* DOUGLAS-FIR, EIGHT YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

The 8-year merchantable gross growth rate was analyzed much the same as the 6-year merchantable growth analysis reported in the last (1976-1978) Biennial Report from the project; the gross increment (cu ft/ac/yr) in merchantable volume was calculated for trees of d.b.h. greater than 6.55 inches and measured to a 4-inch top.

The primary objective is to provide a regional estimate of mean response in merchantable units according to relevant stand variables (e.g. site index, age, etc.). Response is measured as an increase in growth rate due to application of fertilizer and can be thought of as:

RESPONSE = [Unthinned Fertilized Merchantable Stand Growth Rate] minus [Growth Rate as in the Unthinned Unfertilized Merchantable Stand]

The merchantable stand growth results of Phase I were analyzed from 377 plots of 1/10-acre or larger. These comprised at least 80% Douglas-fir type stands, with an additional constraint of at least 100 merchantable trees per acre. The data base covers breast-height age classes 15 through 45, and 50-year site classes 1 through 4. All increment figures are gross p.a.i. without ingrowth.

Tables of plot distribution and raw data are located in Appendix A.

Results of Analysis

Average merchantable stand basal area response in square feet per acre per year is 18% from the 200-pound application and 24% to 400 pounds of nitrogen. Results of the volume increment analysis indicate a mean response of 38 cu ft/ac/yr to 200 pounds of nitrogen application and 52 cu ft/ac/yr to 400 pounds of nitrogen application. These figures represent relative increases of 14% and 19% for the respective levels of fertilizer application over the merchantable growth rate of the untreated stands. Response was significantly related to the level of N-application but did not change significantly with age, site index, or basal area. Smoothed estimates of growth rate are presented in Table 4. An example of smoothed trends of growth rate for untreated and treated stands is presented in Figure 2.

A summary of 8-year unthinned Douglas-fir, comparing total stand p.a.i. and merchantable stand p.a.i., is presented in Figure 3.

Figure 2.

TREATMENT: 0 and 200 lbs-N per acre

Estimated trends of 8-year gross merchantable volume growth for unthinned Douglas-fir; Site II.

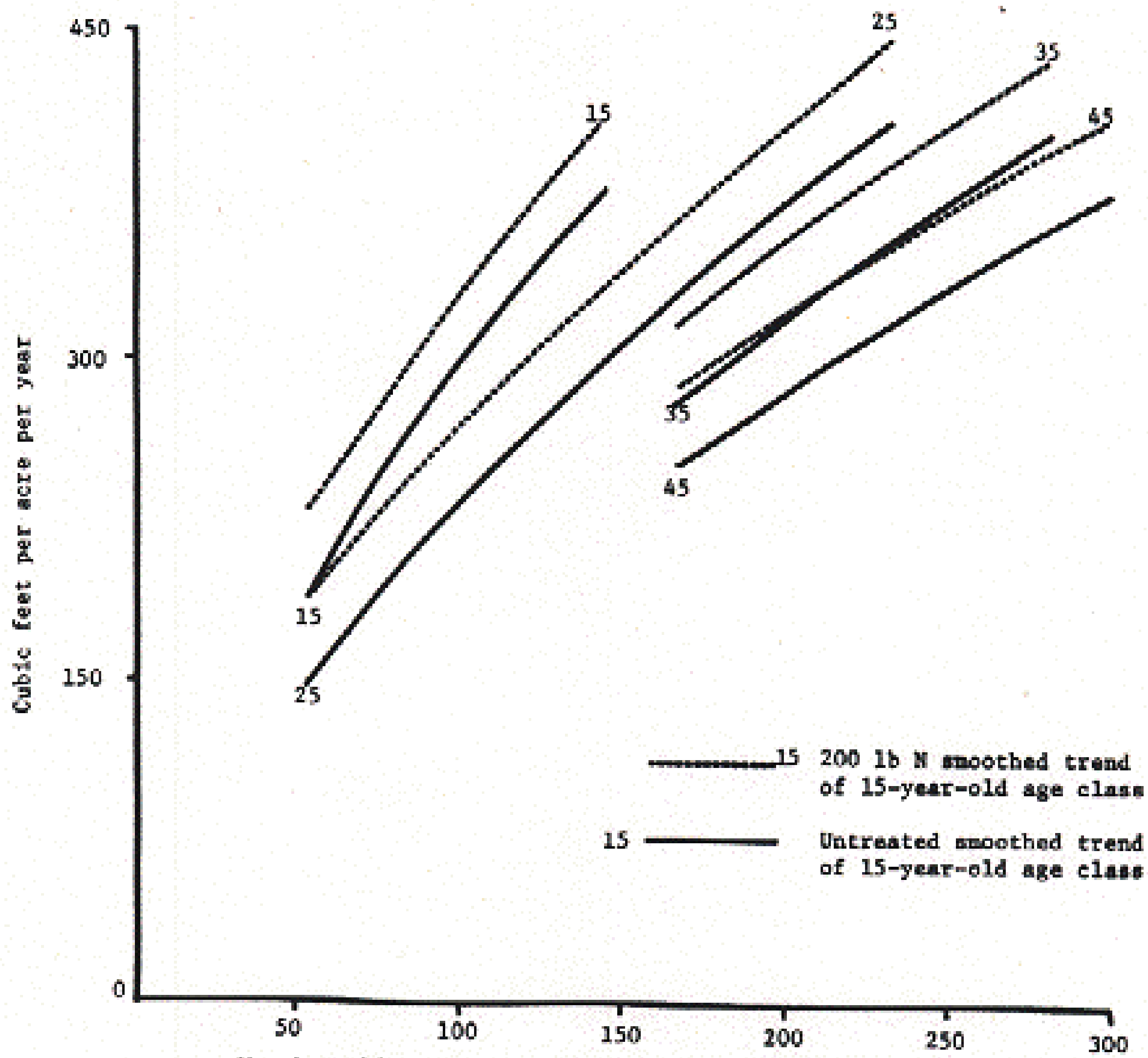


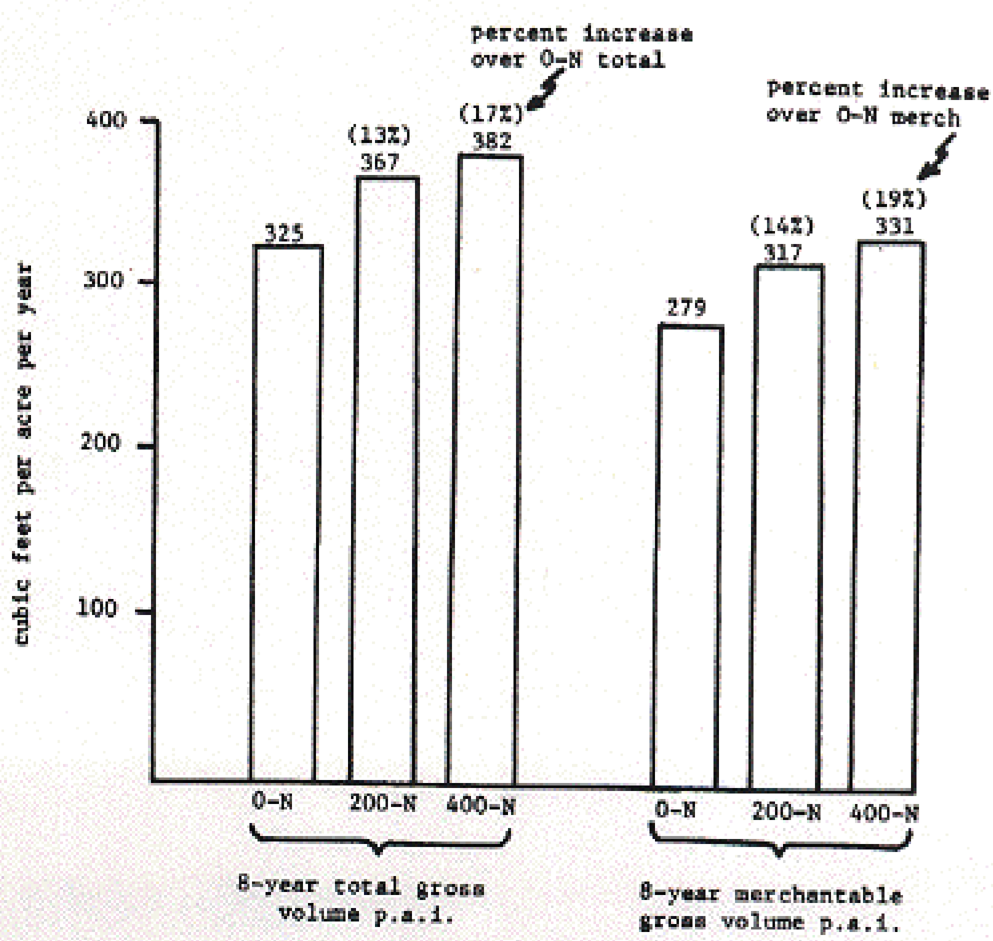
Table 4.

Estimated mean 8-year gross merchantable volume growth (without ingrowth) for unthinned Douglas-fir (cu ft/ac/yr; min. d.b.h. = 6.55 inches to a 4-inch top).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
15	0	364	263	157	-
	200	399	299	192	67
	400	413	-	207	-
25	0	372	293	215	139
	200	408	328	251	174
	400	421	342	264	188
35	0	384	316	249	184
	200	419	351	285	220
	400	432	365	299	234
45	0	396	333	273	215
	200	432	368	308	249
	400	445	382	322	263

Figure 3.

Summary of expected mean 8-year gross volume p.a.i. and percent response of unthinned Douglas-fir for both the total stand (cu ft/ac/yr; min. d.b.h. = 1.55 inches) and the merchantable stand (cu ft/ac/yr; min. d.b.h. = 6.55 inches, to a 4-inch top).



III *DURATION* OF REGIONAL GROWTH RESPONSE OF THE *TOTAL* STAND FOR *UNTHINNED* DOUGLAS-FIR, EIGHT YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

A topic considered equal in importance with a significant level of response is whether or not response is sustained throughout the entire growth period. The results thus far show a substantial effect on 8-year p.a.i. from fertilizer, varying with the level of application. We can more clearly detect changes in response from one growth period to the next by examination of the entire 8-year period in 4 separate periods of 2-year measurement intervals.

The previous (1976-1978) Biennial Report demonstrated an overall decline in response at the 3rd measurement period, with the decline more pronounced for the 200-pound nitrogen application. The belief at that time was that the decline in response would continue. The current analysis reported here confirms that projected viewpoint.

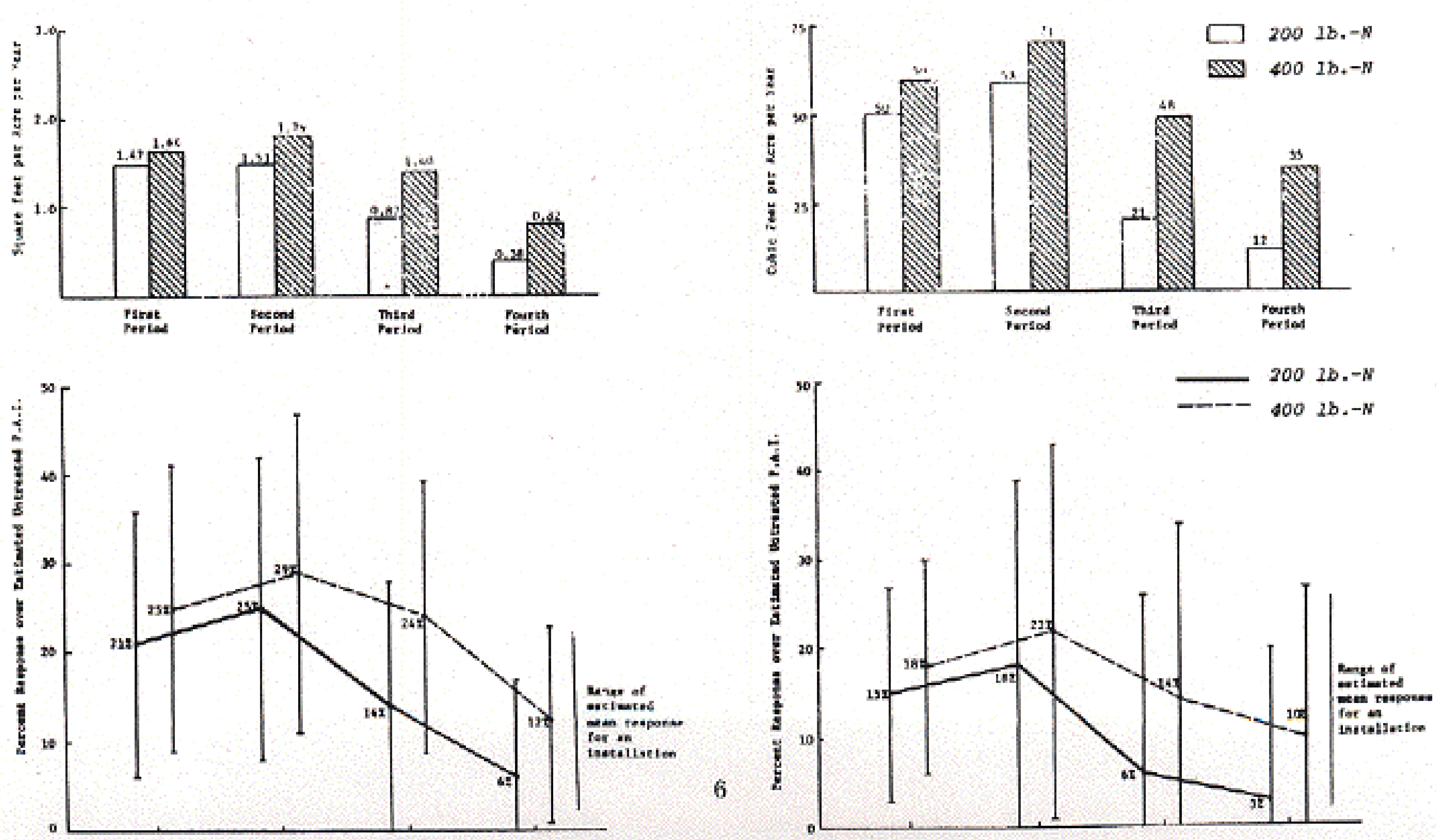
Results of Analysis

Figure 4 clearly shows the decline in response through the 8th growing season for both volume p.a.i. and basal area p.a.i. Although response has declined for both levels of nitrogen, the magnitude of difference in response to the two levels of N-application is much greater as time since application increases. Whereas the advantage of applying 400 vs 200 pounds of nitrogen was perhaps marginal initially, the advantage is quite distinct in the 3rd and 4th 2-year periods.

The analysis by 2-year growth periods substantiates the results of the 8-year analysis. It further indicates that the greater gain from 400 pounds of nitrogen is enhanced by its longevity in response duration.

Figure 4.

Estimated mean response in gross total stand growth for 2-year periods for unthinned Douglas-fir. (sq ft/ac/yr and cu ft/ac/yr; minimum d.b.h. = 1.55 inches)



IV REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE *TOTAL* STAND FOR *THINNED* DOUGLAS-FIR, *SIX* YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

Thinning is regarded as an initial condition of the stand when fertilizer is applied, and response is measured as the increase in growth rate due to fertilizer:

RESPONSE = [Increase in Growth Rate Due to Fertilizer] = [Treated Thinned Stand Growth Rate] minus [Growth Rate as in Untreated Thinned Stand]

As in the previous sections on unthinned stands, the following are being reported:

i) Response in basal area gross p.a.i. of the total thinned stand (minimum d.b.h. = 1.55 inches).

ii) Response in volume gross p.a.i. of total thinned (minimum d.b.h. = 1.55 inches).

iii) Duration of response for both basal area p.a.i. and volume p.a.i. in total thinned stand.

Analysis of total stand response is based on 194 plots of 1/10 acre or larger, containing growing stock of at least 80% Douglas-fir type stands. This data base covers breast-height age classes 15 through 45, and 50-year site classes 1 through 4. All increment figures are 6-year gross p.a.i. The distribution of plots along with tables of raw data are given in Appendix A.

Results of Analysis

1. Gross P.A.I. of Total Basal Area: Although the main topic of interest is response in cubic feet per acre, basal area p.a.i. response was analyzed as a preliminary step. Average response across the data ranges of age, site, and basal area was about 25% to 200 pounds of nitrogen and 31% to 400 pounds of nitrogen. Basal area response was significantly (95% confidence level) related to both initial basal area (after thinning) and level of N-application, response being greatest in the lower range of basal area. Smoothed estimates of total growth rate are presented in Table 5, with estimated response given in Table 6.

Table 5.

Estimated mean 6-year gross total basal area growth for thinned Douglas-fir (sq ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
15	0	-	10.7	10.2	9.6
	200	-	13.1	12.8	12.5
	400	-	13.6	13.3	13.1
25	0	6.9	6.9	6.9	6.8
	200	8.3	8.6	8.9	9.2
	400	8.6	9.0	9.4	9.7
35	0	5.2	5.4	5.6	5.7
	200	6.0	6.5	7.1	7.7
	400	6.2	6.8	7.5	8.1
45	0	-	4.6	4.9	5.1
	200	-	5.2	6.0	6.7
	400	-	5.4	6.3	7.1

Table 6.

Estimated mean response of 6-year gross total basal area growth for thinned Douglas-fir (sq ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
15	200	-	2.4	2.6	2.9
	400	-	2.9	3.2	3.5
25	200	1.4	1.7	2.0	2.4
	400	1.7	2.1	2.5	2.9
35	200	0.8	1.2	1.6	2.0
	400	1.0	1.4	1.9	2.4
45	200	-	0.7	1.1	1.6
	400	-	0.9	1.4	2.0

2. Gross P.A.I. of Total Volume: Results of the volume increment analysis show a mean estimated response of 60 cubic feet per acre per year to 200 pounds of nitrogen. This response represents a 22% increase over the mean estimated growth rate of the unfertilized thinned stands.

Average estimated response to 400 pounds of nitrogen is 71 cubic feet per acre per year, an increase of 26% over the mean estimated growth rate of the unfertilized thinned stands. The standard error associated with the response estimates is about 12% of response for both levels of N-application. That is, the actual mean response to fertilizer may differ from the estimated 60 cu ft/ac/yr (200 lb-N) or the estimated 71 cu ft/ac/yr (400 lb-N) by ± 8 cubic feet per acre per year.

There was no statistically significant effect of age, site index, or basal area on volume response to fertilizer. However, nitrogen application level was statistically significant in explaining response. Smoothed growth estimates of the total thinned stands are summarized in Table 7. Smoothed trends of growth rate are exhibited in Figure 5.

Table 7.

Estimated mean 6-year total gross volume growth for thinned Douglas-fir (cu ft/ac/yr; min. d.b.h. = 1.55 inches).

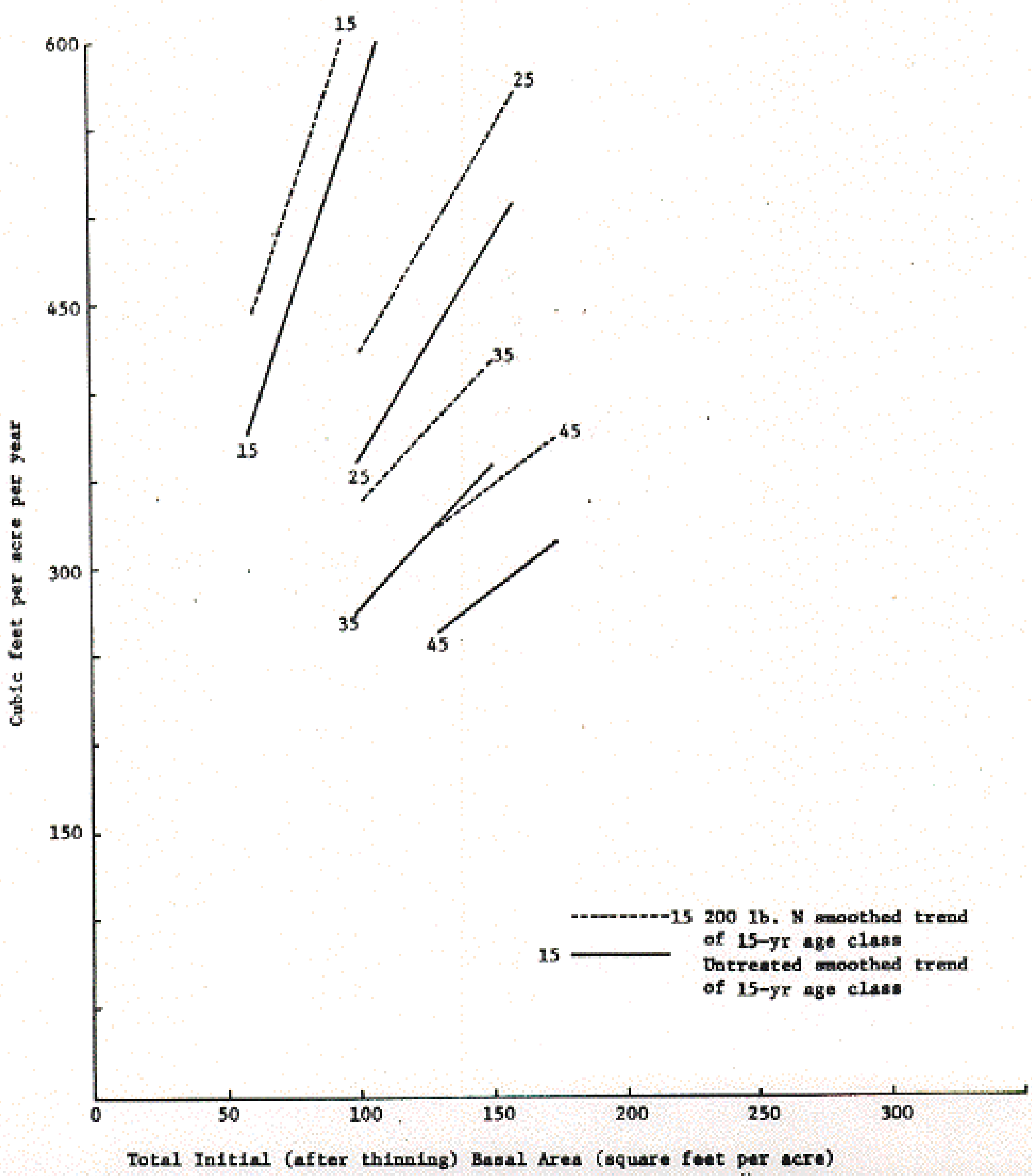
Breast-Height Age	Site Class (50-yr index)			
	I	II	III	IV
15	380	311	225	197
25	340	345	286	186
35	339	285	264	244
45	-	261	231	207

Average response to 200 lb-N: 60 cuft/ac/yr

Average response to 400 lb-N: 71 cuft/ac/yr

Figure 5.

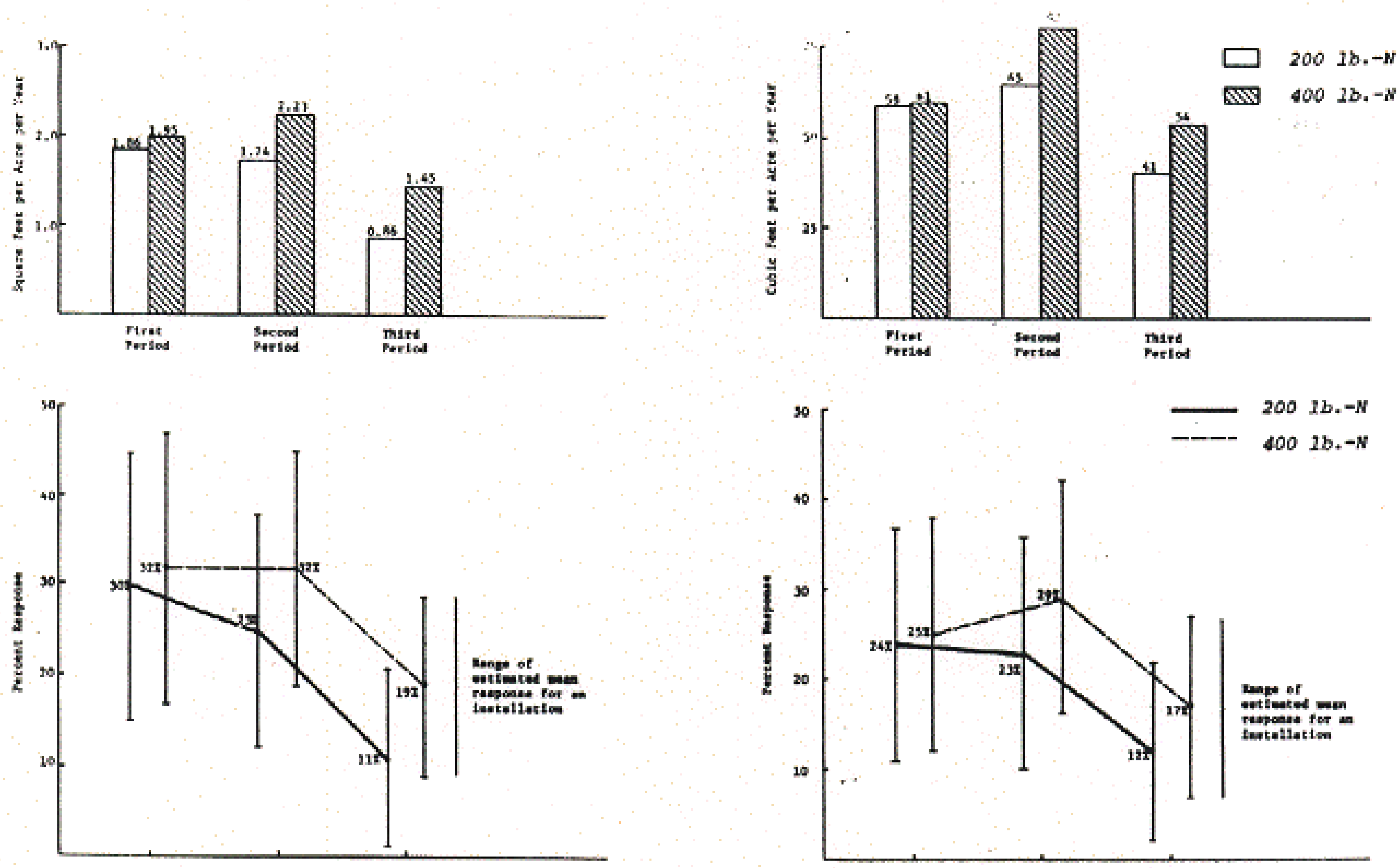
TREATMENT: 0 and 200 lbs. N per acre
Estimated trends of 6-year gross total volume growth for thinned Douglas-fir.



3. Duration of Response: With 6 growing seasons measured and analyzed, three 2-year growth periods are available for examining duration response for the 2 levels of fertilizer application in thinned stands. Following the pattern of the unthinned stands, fertilizer response has dropped off considerably from the second to the third period (Figure 6). The advantage of the 400 pound application of nitrogen over the 200 pound application is evident in the third period. The relationship of such response trends between unthinned and thinned stand conditions are compared in section VI of this report.

Figure 6.

Estimated mean response in gross total stand growth by 2-year periods for thinned Douglas-fir. (sq ft/ac/yr and cu ft/ac/yr; minimum d.b.h. = 1.55 inches)



V REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE *MERCHANTABLE* STAND FOR *THINNED* DOUGLAS-FIR, SIX YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

The 6-year merchantable gross growth rate for thinned stands was analyzed much the same as the merchantable portion of the unthinned stands; the gross increment (cu ft/ac/yr) in merchantable volume was calculated for trees of d.b.h. greater than 6.55 inches and measured to a 4-inch top. Thus, response is measured as increased growth rate from applying fertilizer:

RESPONSE = [Thinned Fertilized Merchantable Stand Growth Rate] minus [Growth Rate as in the Thinned Unfertilized Merchantable Stand]

Results are based on 6 years of growth data, analyzed from 160 plots of 1/10-acre or larger, comprised of at least 80% Douglas-fir type stands having a minimum of 100 merchantable stems per acre. The data base ranges across breast-height age classes 15 through 45, and 50-year site index classes 1 through 4. All increment figures are gross p.a.i. without ingrowth. Tables of plot distribution and raw data are located in Appendix A.

Results of Analysis

The merchantable portion of thinned stands responded with an average 55 cu ft/ac/yr to the 200-pound nitrogen application and 66 cu ft/ac/yr to 400 pounds of nitrogen. These figures represent relative increases of 21% and 25% respectively to be expected over the average merchantable growth rates of untreated stands. Response was significantly related to level of nitrogen application but was not significantly related to stand variables such as age, site index, and stocking. Smoothed estimates of untreated merchantable stand response are given in Table 8. An example of the smoothed trends of growth rate for the merchantable stand is depicted in Figure 7.

A comparison of growth rate in both the total and merchantable thinned stands is given in Figure 8.

Table 8.

Estimated mean 6-year gross merchantable volume growth (without ingrowth) for thinned Douglas-fir (cu ft/ac/yr; min. d.b.h. = 6.55 inches to a 4-inch top).

Breast-Height Age	Site Class (50-yr index)			
	I	II	III	IV
15	387	357	-	-
25	353	297	235	-
35	318	263	232	188
45	-	256	225	202

Average response to 200 lb-N: 55 cuft/ac/yr

Average response to 400 lb-N: 66 cuft/ac/yr

Figure 8.

Summary of expected mean 6-year gross volume p.a.i. and percent response of thinned Douglas-fir for both the total stand (cu ft/ac/yr; min. d.b.h. = 1.55 inches) and the merchantable stand (cu ft/ac/yr; min. d.b.h. = 6.55 inches, to a 4-inch top).

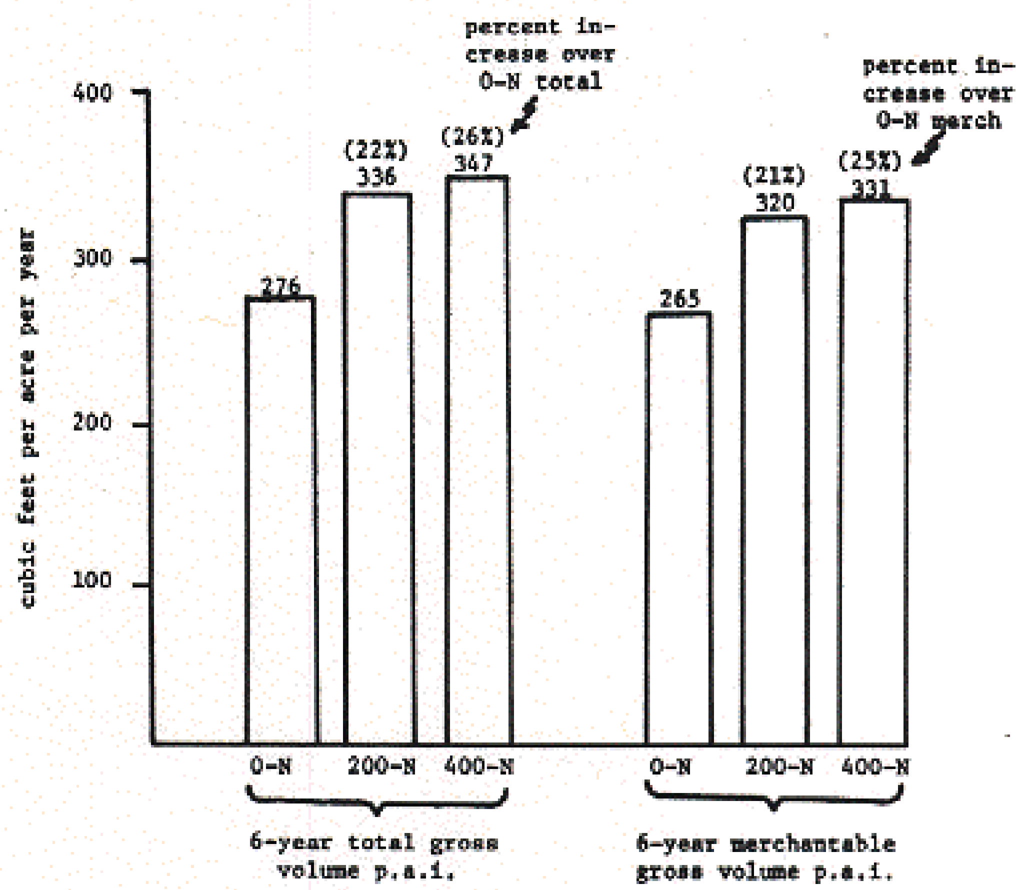
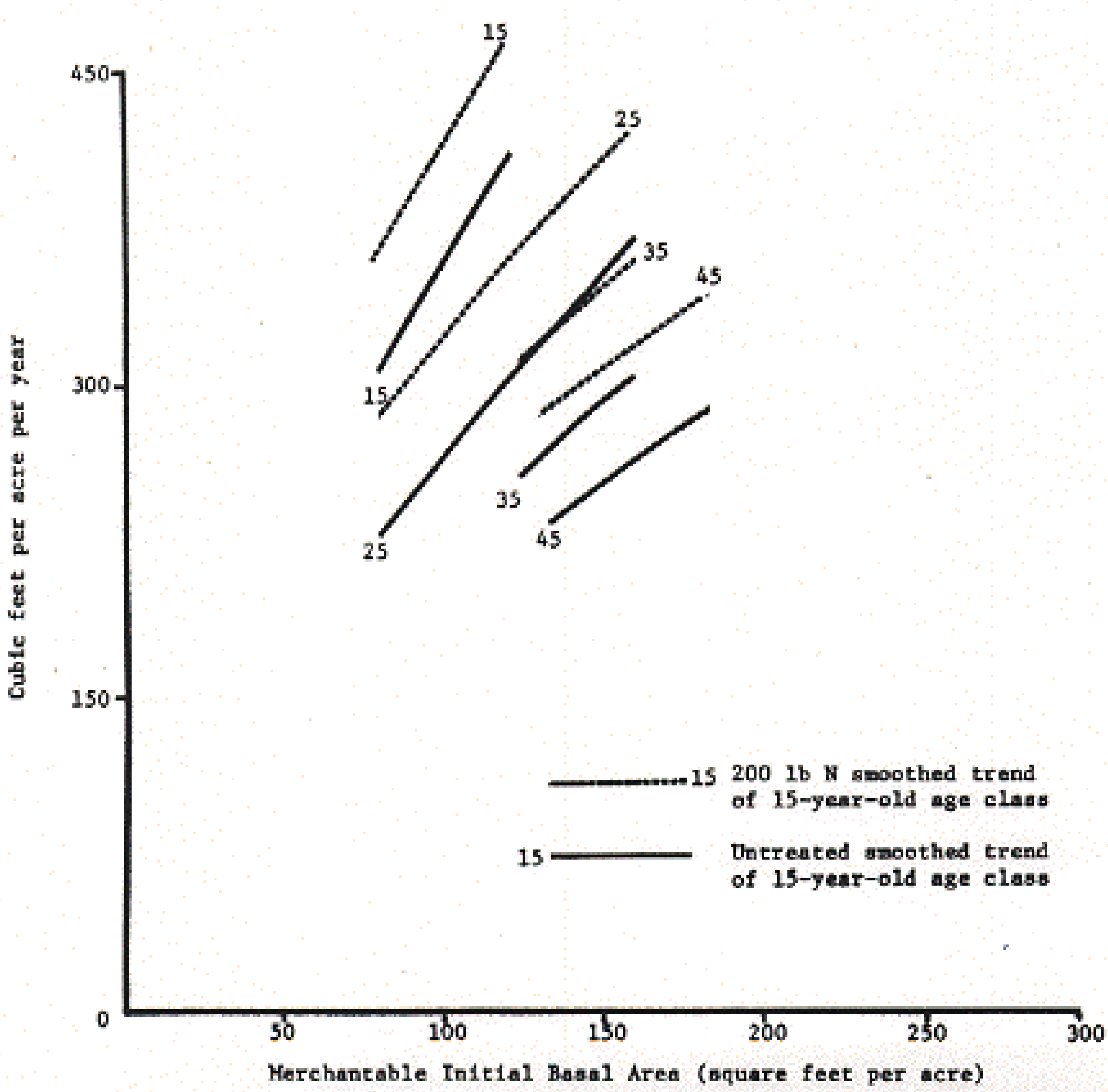


Figure 7.

TREATMENT: 0 and 200 lbs-N per acre

Estimated trends of 6-year gross merchantable volume growth for thinned Douglas-fir; Site II.



VI A COMPARISON OF AVERAGE RESPONSE IN *THINNED* AND *UNTHINNED* DOUGLAS-FIR STANDS, SIX YEARS FOLLOWING FERTILIZER APPLICATION

The purpose of this section of the Biennial Report is to contrast:

i) The overall growth and response of thinned and unthinned stands, from 6-year total gross p.a.i.

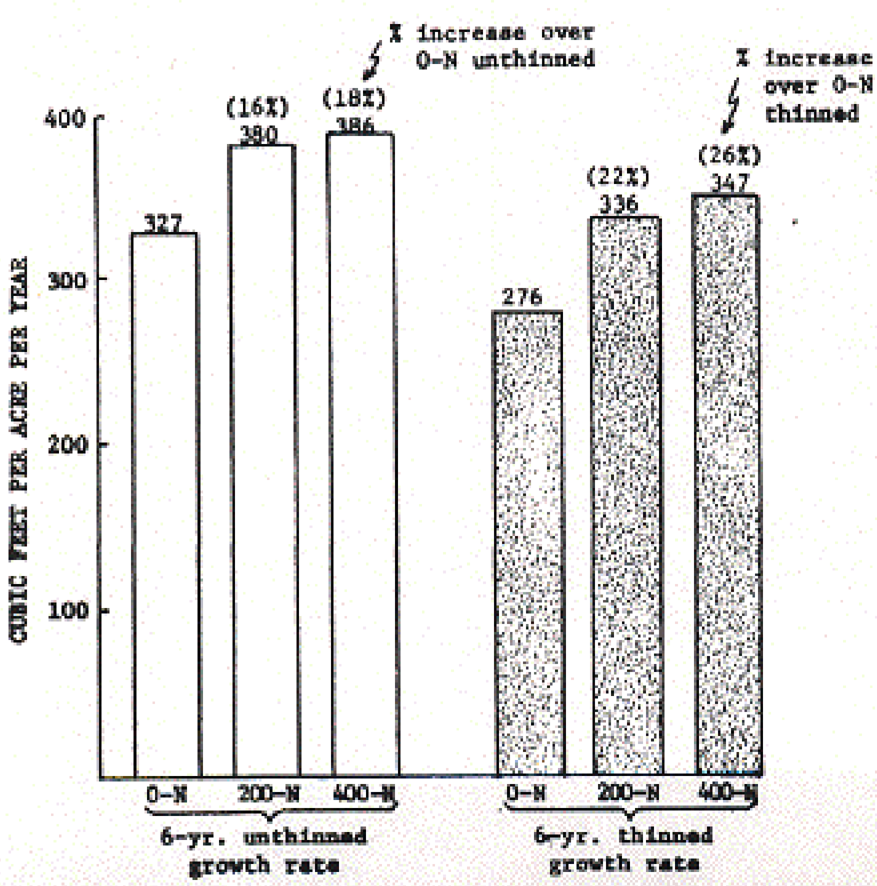
ii) The duration or longevity of response (by 2-year measurement periods) of thinned and unthinned stands.

Average Incremental Response Over Six Years

Figure 9 depicts mean 6-year p.a.i. of both volume and basal area for all treatments, contrasting the unthinned and thinned stands. The growth rate of the thinned stands is understandably less than that of the unthinned stands on a per acre basis due to reduction of growing stock. As pointed out in the most recent Biennial Report (1976-1978), the important null hypothesis that growth in thinned stands is not different from growth in understocked unthinned stands cannot be tested without below-normal stocking conditions (RFNRP has since established installations of low-stocked conditions under Phase IV for implementation into future analyses). However, for the present it is obvious (Table 9) that the average response to fertilizer of thinned stands is greater than that of the unthinned stands in both relative (percent increase over untreated stands) and absolute (sq ft/ac/yr and cu ft/ac/yr) amounts. Note also in Table 9 the differences between thinned and unthinned initial stand conditions. Average breast-height ages and 50-year site indexes are close whereas the big difference lies in basal area stocking.

Figure 9.

Summary of Phase I and Phase II mean estimated 6-year gross total volume growth for Douglas-fir. (cu ft/ac/yr; min. d.b.h. = 1.55 in.)



Summary of Phase I and Phase II mean estimated 6-year total basal area growth for Douglas-fir. (sq ft/ac/yr; min. d.b.h. = 1.55 in.)

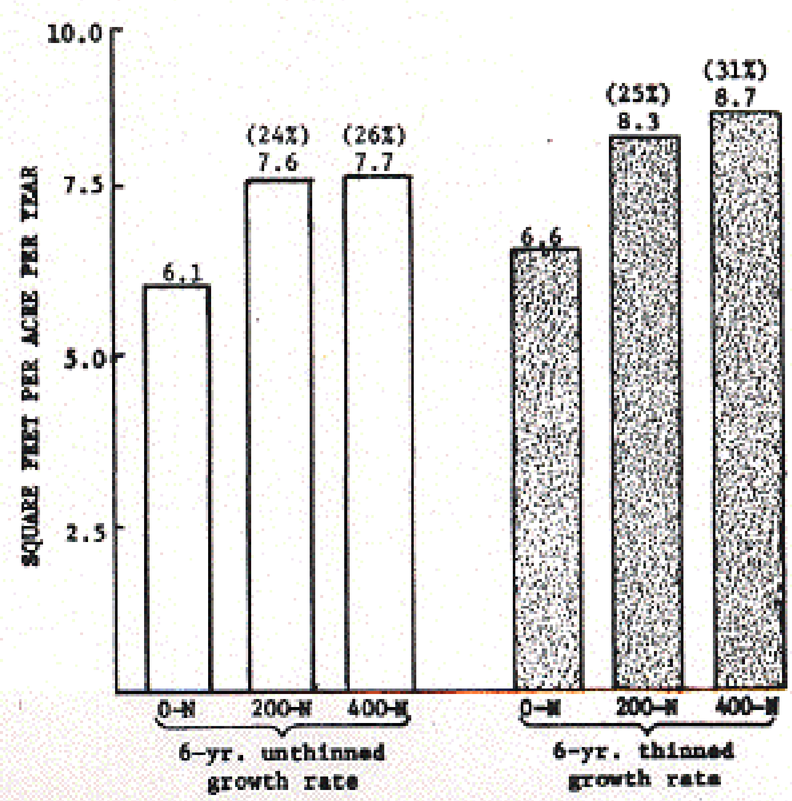


Table 9.

Average stand conditions and estimated mean response for 6-year gross total growth rate of Phase I and Phase II (Douglas-fir).

Treatment: 200 lbs. N/ac

	cu ft /ac /yr	sq ft /ac /yr
Phase I (unthinned)	53 (16%)	1.5 (24%)
Phase II (thinned)	60 (22%)	1.7 (25%)

Treatment: 400 lbs. N/ac

	cu ft /ac /yr	sq ft /ac /yr
Phase I (unthinned)	59 (18%)	1.6 (26%)
Phase II (thinned)	71 (26%)	2.1 (31%)

Average Initial Stand Conditions

	Age	Site Index	Basal Area
Phase I (unthinned)	32 years	117 ft.	202 sq ft /ac
Phase II (thinned)	30 years	114 ft.	120 sq ft /ac

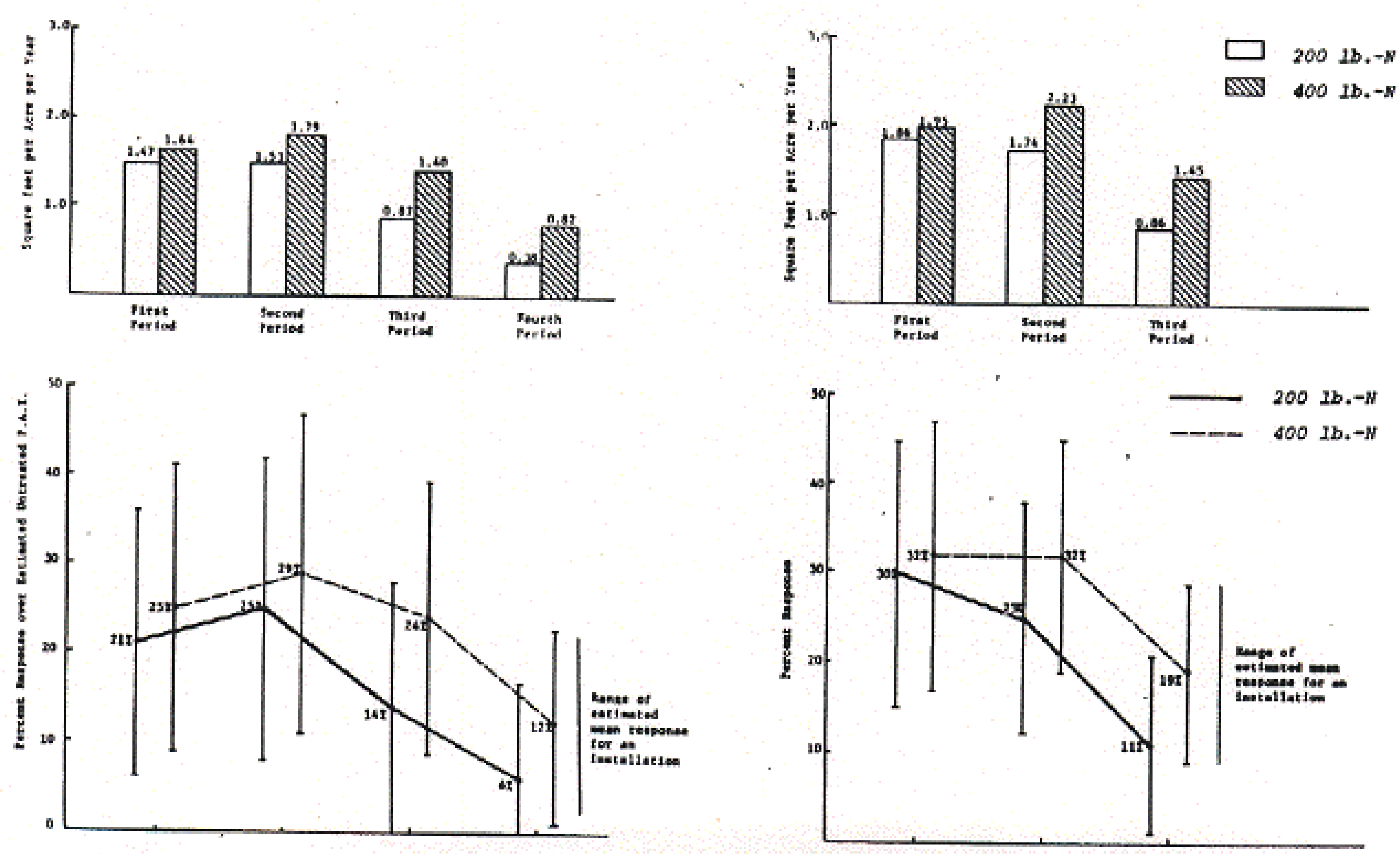
Longevity of Response

Analyses of response by 2-year growth periods provides an interesting contrast of similarities and differences between Phase I (unthinned stands) and Phase II (thinned stands). Whereas the mean response over 6 years was relatively and absolutely greater for Phase II, this relationship changes somewhat when viewed for each 2-year period.

1. Consider first the basal area p.a.i. Note in Figure 10 that the decline in response from the 2nd to the 3rd period follows the same pattern for both phases. However, absolute responses in the 3rd period are about equal, representing a higher percentage response for the unthinned stands. The advantage of the 400-pound application over the 200-pound application is nearly equal in both cases.

Figure 10.

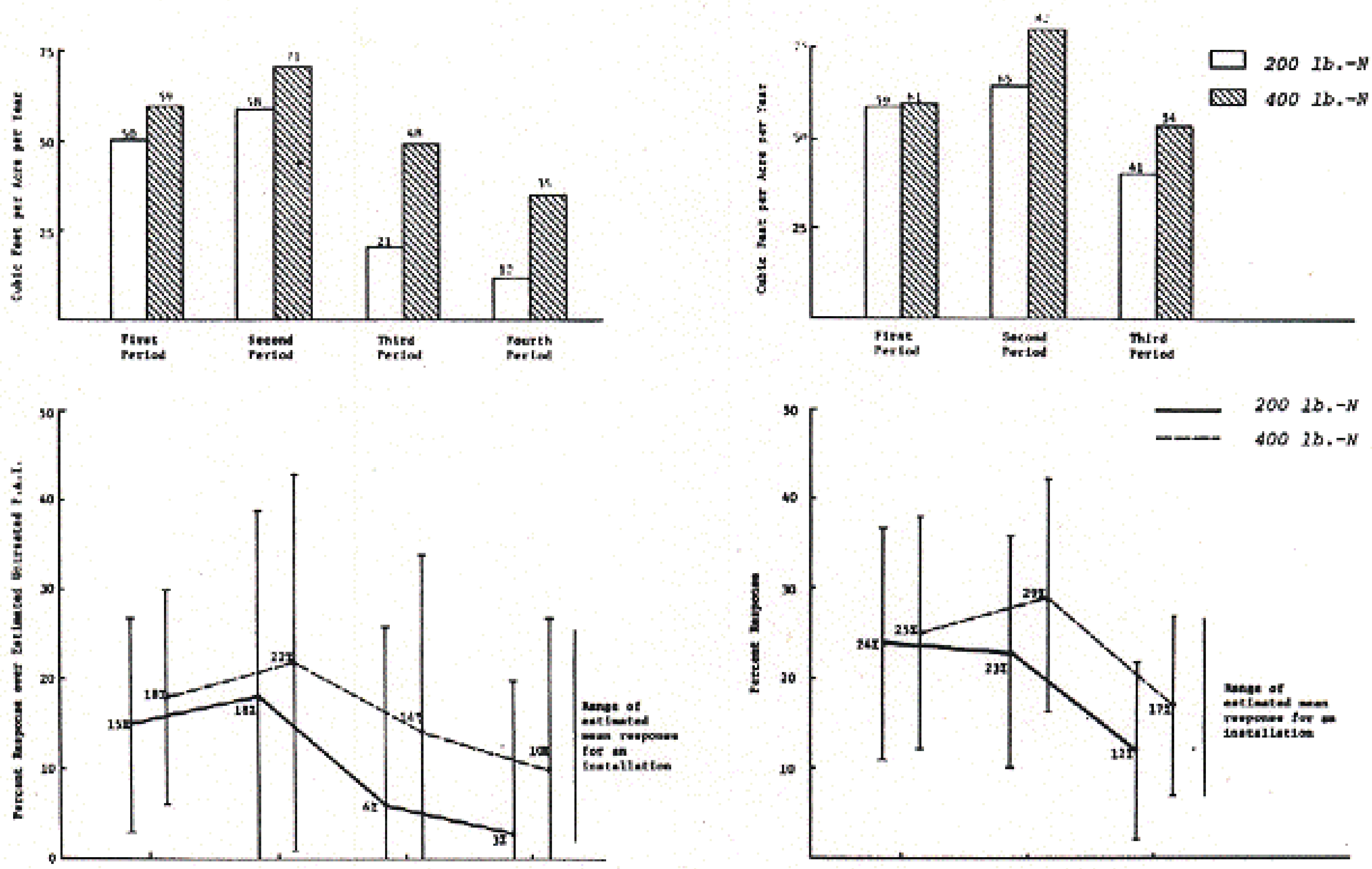
Summary of Phase I and Phase II estimated mean response of gross total basal area growth by 2-year periods for Douglas-fir. (sq ft/ac/yr; minimum d.b.h. = 1.55 inches)



2. Consider now the response in volume growth, focusing on the 3rd period of growth in Figure 11. The average response in thinned stands is still greater in both relative and absolute amounts. Also the advantage of the 400-pound application is not equal in both cases. The higher application rate shows a substantial advantage for the unthinned stands, or from another point of view, the initial thinned condition shows a substantial advantage for the lower application rate. This relationship affords the opportunity to entertain ideas as to what management practices should be followed initially or should be employed at or prior to the 3rd growth period (5-6 years after initial treatment).

Figure 11.

Summary of Phase I and Phase II estimated mean response of gross total volume growth by 2-year periods for Douglas-fir. (cu ft/ac/yr; minimum d.b.h. = 1.55 inches)



VII REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE *TOTAL* STAND FOR *UNTHINNED* WESTERN HEMLOCK, EIGHT YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

A total of 25 surviving installations were established under Phase I (unthinned), each made up of six 1/10-acre or larger plots receiving the same treatment as the Phase I Douglas-fir installations:

- 50 plots - unthinned with no fertilizer
- 50 plots - unthinned with 200 pounds of nitrogen per acre
- 50 plots - unthinned with 400 pounds of nitrogen per acre

As with previous analyses, the data revealed no significant differences in average growth rate among the untreated and treated plots. The data were then stratified into 2 geographical areas (Coastal and Cascade strata) and two breast-height age classes (12-23 years and 24-35 years), and subsequently tested for statistically significant (95% confidence level) differences. A significant difference in mean treatment growth rates within a stratum was interpretted as a significant response. Stands with at least 80% western hemlock stocking were analyzed across a breast-height range of 12-35 years.

Results of Analysis

1. Phase I western hemlock: The only significant response to 200 pounds of fertilizer on the unthinned stands was detected in the young Cascade stratum. The difference in the untreated and treated stand growth rates (8-year p.a.i.) for that stratum was statistically significant (Table 10), for both basal area and volume. Six-year p.a.i. results, as well as a breakdown of the data by 2-year growth periods, are presented in the next section for comparison with the (6-year) thinned hemlock stands.

Table 10.

Results of 1-tailed t-tests for significant (95% confidence level) differences between mean total growth rate of unthinned unfertilized stands and mean total growth rate of unthinned fertilized (200 lb.-N/ac) stands for western hemlock (80% hemlock spp.)

Phase I

Eight-year Response of Basal Area p.a.i.
(sq ft /ac/yr; min d.b.h. = 1.55 in.)

	Older(24-35 yrs.)	Younger(12-23 yrs.)
CASCADE	diff = 0.52 s.e. = .552 n = 13 nonsignificant	diff = 3.62 (32%) s.e. = .357 n = 8 significant
COASTAL	diff = -0.77 s.e. = .585 n = 22 nonsignificant	diff = -0.76 s.e. = .544 n = 12 nonsignificant

Eight-year Response of Volume p.a.i.
(cu ft /ac/yr; d.b.h. = 1.55 in.)

	Older(24-35 yrs.)	Younger(12-23 yrs.)
CASCADE	diff = 24.5 (6%) s.e. = 32.4 n = 13 nonsignificant	diff = 66 (24%) s.e. = 27.0 n = 8 significant
COASTAL	diff = -35.4 s.e. = 23.9 n = 22 nonsignificant	diff = -54.2 s.e. = 45.9 n = 12 nonsignificant

VIII REGIONAL GROWTH AND RESPONSE ANALYSIS OF THE TOTAL STAND FOR *THINNED* WESTERN HEMLOCK, SIX YEARS FOLLOWING FERTILIZER APPLICATION

Introduction

A total of eight western hemlock installations, each with 6 plots 1/10-acre or larger, received the following treatments in Phase II:

16 Plots-thinned and unfertilized.
16 Plots-thinned and 200 pounds of nitrogen per acre
16 Plots-thinned and 400 pounds of nitrogen per acre

Analysis of the data overall revealed no significant differences in average growth rate among these three treatments. The data were then stratified into two geographical areas (Coastal and Cascade strata) and into two breast-height age groups (12-23 years and 24-35 years) within the areas and tested for differences. Finally the results were compared with a similar analysis completed for the western hemlock installations of Phase I (six years after fertilizer application).

A statistically significant difference (at 95% confidence level) in mean growth rates between fertilized and unfertilized stands was considered a significant response. This section is concerned with:

1) Response to 200 lb-N application on younger (12-23 years) and older (24-35 years) thinned hemlock stands within the Coastal area.

2) Response to 200 lb-N application on younger (12-23 years) and older (24-35 years) thinned hemlock stands within the Cascade area.

3) Contrast of response to fertilizer between Phase I (unthinned) stands and Phase II (thinned) stands.

Results of Analysis

1. Basal area gross p.a.i.

   i) The younger stands in the Coastal area had a statistically significant response of 19% (Table 11).

   ii) The younger stands and older stands showed a 27% and 4% respective response (Table 11) in the Cascade area. These relative responses are statistically nonsignificant.

   iii) The only statistically significant response to fertilizer on the unthinned stands of Phase I was 37% in the Cascade younger stands (Table 12).

2. Volume gross p.a.i.

   i) There was no significant response for either age group in the thinned Coastal area (Table 11).

   ii) The younger stands of the thinned Cascade area also exhibit a nonsignificant response (Table 11).

   iii) For the unthinned stands of Phase I, the younger Cascade stratum showed a significant response of 25% to fertilizer (Table 12).

Conclusions

Since any response in western hemlock is more apt to show in basal area than volume (higher variability), the remarks here will be confined to basal area p.a.i. and with reference to the 200-pound application of nitrogen.

The previous Biennial Report (1976-1978) compared 4-year response of hemlock in both thinned and unthinned initial stand conditions. At that time the unthinned stands responded significantly only in the young Cascade stratum, whereas the thinned stands showed significant response in all strata excepting the older coastal stands. However, the present comparative analysis of the 6-year data shows that while the unthinned stands still respond significantly in the young-Cascade stratum, the thinned stands respond now only in the young-Coastal stratum. The lack of statistical significance of response is due to the high variability associated with that response relative to the sample size.

Table 11.

Results of 1-tailed t-tests for significant (95% confidence level) differences between mean total growth rate of thinned unfertilized stands and mean total growth rate of thinned fertilized (200 lbs.-N/ac) stands for western hemlock (80% hemlock spp.)

Phase II

Six-year Response of Basal Area p.a.i.
(sq ft /ac/yr; min d.b.h. = 1.55 in.)

	Older (24-35 yrs.)	Younger (12-23 yrs.)
CASCADE	diff = .28 (4%) s.e. = .264 n = 8 nonsignificant	diff = 3.15 (27%) s.e. = 1.667 n = 8 nonsignificant
COASTAL	diff = -.20 s.e. = .633 n = 8 nonsignificant	diff = 2.175 (19%) s.e. = .875 n = 8 significant

Six-year Response of Volume p.a.i.
(cu ft /ac/yr; min. d.b.h. = 1.55 in.)

	Older (24-35 yrs.)	Younger (12-23 yrs.)
CASCADE	diff = 0.5 s.e. = 13.7 n = 8 nonsignificant	diff = 60.5 (18%) s.e. = 31.39 n = 8 nonsignificant
COASTAL	diff = -13.0 s.e. = 41.1 n = 8 nonsignificant	diff = 34.8 (8%) s.e. = 38.6 n = 8 nonsignificant

Table 12.

Results of 1-tailed t-tests for significant (95% confidence level) differences between mean total growth rate of unthinned unfertilized stands and mean total growth rate of unthinned fertilized (200 lb.N/ac) stands for western hemlock (80% hemlock spp.)

Phase I

Six-year Response of Basal Area p.a.i.
(sq ft /ac/yr; min. d.b.h. = 1.55 in)

	Older(24-35 yrs.)	Younger(12-23 yrs.)
CASCADE	diff = 0.12 s.e. = 0.685 n = 14 nonsignificant	diff = 4.3 (37%) s.e. = 0.463 n = 8 significant
COASTAL	diff = -0.47 s.e. = 0.59 n = 23 nonsignificant	diff = -1.14 s.e. = 0.648 n = 14 nonsignificant

Six-year Response of Volume p.a.i.
(cu ft /ac/yr; min. d.b.h. = 1.55 in.)

	Older(24-35 yrs.)	Younger(12-23 yrs.)
CASCADE	diff = 0.7 s.e. = 37.9 n = 14 nonsignificant	diff = 66.5 (25%) s.e. = 16.4 n = 8 significant
COASTAL	diff = -20.3 s.e. = 25.6 n = 23 nonsignificant	diff = 13.0 (3%) s.e. = 51.3 n = 14 nonsignificant

IX PRELIMINARY DATA OF DOUGLAS-FIR AND WESTERN HEMLOCK INSTALLATIONS IN PHASE III OF RFNRP

A total of 23 Douglas-fir installations and 6 western hemlock installations were established in 1975-1976 to supplement the age and site distributions of both Phase I (unthinned) and Phase II (thinned). Rather than adding to what is already a large body of data in the middle of the age and site ranges, these installations are located primarily at either end of the data ranges (i.e. young and old ages; high and low sites).

In addition to standard treatments applied in the first 2 phases, additional Douglas-fir plots received 200 pounds of nitrogen in the form of ammonium nitrate. Also 1 Douglas-fir installation received a delayed treatment of thinning initially followed by 200-pound nitrogen fertilizer application after 2 years. Since the preliminary data reported here are for a 2-year growth period, this installation was combined with the thinned-unfertilized installations for obvious reasons.

The distribution by age and site of 1/10-acre or larger plots, basal area p.a.i., and volume p.a.i. is given in Appendix A. The breakdown of plots by treatment is as follows:

Douglas-fir

- 41 plots - unthinned; no fertilizer
- 27 plots - unthinned; 200-lbs N/A (ammonium nitrate)
- 39 plots - unthinned; 200-lbs N/A (urea)
- 27 plots - unthinned; 400-lbs N/A (urea)
- 14 plots - thinned; no fertilizer
- 15 plots - thinned; 200-lbs N/A (urea)
- 6 plots - thinned; delayed by 2 years 200-lbs N/A (urea)

Western Hemlock

- 12 plots - unthinned; no fertilizer
- 12 plots - unthinned; 200-lbs N (urea)
- 12 plots - thinned; no fertilizer
- 12 plots - thinned; 200-lbs N (urea)

This raw data has not been analyzed in its entirety, especially in light of the short (2-year) period of growth data available here.

X THE CONTRIBUTION OF AN INCREASE IN LOG SIZE TO PROFITABILITY OF FOREST FERTILIZATION

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Graduate Student

The specific objective of this study is to quantify the contribution of an increase in log size to the profitability of forest fertilization, and to compare this to the contribution from an increase in wood yield. For second growth Douglas-fir (the object of this study) it is assumed that the scaling diameter is the most important determinant of log grade. An increase in log size results in higher product values due to an increase in product recovery and grade. Total production costs increase only slightly with an increase in log size.

The data indicates that the increase in log size plays a significant role in the value added from fertilization (Tables 13 and 14; Figure 12). Increases in average mill price ranged from $1.50 to $5.80/MBF higher on plots treated with 200 lb N/acre than the untreated plots, and from $3.00 to $8.50/MBF higher on plots fertilized with 400 lb N/acre. Increased mill prices averaged 25% of the value added at the mill from fertilization from 200 lb N/acre treatments, and 30% of the value added at the mill from the 400 lb N/acre treatments.

Mill value increases from an increase in the value/unit, and an increase in wood yield. Because the increase in total harvesting costs are slight, they are not accounted for in calculating changes in timber value. The result is that the increase in timber value from fertilization is nearly the same as the increase in revenue at the mill. Because of this, the contribution of an increase in log size and an increase in yield to the profitability of fertilization for the plots studied can be compared in columns 2 and 3 of Table 15. It should be noted that the assumed value gain from fertilization is larger than what was found in previous studies. There are two main reasons for this. First, the growth response from fertilization on the plots studied was more than double the average volume response measured on plots of comparable site and age in similar studies. Second, harvesting costs were not deducted from the additional revenues received at the mill.

Many more aspects of this study could be discussed. This study resulted from a sampling of only a few plots of a particular species, age, and site. The extent to which the findings can be applied to other stands remains to be determined.

Figure 12.

Average change in revenue per acre for unfertilized and fertilized plots.
(Based upon data in Table 16)

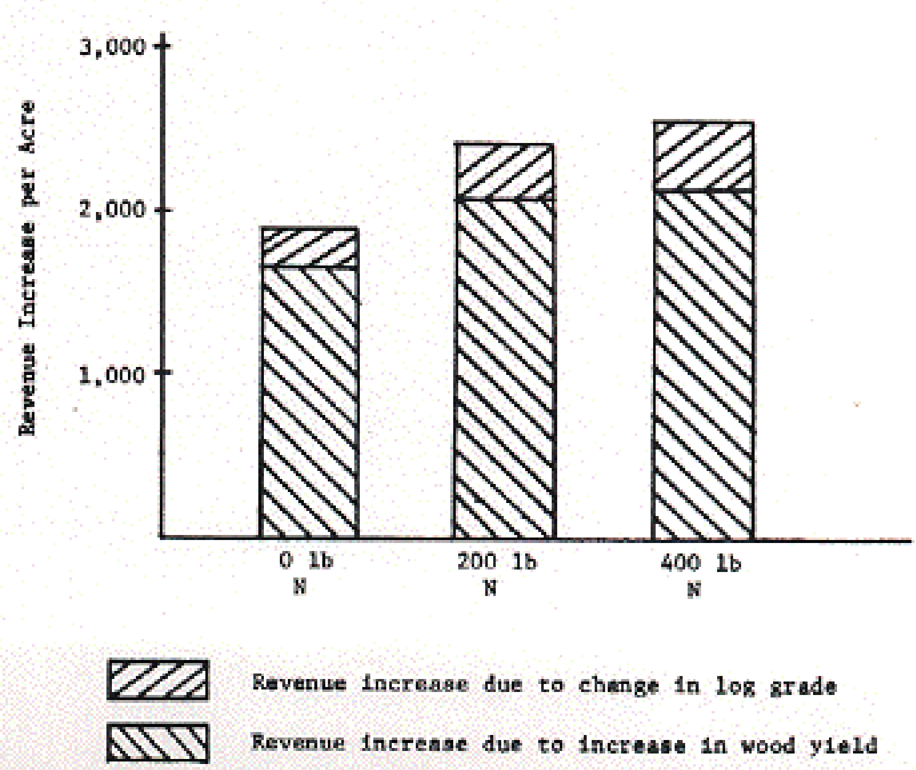

Table 13.

Average Change In Weighted Average Mill Price/MBF in Constant Dollars 1969-1977 for Unfertilized and Fertilized Plots.

	1969 Price	1977 Price	Price Increase 1969-1977	Percent Price Increase
0 lb N	$188.70	$195.00	$ 6.30	3.4
200 lb N	190.40	199.60	9.20	4.8
400 lb N	184.00	196.60	11.60	6.3

Table 14.

Average Revenue Added per Acre at Mill 1969-1977 for Unfertilized and Fertilized Plots.

	Total Increase in Value	Increase Due to Increased Yield	Increase Due to Change in Grade	% Increase Due to Change in Grade
0 lb N	$1,880.00	$1,690.00	$190.00	10.0
200 lb N	2,452.00	2,123.00	320.00	13.4
400 lb N	2,579.00	2,183.00	396.00	15.4

Table 15.

Average Difference In Revenue Added per Acre Between Unfertilized and Fertilized Plots.

	Total $ Difference from 0 lb N/Ac	$ Difference Due to Change in Yield	$ Difference Due to Change in Grade	Change In Grade as % of Total Change
0 lb N	-	-	-	-
200 lb N	$573.00	$432.00	$141.00	24.5%
400 lb N	699.00	492.00	207.00	29.6%

XI INTERIM REPORT ON RFNRP SOILS AND FOREST FLOOR DATA MANAGEMENT

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Introduction

With the establishment of the Regional Forest Nutrition Research Project, a single soil pit was excavated in a representative location at each installation. The soil profile was described using methods given in the USDA-SCS Handbook #18 (1) and samples from each diagnostic horizon were taken for further physical and chemical characterization.

The forest floor of the control plots were also sampled and composited for each installation. Cromer (2) has detailed the sampling procedures, the properties analyzed, and the laboratory techniques that were used for both the soil and litter samples.

At the instigation of this present research the soil and forest floor data existed as two files: the first containing the field description sheets of the soil profiles, and the second containing the analytical data for the soil profile samples, the soil composite samples, and the forest floor samples.

The objectives of this research are to:

1) Create a computer filing system for the storage of all RFNRP soil and forest floor data for Phase I and II installations;

2) To design this computer file so that the soil and litter data can be easily updated, manipulated, and retrieved, and;

3) To design this computer file so that retrieved soil or forest floor data would be in a form compatible with the existing mensuration data and also to the statistical packages used to analyze such data.

Methods

The Scientific Information Retrieval (SIR) Data Management System was chosen as a suitable program package to meet the above objectives. The chief features of the SIR system are:

1) Capability of handling data having inherent hierarchical interrelationships;

2) Data stored in sequential form;

3) A report writer and good interfaces to statistical packages;

4) Powerful data checking and data reformation capabilities.

The initial SIR file compiled contained only carbon and nitrogen data for the soil profile and forest floor of Phase I and II installations. This SIR file is now operational and several of the retrievals of this data will be summarized below.

The second SIR file is presently under compilation. This is an extended version of the initial file and will contain most of the soil profile and forest floor data available for Phase I and II installations. This SIR has the following structure with the installation number as the basic unit of the file.

a) Record Type #1:

Contains general information pertinent to each installation: e.g. installation number, owner, legal description, state, county, province, site class, site index, total stand age, elevation, slope, aspect, and precipitation.

b) Record Type #2:

Contains general information pertinent to the installation's soils; the geology of the parent material, the soil series or name (if known) and the soil classification (if known). This will be updated as more areas of forest soils are summarized.

c) Record Type #3:

Contains the total forest floor data consisting of the total weight, percentage nitrogen and carbon, carbon and nitrogen weights, and the C:N ratio.

d) Record Type #4:

Contains the soil profile physical, chemical, and morphological data by horizon.

Example Selective Data Retrievals

The following is an analysis of the soil profile and forest floor carbon and nitrogen contents of the Phase I and II installations.

For each installation a set of 10 summary variables were created within the SIR file (Table 16).

1. A comparison was made of soil profile and forest floor C and N data between Douglas-fir and western hemlock installations:

Values of each summary variable were pooled for installations of the same species. The means were compared using Student's t-test. Figure 13 is a sample of how these results can be displayed. Only the two C:N ratios were found not to be significantly different between species.

Douglas-fir installations generally have lower amounts of C and N in the soil and the forest floor than do western hemlock installations although the C:N ratios of the soil and litter were not found to differ between the two species.

2. A comparison of soil profile and forest floor C and N data between each Province:

Values of each summary variable were pooled for installations of the same province and the means compared statistically using the Newman-Keuls (SNK) test (Results could be displayed in a manner similar to Figure 13.

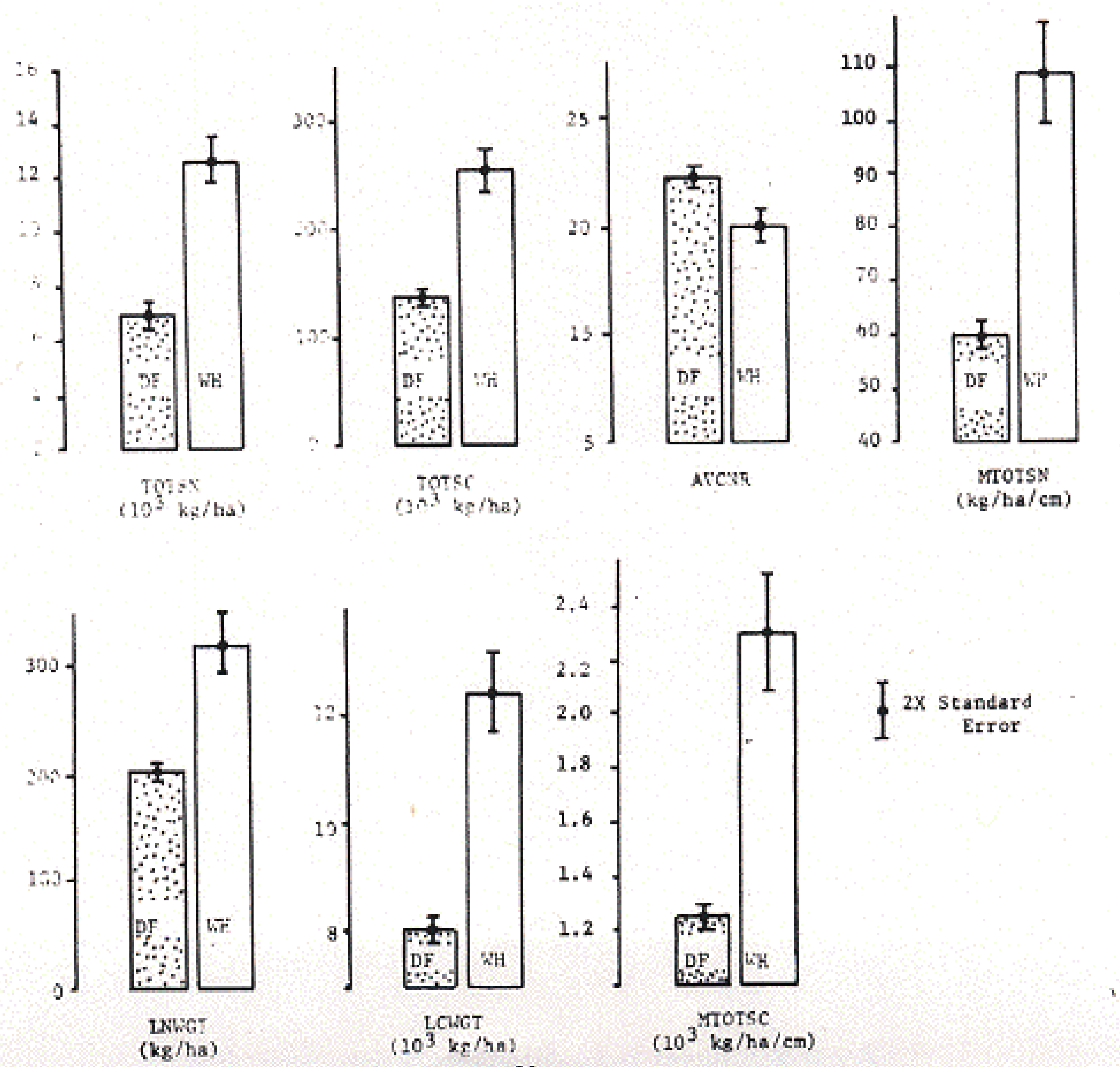
Table 16.

Installation Soil and Forest Floor Summary Variables.

Variable	Value	Unit
LNWGT	Standing litter N weight	Kg Ha^{-1}
LCWGT	Standing litter C weight	Kg Ha^{-1}
LCTONR	Standing litter C:N ratio	Kg Ha^{-1}
TOTSN	Sum of the N weights of the A and B horizons	Kg Ha^{-1}
TOTSC	Sum of the C weights of the A and B horizons	Kg Ha^{-1}
AVCNR	The mean horizon C:N ratio	---
INSTALN	LNWGT + TOTSN	Kg Ha^{-1}
INSTALC	LCWGT + TOTSC	Kg Ha^{-1}
MTOTSN	(TOTSN)/depth of soil profile analyzed	Kg $Ha^{-1}cm^{-1}$
MTOTSN	(TOTSC)/depth of soil profile analyzed	Kg $Ha^{-1}cm^{-1}$

Figure 13

A comparison of soil and forest floor carbon and nitrogen summary variables between Douglas-fir(DF) and western hemlock(WH) installations.



Province I (Puget Lowlands) generally had the lowest C and N variable values except in the case of AVCNR (average soil horizon C:N ratio) where its value was significantly higher than all the other provinces. The western hemlock provinces (III, V and IX) had generally the highest C and N variable values which would be expected from the results of retrieval #1 above.

3. A comparison of soil profile and forest floor C and N data between site classes within species:

The installations were separated by species and then the means of the summary variables within each site class were compared using the SNK test.

Only the Douglas-fir installations were considered because they represented a better distribution of site classes than western hemlock installations. For the Douglas-fir installations none of the litter summary variables (LNWGT, LCWGT, or LCTONR) were significantly different between site classes. MTOTSC was also not significant.

As site class improves, C and N increase in quantity in the soil and forest floor. An aberation does exist however for site class V where C and N values are higher than for site class IV and the mean C:N ratio of site class V installations is low, grouped with the site classes I, II and III. This may be due to the sample size of site class V installations.

Conclusion

The above example retrievals display some of the capability of the SIR Data Management System. Once the full soil and forest floor data is entered into the expanded SIR file more complicated data retrievals will be possible. The SIR files will allow increased accessibility of any of the soil or forest floor data to meet the needs of the co-operators and future research programs.

References

1) Soil Survey Staff. 1951. Soil survey manual. USDA Handbk. #18. U.S. Govt. Printing Office, Washington, D.C.

2) Cromer, R.N. 1974. Early response of unthinned Douglas-fir to urea in western Washington and Oregon. An unpublished report to the Regional Forest Nutrition Research Project; Dr. S.P. Gessel, Principal Investigator.

XII WOOD QUALITY STUDIES IN TWO DOUGLAS-FIR STANDS 12-18 YEARS AFTER THINNING AND FERTILIZER TREATMENTS

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Wood Sciences and Technology

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Graduate Student

Introduction

Two stands of Douglas-fir of different age and site were studied to determine the effects of thinning and fertilizing on several wood quality parameters. Both stands are located in western Washington on Weyerhaeuser Company tree farms. Since these stands provided information for a greater number of years than the oldest RFNRP plots (dating to 1969), Weyerhaeuser Company made them available to project personnel and assisted in the collection of data. Financial support for this project was provided by the Regional Forest Nutrition Research Project and a supplemental grant from the Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service.

The Fuller Hill stand is located near Elma in Grays Harbor County. The initial 50-year site index was 142 feet, a low site I. The stand averaged 35 years old at the start of treatment, a thinning in the autumn of 1961. Designed to test the effects of repeated fertilization on different intensities of thinning, a heavy thinning (to 125 trees per acre) and a light thinning (to 174 trees per acre) were made. The unthinned control was 182 trees per acre. Heavy, light and no thinning had 4 replications on 1/2 acre plots. Half of each plot was fertilized in the spring four times: 1962, 1965, 1969, and 1973. Each application consisted of 200 lbs nitrogen/acre as urea, 44 lbs P_2O_5/acre as Triple Super Phosphate, and 80 lbs K_2O/acre as muriate of potash (respective totals 800, 176, and 320 lbs). Core samples were taken after the 1973 growing season, at which time the stand was approximately 47-years-old and the dominant trees ranged from 15 to 23 inches d.b.h. These samples were taken from each of the four available treatments: control, thinned only, fertilized only, and thinned and fertilized, symbolized respectively by C, T, F, and TF.

The Yacolt stand is located near Yacolt in Clark County. The initial 50-year site index was 116 feet, on the borderline between sites II and III. Younger than the Fuller Hill stand, it averaged 19-years-old at the time of initial thinning in 1954. The study was intended to stimulate seed production by intensive fertilization on widely-spaced trees, and the thinning brought the stocking level down to 70 trees per acre. The entire stand was thinned to this level, and only T and TF plots are available. Again with 4 replications per treatment, one treatment was fertilized annually with 100 lbs N as ammonium nitrate and 88 lbs P_2O_5 as TSP per acre in 1955-1957, 100 lbs N/acre in 1960-1964, and 200 lbs N/acre in 1965-1969 (totaling 1800 lbs N and 264 lbs P_2O_5). This treatment is hereinafter referred to as 1NTF. Another treatment received 200 lbs N and 88 lbs P_2O_5 per acre in 1955-1957, and 200 lbs N in 1960-1964 (totaling 1600 lbs N and 264 lbs P_2O_5). This treatment is hereinafter referred to as 2NTF. Core samples were again taken in 1973, at which time the stand was approximately 38-years-old and the trees ranged from 16 to 22 inches d.b.h.

In each location, seven trees were sampled from each treatment with a 12 mm increment borer, two cores from opposite sides at breast height. The wood characteristics which were assessed were specific gravity, percent lignin content, radial growth rate, unit ring yield (grams of wood per square centimeter of cambial area), and percent latewood. These parameters were measured 12 years prior to treatment for Fuller Hill, and 6 years prior to treatment for the younger Yacolt stand.

One-way analysis of variance was used to test for differences between plot averages, both before and after treatment. Duncan's multiple-range test was used to rank plot curves according to similarity. Table B-1 (Appendix B) lists the variable averages and their ranking, both before and after treatment, and the statistical significance between averages.

Results of Analysis

1. Fuller Hill:

At Fuller Hill, all treatments were not statistically similar for the years before treatment. However, for most variables, the differences were not great and in most cases control pretreatment was equivalent to two or three of the other treatments at the 95 percent confidence level.

Specific gravity is noticeably lower in the TF group prior to treatment. Nonetheless, it appears to have decreased more after treatment relative to the other trends (Figure 14). The TF group also shows a distinctly higher percent lignin content in Figure 15, as well as greater annual radial increment (Figure 16). Unit ring yield is generally higher in the TF group (Figure 17); however, the T group appears to be noticeably on the upswing since the second fertilizer application. Figure 18 does not depict any real difference in trends of percent latewood among the four treatments.

Following the initial treatment in 1961, control trees normally exhibited the highest specific gravity, and the lowest lignin content, radial increment, and unit ring yield. Fertilizer-only seems to have had a greater impact on reducing specific gravity than did thinning-only. The initial advantage of fertilizer-only over thinning-only in radial increment (and the closely-related unit ring yield) seemed to reverse about seven years after treatment, perhaps indicating a full utilization of growing space in the unthinned fertilized stand.

2. Yacolt:

At the 95 percent confidence level, there were no significant differences between plots before treatment for any of the variables except latewood percent, which, as in the case of Fuller Hill, exhibits wide variability. It should be remembered that all Yacolt plots were thinned.

Figure 15. Fuller Hill Stand

Percent Lignin Content

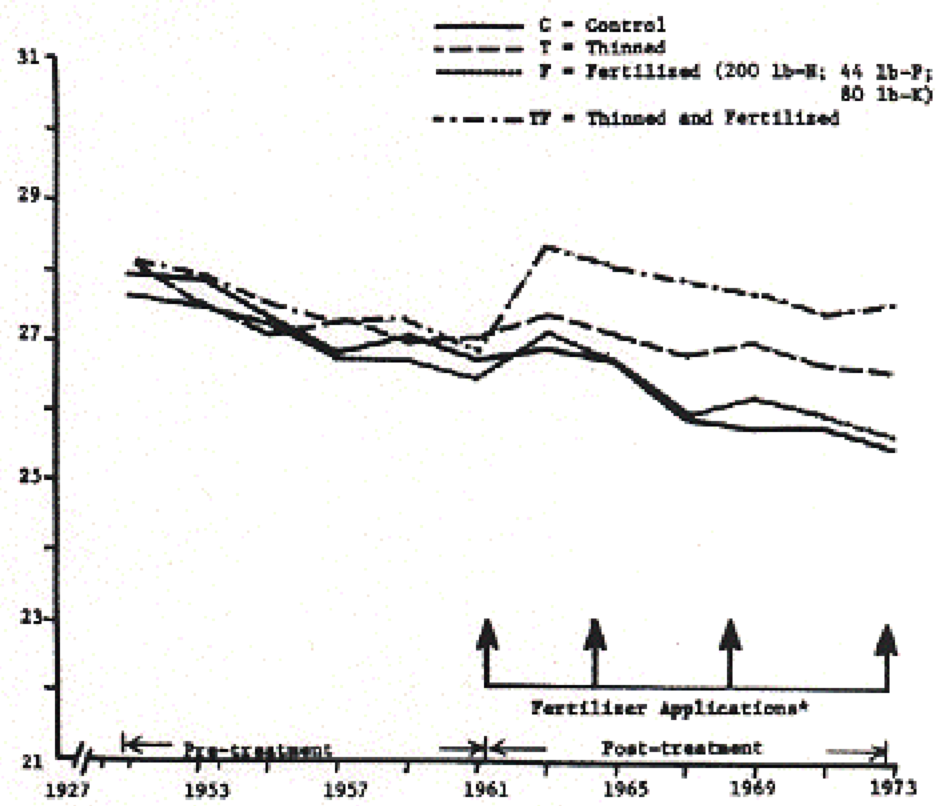


Figure 14. Fuller Hill Stand

Specific Gravity (O.D. wt.--Green vol.)

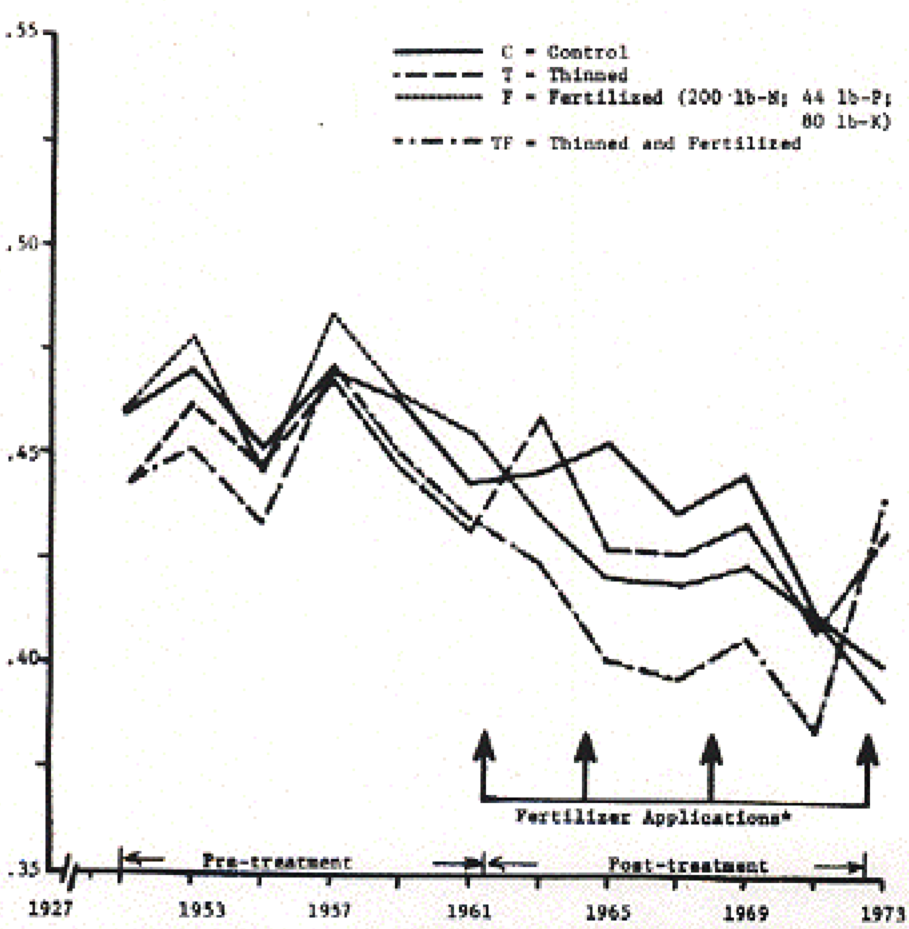


Figure 16. Fuller Hill Stand

Annual Radial Increment (millimeters)

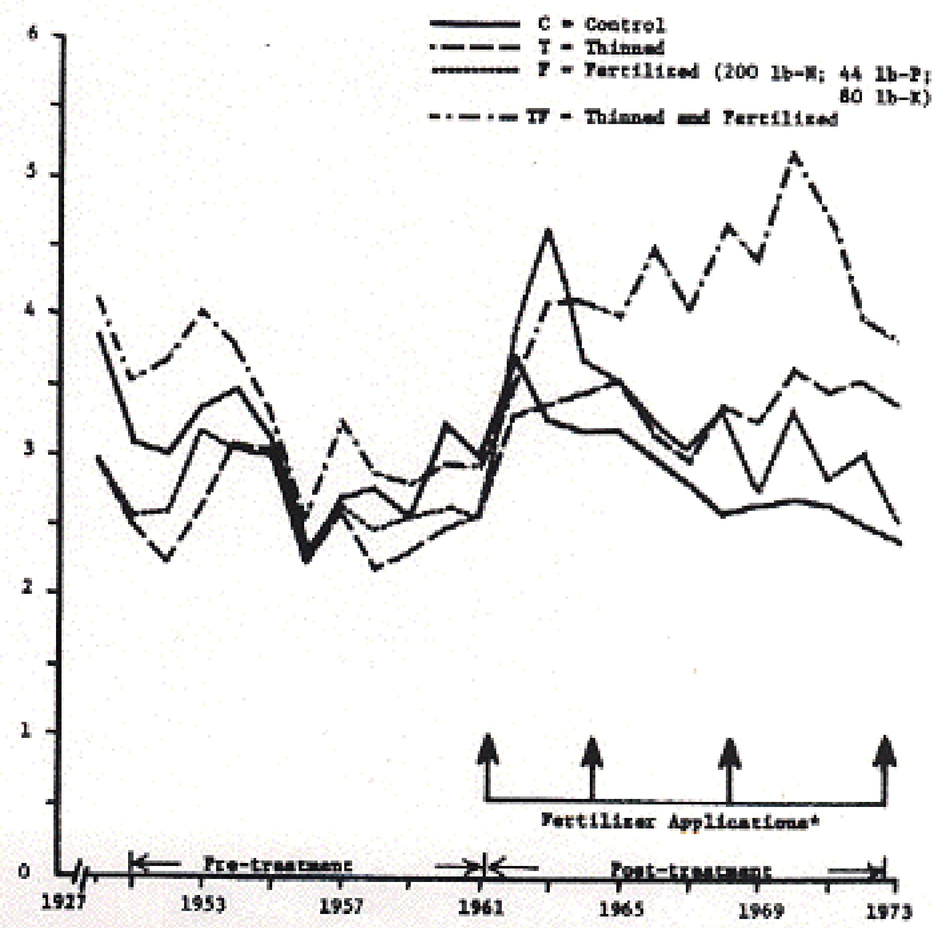


Figure 17. Fuller Hill Stand

Unit Ring Yield
(gm/sq cm, Cambial Area)

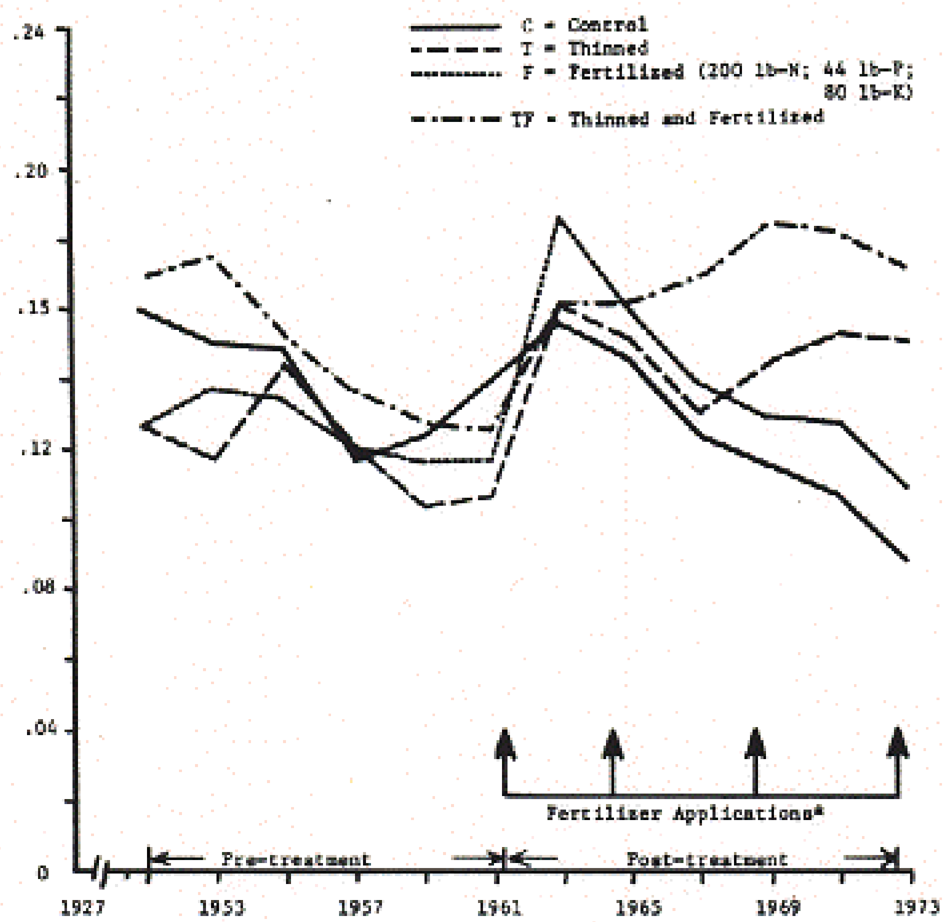
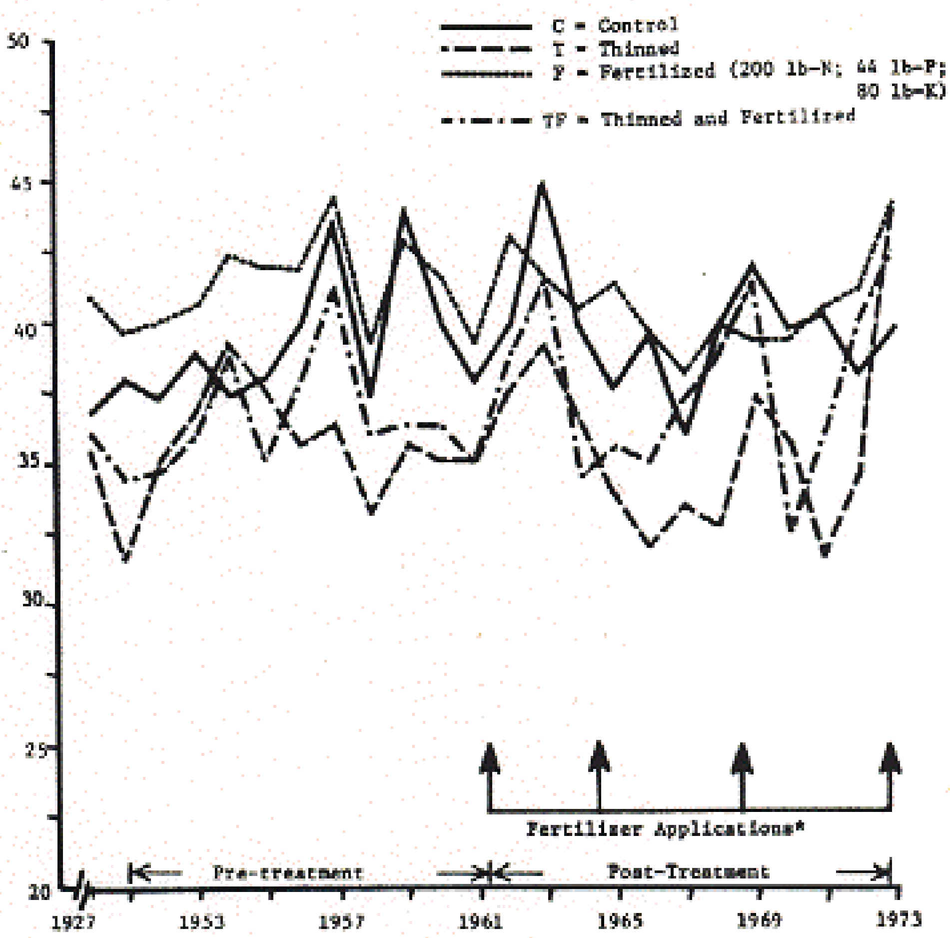


Figure 18. Fuller Hill Stand

Percent Latewood



Specific gravity is again lowest in the fertilized plots, although all trees showed increases following initial treatment (Figure 19). The wood density values before treatment were higher at Fuller Hill than at Yacolt (0.455 vs 0.397), but the latter area was a younger stand in which the data represent wood which was still clearly in the juvenile stage, aged 5-10 years. After treatment, the densities became more nearly alike (0.423 vs 0.430), because all the Fuller Hill values were declining and the Yacolt values were increasing, partly due to the relative ages of the trees.

As with Fuller Hill, the Yacolt installation exhibited higher percent lignin contents with the fertilizer-thinning combinations than with thinning alone (Figure 20). The observation that lignin content is consistently about two percentage points higher at Yacolt seems again to be due to the age factor. As with specific gravity, it is difficult to decide whether there is much difference between the Yacolt 1NTF and 2NTF treatments. A complicating factor of indeterminate consequence is the unusually wide spacing and, hence, open-grown nature of the Yacolt installation (70 trees per acre).

The Yacolt area likewise obtained higher annual increments with fertilizer than without (Figure 21). The advantage of the initially heavier fertilization is apparent, although cessation of heavy N fertilization coincided with a pronounced decline and attainment of virtually the same level of radial growth as the initially lighter fertilizer application.

Figure 19. Yacolt Stand

Specific Gravity
(O.D. wt.--Green vol.)

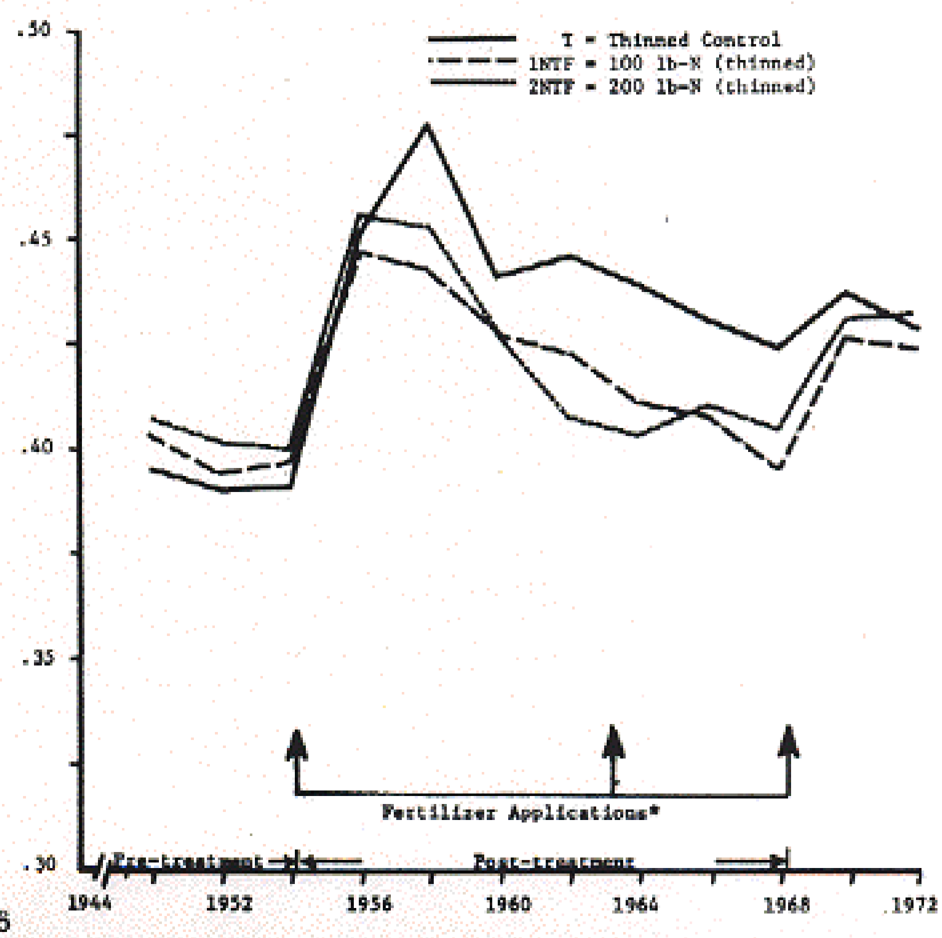


Figure 20. Yacolt Stand

Percent Lignin Content

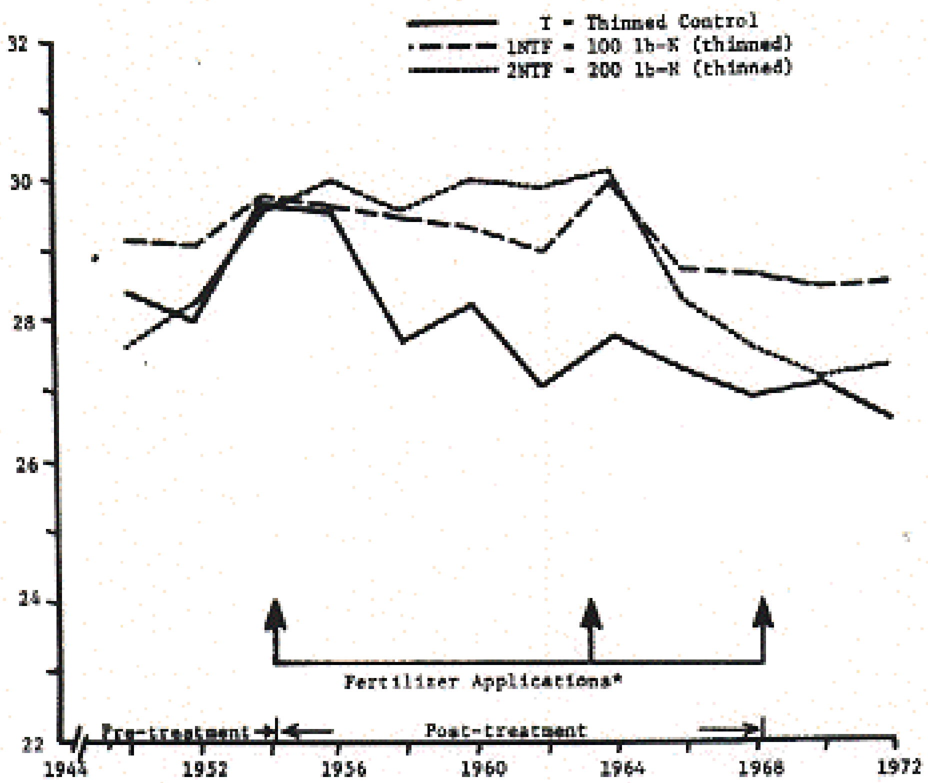
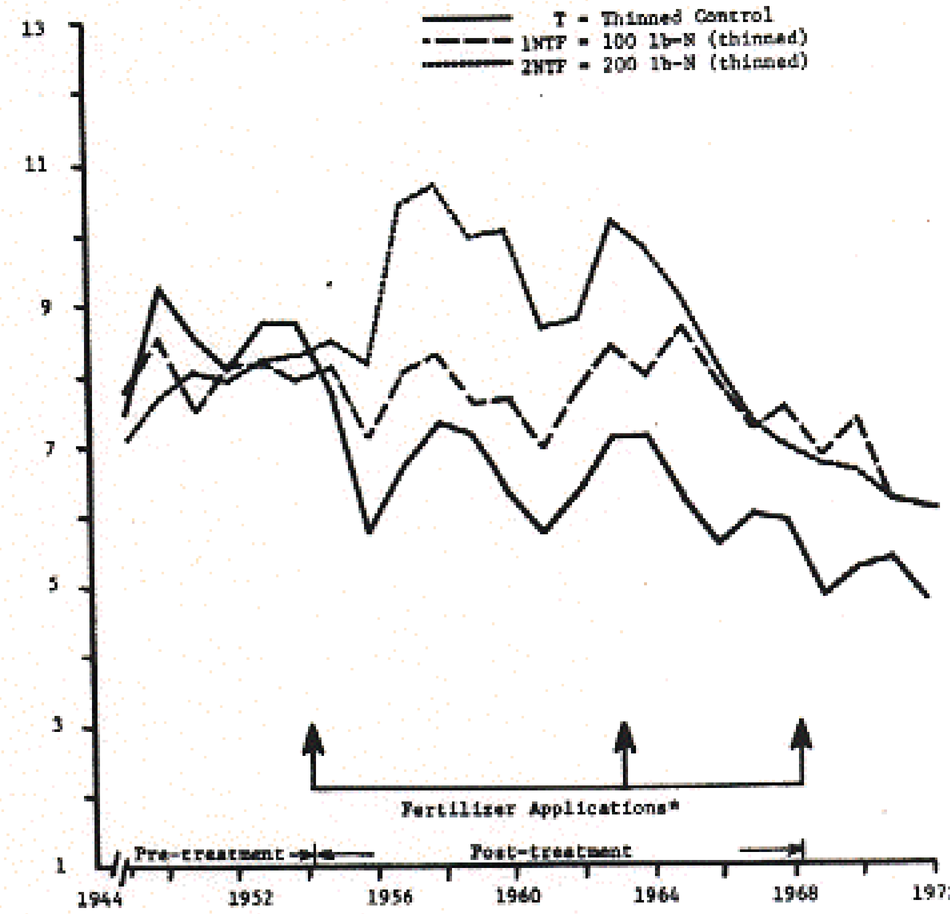


Figure 21. Yacolt Stand

Annual Radial Increment
(millimeters)



Yacolt was quite different from Fuller Hill in the magnitude of radial growth rates. Growth was 2.8 times greater at Yacolt before treatment, again an expected phenomenon due to the very young age of the Yacolt trees at that time. The overall decline of the Yacolt increments is perhaps due to little more than the progression toward a mature growth-rate equilibrium. Significantly, the older, higher site Fuller Hill installation, that had been in general decline of radial growth prior to treatment, has subsequently leveled off in control and rebounded in treated plots. As with Fuller Hill, growth rate was the dominant factor in unit-ring yield at Yacolt (Figure 22) and the trends are hence very much like those of annual radial increment.

At Yacolt, the T and 1NTF plots increased in latewood by 6.7 and 6.2 percentage points respectively, but the initially-heavy fertilized plots, 2NTF, did not change on the average. This may have been a consequence of the much faster growth rate exhibited by this treatment during the initial heavy fertilizing period, which also coincides with the period of lowest latewood percent (Figure 23).

By way of comparison, the percent latewood values were higher at Fuller Hill than at Yacolt both before (38.2 vs 22.4) and after treatments began (38.6 vs 26.7). This is probably a consequence of the age difference in part, but it can by hypothesized that, as with variability in

Figure 22. Yacolt Stand

Unit Ring Yield
(gm/sq cm, Cambial Area)

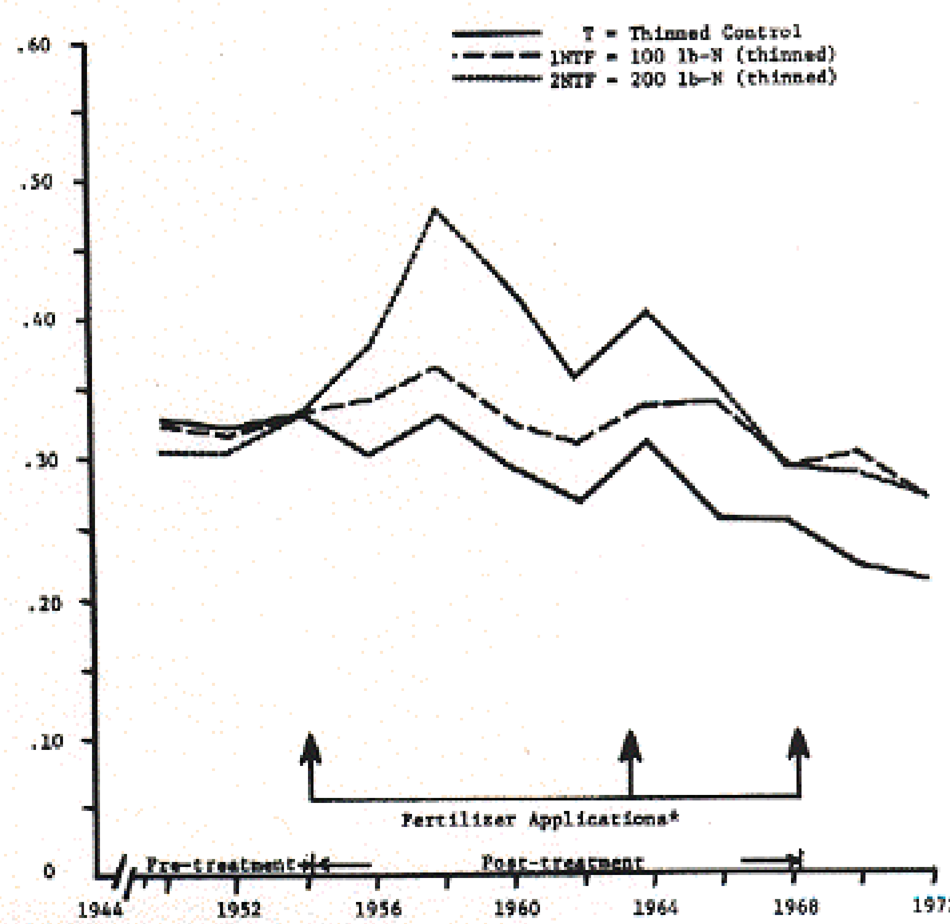
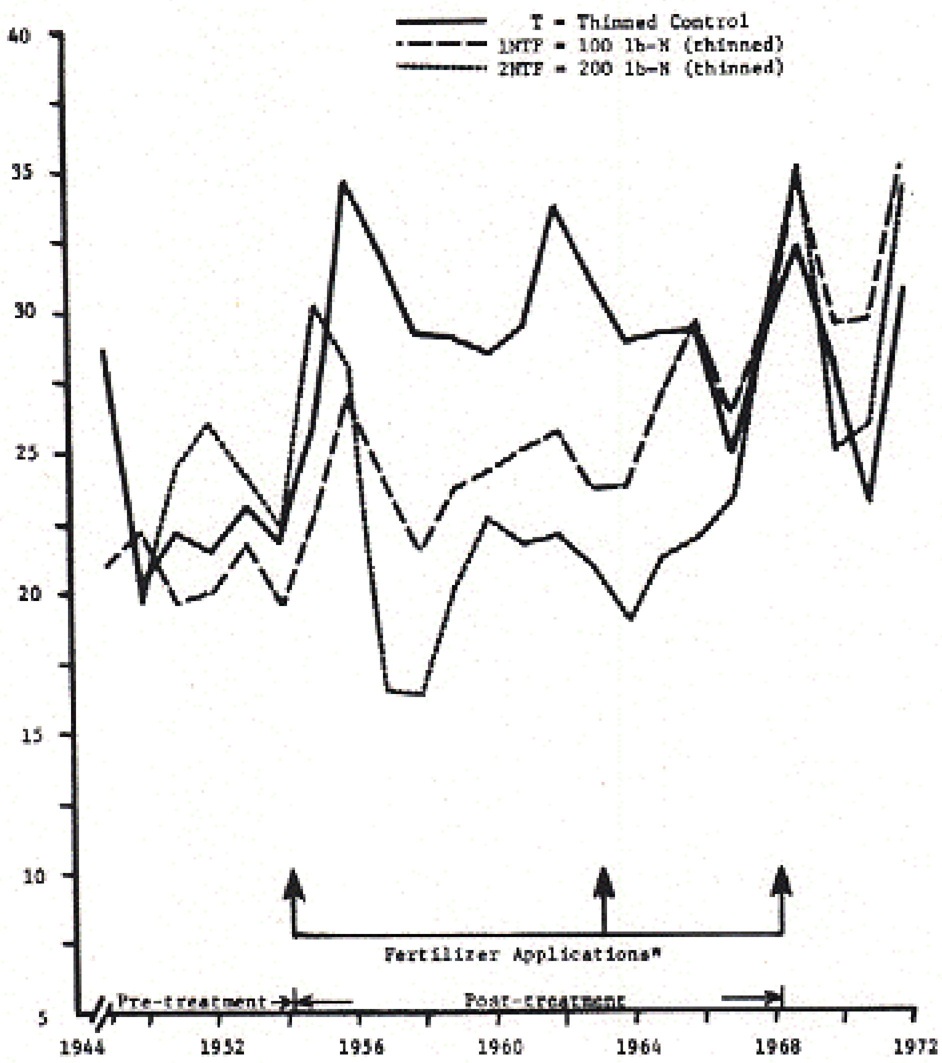


Figure 23. Yacolt Stand

Percent Latewood



the other parameters, these differences are also due to such factors as site index, stand density, soil characteristics, inherent family variability, and myriad environmental factors. Therefore, it is difficult to directly compare the two areas.

Conclusions

The thinned-fertilized plots in both areas produced wood of lowest specific gravity, but when fertilization was stopped, specific gravity usually recovered slightly.

Lignin content was lowest in control and fertilized plots, in the older stand, higher in the thinned plots, and highest in the thinned-fertilized plots of both stands by 1.5 to 1.7%. With cessation of fertilization, lignin content soon decreased to near that of thinned plots. In the younger, faster-growing stand, lignin was nearly 2% higher than in the older stand.

In both areas, growth rate was greatest in the thinned-fertilized plots. In the older high-site stand, both thinning and fertilization caused greater radial increment for about 6 years, after which the thinned plots maintained better growth than did the fertilized-only plots.

Latewood percent was different in the two areas and even maximum treatment caused some increase only in the younger stand.

Consideration of tree age, site characteristics, and stand density are necessary for comparing and assessing treatment effects.

Financial support for this project was supplied by the Regional Forest Nutrition Research Project, University of Washington, Seattle, WA, and by the PNW For. and Rg. Exp. Sta., USFS, Portland, OR.

XIII SHARING OF RFNRP DATA BANK; WEYERHAEUSER-RFNRP FERTILIZER RESPONSE ANALYSIS

The Regional Forest Nutrition Research Project has developed over the past decade an extensive data bank on stocking, growth, and response to fertilizer and thinning. From time to time RFNRP has been asked to share these data with cooperating landowners and other researchers. Such requests have generally been for small amounts of data, such as growth of an installation or two. These have been reviewed on an individual basis and generally the requests have been granted.

As this data bank matures, however, its value increases enormously. Today it is probably the largest single source of information on growth and yield of young Douglas-fir and western hemlock. Because of this increasing value, the College of Forest Resources Advisory Committee has promulgated the following policy concerning use and availability of the RFNRP data bank.

1. Any cooperator can have access to data from his own plots. If a significant cost is involved he will reimburse the Project.

2. Access to data from other cooperator's plots will be permitted only if:

   a) Anonymity of ownership is maintained.

   b) Specifics (legal description) of location are not provided. General locational information (e.g. province) will be provided.

3. Any individual organization requesting access to the general Project data bank must provide a description as to how the data will be used, i.e., the questions to be examined, the analytical techniques to be employed, and the extent and magnitude of other data to be used in addition to Project data.

4. No one will be permitted access to the general Project data bank unless results and conclusions of subsequent analyses are shared with Project mensurationists, and ultimately with all cooperators.

   a) Shared results and conclusions may be general in nature, i.e., it may not be necessary to provide precise details of all results; however, shared results and conclusions must be substantive.

   b) The nature and extent of shared results and conclusions will be negotiated prior to release of Project data. A memorandum of understanding will be drawn up and signed.

The general intent of this policy is to further the goal of gaining more knowledge through cooperation than any one cooperator could reasonably obtain alone; similarly if any one cooperator is to gain more through special use of the entire body of data, the intent of this policy is to obtain some benefit to all cooperators from the use made of their data.

One of the cooperating organizations which requested and received some of the RFNRP data was the Weyerhaeuser Company. Their report on this data follows.

COMBINED WEYERHAEUSER / RFNRP
FERTILIZER RESPONSE ANALYSIS

STEVE WEBSTER - Soil Scientist

PETER FARNUM - Biometrician

This analysis of the Regional Forest Nutrition Research Project Phase I data was divided into three parts. Primary emphasis was placed on combining this data with similar data from Weyerhaeuser's empirical fertilizer trials to better define the shape of the gross volume response vs. nitrogen dosage curve. Before this analysis was done, two preliminary studies were completed to compare plot summary routines and statistical models applied to the same data set.

The tree detail information (diameters and subsample of heights) from the 4-year RFNRP data was summarized into plot average statistics using two different routines. The RFNRP routine is based on a tariff system while the Weyerhaeuser routine involves fitting a local height-dbh curve to each plot and calculating volumes with a regional volume equation. The mean paired difference in 4-year gross volume growth for all plots was 2.15 ± 1.29 cu ft/ac/yr (.15 ± .09 m^3/ha/yr) which was not statistically different from zero. Regression equations describing gross volume growth on control plots as a function of age, site, and basal area were not significantly different when fit on the two data sets.

Again using the 4-year RFNRP data (summarized by the RFNRP method) a test was made for differences in mean response estimates (averaged over all ages and sites) when these estimates were calculated from different statistical models. The RFNRP model is described in the 4-year biennial report. The Weyerhaeuser model differs in two ways. First a non-linear asymptotic function is assumed to describe the response-dosage relationship with the level of the asymptote given by multiplicative interaction of stand characteristics (age, site, etc.). Second, dummy (zero or one) variables are used to estimate a block effect for each installation.

Response estimates calculated from these two models were not significantly different as indicated below:

	Response	
Dosage	Weyerhaeuser Model	RFNRP Model
200 lb N/ac	310 ± 19 cu ft/ac/5 yrs	293 ± 29 cu ft/ac/5 yrs
(224 kg N/ha)	(21.7 ± 1.3 m^3/ha/5 yrs)	(20.5 ± 2.0 m^3/ha/5 yrs)
400 lb N/ac	319 ± 17 cu ft/ac/5 yrs	307 ± 27 cu ft/ac/5 yrs
(448 kg N/ha)	(22.3 ± 1.2 m^3/ha/5 yrs)	(21.5 ± 1.9 m^3/ha/5 yrs)

In a similar manner both models indicated that response changed significantly with site index for the 4-year data. The RFNRP model suggested response decreased linearly with increasing site index while the Weyerhaeuser model indicated response varied according to the following relation (in metric):

$$\left(\frac{50.3 - SI}{6.1}\right)^{.8}$$

These two relations are not substantially different.

The major difference between these two statistical approaches was not in the point estimates they generated but in the inclusion of the block effect in the Weyerhaeuser analysis which reduced the residual variance unexplained by the model. The residual standard error in the RFNRP model was ± 300 cu ft/ac/5 yrs (± 21 m^3/ha/5 yrs) while the residual standard error in the Weyerhaeuser model on the same data was ± 186 cu ft/ac/5 yrs (± 13 m^3/ha/5 yrs).

The third part of the analysis involved combining the RFNRP data with Weyerhaeuser's own empirical fertilizer data set. Like the RFNRP data, Weyerhaeuser's data was from well-stocked natural Douglas-fir stands. Each installation consisted of four plots receiving either 0, 100, 300, or 500 lb N/ac (0, 112, 336, or 560 kg N/ha). Thus there was no replication within an installation. The Weyerhaeuser data had a slightly wider distribution of plots by age than did the RFNRP data.

Results of this analysis generally confirmed results published in the RFNRP 1974-76 biennial report. Response generally increases with dosage until it approaches an asymptote. Many different asymptotic models were tried and little difference was found between them. The level of the asymptote changes in an approximate linear relation with site index. No effect of stand age on the level of this asymptote was found.

BUDGET SUMMARY

Expenditures all phases from Project initiation to June 30, 1980.

Fiscal Year	Salaries, Benefits, Overhead	Travel	Supplies, Equipment, Contractual Services	Annual Total	Cumulative Total
69-70	$ 57,296.52	$17,179.92	$10,580.33	$ 85,056.77	$ 85,056.77
70-71	77,052.25	18,052.08	5,663.31	100,767.64	185,824.41
71-72	69,875.49	12,680.81	10,339.28	92,895.58	278,719.99
72-73	68,945.49	14,581.74	9,016.18	92,543.41	371,263.40
73-74	67,002.83	19,731.71	9,628.02	96,362.56	467,625.96
74-75	122,735.47	16,123.71	15,951.16	154,810.34*	622,436.30
75-76	114,786.86	23,355.79	16,957.83	155,100.48	777,536.78
76-77	69,623.56	19,154.61	22,843.42	111,621.59**	889,158.37
77-78	124,438.34	33,071.33	16,997.31	174,506.98	1,063,665.35
78-79	135,525.93	34,826.34	25,437.35	195,789.62	1,259,454.97
79-80	151,065.41	31,614.70	40,649.71	223,329.82	
				Eleven-year Total:	$1,482,784.79

*Initiation Phase III

**During F.Y. 76-77 it was possible to shift certain project personnel to other budgets for supplemental studies.

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This list has been compiled to keep our cooperators more informed about the research that has been generated by this Project. Included in this list are publications and reports that are direct products of Project personnel, and those which are results of research using the Project data base.

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APPENDICES

Appendix A - Mensurational Studies

All tables pertain to Douglas-fir unless otherwise noted.

<u>Tables</u>

Table A-1.

Distribution of 1/10-acre plots for 8-year total gross response analysis of unthinned Douglas-fir; 392 plots.

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
10	0	2	3	1	-
	200	2	2	-	-
	400	2	1	1	-
20	0	3	12	10	1
	200	4	15	8	2
	400	1	10	13	-
30	0	11	19	11	5
	200	12	14	11	8
	400	14	12	16	7
40	0	4	14	12	6
	200	2	20	14	7
	400	2	21	10	5
50	0	2	8	3	2
	200	2	4	5	3
	400	2	3	8	-

Table A-2.

Observed mean 8-year gross total basal area growth for unthinned Douglas-fir.
(square feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	12.3	9.7	9.1	-
	200	14.0	14.9	-	-
	400	13.2	16.0	13.8	-
20	0	8.3	7.2	7.9	9.9
	200	9.9	8.2	10.4	9.8
	400	7.1	9.0	10.2	-
30	0	5.9	6.4	5.5	6.8
	200	7.1	7.3	7.0	8.9
	400	7.2	7.7	7.6	9.2
40	0	6.1	5.2	4.9	5.5
	200	6.7	5.9	5.8	7.4
	400	4.5	6.5	5.9	6.9
50	0	6.9	5.1	3.5	4.8
	200	7.3	6.3	4.9	5.5
	400	6.5	6.5	5.6	-

Table A-3.

Observed mean 8-year gross total volume growth for unthinned Douglas-fir.
(cubic feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	324.5	246.7	118.0	-
	200	340.0	233.5	-	-
	400	406.5	280.0	209.0	-
20	0	357.0	336.7	317.0	300.0
	200	390.3	389.6	386.9	342.5
	400	404.0	425.7	365.2	-
30	0	378.3	378.1	280.5	260.0
	200	433.4	419.6	335.5	323.3
	400	424.7	422.8	361.8	347.9
40	0	433.0	354.6	276.3	229.3
	200	455.0	377.8	330.7	315.1
	400	351.0	410.3	338.1	320.0
50	0	360.5	367.8	215.3	227.5
	200	376.0	423.3	301.0	248.3
	400	340.0	468.3	341.6	-

Table A-4.

Distribution of 1/10-acre plots for 8-year merchantable gross response analysis of unthinned Douglas-fir; 377 plots.

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
10	0	2	-	-	-
	200	-	-	-	-
	400	2	-	-	-
20	0	3	13	9	1
	200	4	15	8	1
	400	1	10	11	-
30	0	11	20	12	5
	200	12	14	11	7
	400	14	12	16	7
40	0	4	14	12	6
	200	2	19	14	7
	400	2	21	10	5
50	0	2	8	3	2
	200	2	4	5	3
	400	2	3	8	-

Table A-5.

Observed mean 8-year gross merchantable (without ingrowth) volume growth for unthinned Douglas-fir.
(cubic feet/acre/year; minimum d.b.h. = 6.55 inches to a 4-inch top)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	185.5	-	-	-
	200	-	-	-	-
	400	338.5	-	-	-
20	0	287.0	253.9	163.0	154.0
	200	321.8	285.9	228.3	129.0
	400	372.0	314.9	203.9	-
30	0	357.3	344.2	244.5	168.0
	200	411.3	380.2	295.7	237.4
	400	405.1	373.3	301.9	257.7
40	0	412.5	340.0	247.1	154.5
	200	441.0	362.6	305.3	217.9
	400	339.5	394.3	318.5	230.6
50	0	347.5	350.8	204.3	167.0
	200	362.0	407.8	285.4	200.7
	400	330.0	448.7	326.6	-

Table A-6.

Distribution of 1/10-acre plots for 6-year total gross response analysis of thinned Douglas-fir; 194 plots.

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
15	0	-	5	3	2
	200	2	3	4	3
	400	-	4	6	2
25	0	3	7	4	3
	200	3	8	4	2
	400	3	10	4	2
35	0	4	7	9	4
	200	5	6	7	2
	400	4	8	7	2
45	0	-	7	6	1
	200	-	5	8	-
	400	-	7	5	3

Table A-7.

Observed mean 6-year gross total basal area growth for thinned Douglas-fir.
(square feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
15	0	-	10.2	8.7	6.0
	200	10.6	13.3	11.9	10.1
	400	-	12.3	12.7	10.8
25	0	6.8	9.1	7.0	7.3
	200	9.2	9.4	9.4	8.9
	400	8.3	9.8	11.1	9.9
35	0	6.1	5.6	6.0	6.2
	200	6.7	6.8	7.9	8.0
	400	7.3	7.3	7.8	9.1
45	0	-	4.2	4.5	5.5
	200	-	6.1	5.3	-
	400	-	5.7	6.2	6.3

Table A-8.

Observed mean 6-year gross total volume growth for thinned Douglas-fir.
(cubic feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
15	0	-	335.6	207.3	122.5
	200	386.5	352.0	284.8	223.3
	400	-	398.5	301.5	256.0
25	0	342.0	361.0	293.5	182.3
	200	443.3	402.3	374.0	268.0
	400	397.0	398.9	438.5	220.0
35	0	340.0	291.0	271.8	248.0
	200	397.0	321.5	333.7	319.0
	400	399.5	351.6	326.7	370.0
45	0	-	240.4	229.3	224.0
	200	-	363.2	264.6	-
	400	-	325.6	308.6	259.0

Table A-10.

Observed mean 6-year gross merchantable (without ingrowth) volume growth for thinned Douglas-fir. (cubic feet/acre/year; minimum d.b.h. = 6.55 inches to a 4-inch top)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
15	0	-	335.0	-	-
	200	364.5	163.0	-	-
	400	-	399.5	-	-
25	0	322.7	310.9	235.3	-
	200	425.0	361.2	292.3	-
	400	385.3	358.2	294.5	-
35	0	331.3	281.3	254.9	193.3
	200	384.2	313.0	303.1	267.5
	400	388.8	342.1	299.9	348.0
45	0	-	233.6	218.7	152.5
	200	-	353.4	256.4	-
	400	-	316.0	296.0	239.7

Table A-9.

Distribution of 1/10-acre plots for 6-year merchantable gross response analysis of thinned Douglas-fir; 160 plots.

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
15	0	-	2	-	-
	200	2	1	-	-
	400	-	2	-	-
25	0	3	7	4	-
	200	3	9	3	-
	400	3	10	4	-
35	0	4	7	9	3
	200	5	6	7	2
	400	4	8	7	2
45	0	-	7	6	2
	200	-	5	8	-
	400	-	7	5	3

Table A-11a.

Distribution of Phase III 1/10-acre plots for 2-year total gross response analysis of unthinned Douglas-fir. (134 plots)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
10	0	4	4	3	-
	200*	-	-	-	-
	200	6	3	2	-
	400	-	-	-	-
20	0	1	3	3	-
	200*	-	5	1	-
	200	1	3	1	1
	400	2	2	1	-
30	0	-	1	2	2
	200*	-	-	2	2
	200	-	-	3	2
	400	-	1	2	2
40	0	-	1	3	7
	200*	-	-	4	3
	200	-	-	2	7
	400	-	-	2	8
50	0	-	-	3	4
	200*	-	1	1	8
	200	-	2	-	6
	400	-	1	1	5

*nitrogen source is ammonium nitrate.

Table A-11b.

Distribution of Phase III 1/10-acre plots for 2-year total gross response analysis of thinned Douglas-fir. (35 plots)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS			
		I	II	III	IV
10	0	8	7	2	-
	200	6	6	1	-
20	0	-	1	-	2
	200	-	-	-	2

Table A-12a.

Observed mean gross total basal area growth for unthinned Douglas-fir in Phase III.
(square feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	13.2	15.0	13.8	-
	200*	-	-	-	-
	200	15.9	19.8	22.3	-
	400	-	-	-	-
20	0	8.4	11.6	8.5	-
	200*	-	13.0	12.1	-
	200	10.6	11.8	11.7	11.3
	400	10.9	13.9	10.7	-
30	0	-	9.0	9.6	8.0
	200*	-	-	11.1	9.9
	200	-	-	12.1	8.0
	400	-	10.4	9.7	12.2
40	0	-	8.8	4.9	4.2
	200*	-	-	8.4	6.0
	200	-	-	8.5	7.1
	400	-	-	8.8	8.0
50	0	-	-	5.5	5.4
	200*	-	5.9	6.0	7.5
	200	-	7.0	-	6.8
	400	-	8.0	6.3	7.6

*nitrogen source is ammonium nitrate.

Table A-13a.

Observed mean gross total volume growth for unthinned Douglas-fir in Phase III.
(cubic feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	265.5	240.0	174.7	-
	200*	-	-	-	-
	200	293.8	309.3	314.0	-
	400	-	-	-	-
20	0	275.0	346.7	218.3	-
	200*	-	387.4	307.0	-
	200	327.0	364.3	294.0	244.0
	400	347.5	407.0	305.0	-
30	0	-	294.0	279.0	202.0
	200*	-	-	333.5	278.5
	200	-	-	358.7	221.5
	400	-	-	338.0	246.3
40	0	-	334.0	176.3	123.6
	200*	-	-	308.8	182.3
	200	-	-	309.5	227.7
	400	-	-	338.0	246.3
50	0	-	-	227.3	153.3
	200*	-	286.0	243.0	230.5
	200	-	323.0	-	207.8
	400	-	355.0	272.0	231.8

*nitrogen source is ammonium nitrate.

Table A-12b.

Observed mean gross total basal area growth for thinned Douglas-fir in Phase III.
(square feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	11.7	8.9	7.2	-
	200	13.2	10.4	12.6	-
20	0	-	6.6	-	4.1
	200	-	-	-	7.4

Table A-13b.

Observed mean gross total volume growth for thinned Douglas-fir in Phase III.
(cubic feet/acre/year; minimum d.b.h. = 1.55 inches)

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	50-year SITE CLASS I	II	III	IV
		P.A.I.	P.A.I.	P.A.I.	P.A.I.
10	0	238.3	156.6	118.5	-
	200	269.5	178.3	219.0	-
20	0	-	130.0	-	96.0
	200	-	-	-	180.5

Table 14a.

Distribution of Phase III 1/10-acre plots for 2-year total gross response analysis of unthinned western hemlock (24 plots).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I	II	III	IV
10	0	-	1	1	-
	200	-	-	1	-
20	0	2	4	1	2
	200	4	1	4	1
30	0	-	-	-	1
	200	-	-	-	1

Table 15a.

Observed mean gross total basal area growth for unthinned western hemlock in Phase III (sq ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
10	0	-	22	21	-
	200	-	-	21	-
20	0	13.4	14.7	17.1	15.4
	200	15.2	15.2	18.8	13.9
30	0	-	-	-	12.7
	200	-	-	-	15.7

Table 14b.

Distribution of Phase III 1/10-acre plots for 2-year total gross response analysis of thinned western hemlock (24 plots).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I	II	III	IV
20	0	4	1	4	3
	200	2	3	3	3
30	0	-	-	-	-
	200	-	-	-	-

Table 15b.

Observed mean gross total basal area growth for thinned western hemlock in Phase III (sq ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
20	0	9.6	14.1	9.0	6.4
	200	11.7	11.2	10.6	8.2
30	0	-	-	-	-
	200	-	-	-	5.8

Table 16a.

Observed mean gross total volume growth for unthinned western hemlock in Phase III (cu ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
10	0	-	307.0	361.0	-
	200	-	-	369.0	-
20	0	355.0	369.5	270.0	260.0
	200	398.2	369.0	351.0	294.0
30	0	-	-	-	237.0
	200	-	-	-	284.0

Table 16b.

Observed mean gross total volume growth for thinned western hemlock in Phase III (cu ft/ac/yr; min. d.b.h. = 1.55 inches).

B.H. AGE CLASS (yrs.)	TREATMENT (Pounds of N per acre)	100-year SITE CLASS I P.A.I.	II P.A.I.	III P.A.I.	IV P.A.I.
20	0	262.8	376.0	181.5	126.7
	200	309.0	322.3	198.7	145.0
30	0	-	-	-	-
	200	-	-	-	126.0

Appendix B - Wood Quality Studies

Table B-1. Analysis of Variance and Duncan Multiple Range Test on Douglas-fir Data From Two Locations.

Table B-1.

Analysis of Variance and Duncan Multiple Range Test on Douglas-fir Data from Two Locations

		Fuller Hill				Yacolt			
Wood variable	Treatment reference	F ratio	F prob.	P = 0.05 level, subsets, means, and rank	P = 0.01 level	F ratio	F prob.	P = 0.05 level, subsets, means, and rank	P = 0.01 level
Specific gravity	Before	2.391	.071	TF .447 T .450 C .459 F .465	TF T C F	.433	.651	T .392 1 N TF .398 2 N TF .402	T 1 N TF 2 N TF
	After	3.216	.024	TF .409 F .418 T .431 C .433	TF F T C	5.638	.004	1 N TF .423 2 N TF .425 T .442	1 N TF 2 N TF T
Lignin %	Before	1.293	.279	F 26.56 C 26.82 T 26.87 TF 27.01	F C T TF	1.917	.157	2 N TF 28.15 T 28.22 1 N TF 28.85	2 N TF T 1 N TF
	After	18.403	.000	C 25.61 F 25.79 T 26.44 TF 27.34	C F T TF	21.497	.000	T 27.07 2 N TF 28.41 1 N TF 28.59	T 2 N TF 1 N TF
Growth, radial, mm/yr	Before	9.976	.000	T 2.58 F 2.72 C 3.01 TF 3.32	T F C TF	1.762	.177	1 N TF 8.02 2 N TF 8.04 T 8.51	1 N TF 2 N TF T
	After	20.275	.000	C 2.90 F 3.34 T 3.39 TF 4.28	C F T TF	69.835	.000	T 6.17 1 N TF 7.53 2 N TF 8.46	T 1 N TF 2 N TF
Unit ring yield	Before	3.535	.016	T .120 F .126 C .141 TF .148	T F C TF	.215	.807	2 N TF .318 1 N TF .323 T .327	2 N TF 1 N TF T
	After	7.008	.000	C .123 F .143 T .149 TF .172	C F T TF	29.443	.000	T .270 1 N TF .319 2 N TF .360	T 1 N TF 2 N TF
Latewood %	Before	20.678	.000	T 35.65 TF 36.59 C 39.34 F 41.27	T TF C F	3.080	.050	1 N TF 20.64 T 22.65 2 N TF 24.03	1 N TF T 2 N TF
	After	10.333	.000	T 35.92 TF 37.94 C 39.91 F 40.77	T TF C F	17.355	.000	2 N TF 24.05 1 N TF 26.82 T 29.36	2 N TF 1 N TF T

Vertical lines indicate plots which are not significantly different at the probability levels shown.