REGIONAL FOREST NUTRITION RESEARCH PROJECT

BIENNIAL REPORT

1984 - 1986

January 1987

College of Forest Resources
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Page 17:

Table 4. Basal area growth responses not underscored by the sar line are significantly ($p < 0.10$) different.

Period 1	2.22(2N)	2.48(2A)	3.10(4N)
Period 2	0.98(2A)	1.23(2N)	2.01(4N)

Page 18:

Table 5. Volume growth responses not underscored by the sar line are significantly ($p < 0.10$) different.

Period 1	86.0(2N)	99.4(2A)	113.7(4N)
Period 2	48.0(2N)	48.6(2A)	84.0(4N)

Page 31:

The number of installations established in 1980 (Phase IV) wi active status as of 6/86 is 30.

EXECUTIVE SUMMARY

Forest fertilization continues to be an important silvicultural practice on private and public forest lands in the Pacific Northwest. An update of a 1983 survey shows the ongoing use of nitrogen fertilizers in forests of western Washington and Oregon, with multiple fertilizer applications planned for many stands planted today. Fertilization plans for the region call for about 150,000 acres to be treated annually over the next several years.

A five-year plan developed for the RFNRP (Phase V, 1985-90) has as the first priority improvement of selection criteria for Douglas-fir fertilization prescriptions. Analyses in the first year of Phase V were directed toward site-specific response information. Relationships between volume growth response and initial diameter distributions were explored for thinned and unthinned installations. Other analyses examined forest floor and surface soil properties in relation to growth and response of Douglas-fir and western hemlock. An evaluation of response by size class is underway.

Volume growth response after multiple fertilizations of unthinned Douglas-fir stands was significant for both initial and refertilizations. Weather factors appear to affect long-term response estimates. For installations where nitrogen was applied as urea and as ammonium nitrate, both sources produced similar growth responses over an 8-year period. For a limited sample of plots where fertilizer application was delayed 2 years after precommercial thinning, no enhancement of growth response was evident.

This Biennial Report provides brief summaries and abstracts of RFNRP projects and reports, and progress reports on several current efforts. More detailed information is available in the RFNRP Report series, journal articles, and other publications.

CONTENTS

Foreword 1

Introduction 2

Forest fertilization and stand management: survey update . . . 4

Acid tolerance of Pacific Northwest conifers in solution culture 5

Responding and nonresponding installations as affected by differences in initial plot diameter distributions . . . 6

Volume growth response after fertilization of unthinned Douglas-fir stands 9

Using nitrogen fertilizer in management of coast Douglas-fir . 12

RESEARCH SUMMARIES AND ABSTRACTS

A comparison of growth responses to ammonium nitrate and urea fertilizers in unthinned Douglas-fir stands 15

Growth response to delayed fertilization in precommercially thinned Douglas-fir plantations 19

Fertilizer effects on proportional growth relationships 22

Responses to sulfur in nitrogen fertilized Douglas-fir . 24

Western hemlock productivity in relation to stand and soil variables 24

Response of Douglas-fir and hemlock seedlings to N, P, and N+P applications 25

Tissue nutrient status and DRIS as indicators of outplanted Douglas-fir and western hemlock growth . . . 25

RESEARCH PROGRESS REPORTS

Fertilization responses in the Pacific silver fir zone . 26

Western hemlock cooperative database project 27

Response analysis by size class 28

Fieldwork overview 30

Graduate students 32

RFNRP personnel 35

Cooperators' Liaison Committee 36

Technical Advisory Committee 37

RFNRP publications, reports, and presentations 1984-1986 . . . 38

FOREWORD

I have been fortunate to be associated with this regional cooperative since the time it was only an idea in the minds of a group of forest nutrition scientists. The Cooperative developed successfully and has contributed a substantial amount of information to forest management in the Northwest. My role at the University has changed to an emeritus status, and I maintain an office and contribute my time and effort to certain programs. I have chosen to make one of these the RFNRP. I made this choice because I believe this is one of the most productive programs with which I have been involved. In addition to important contributions to forestry in the Northwest, it has been a model for other research cooperatives around the world. The Project serves as the Northwest focal point for forest nutrition research, and significant benefits accrue to the Cooperators from activities associated with information exchanges.

This Biennial Report, covering 17 years of Project activities, comes at a time of uncertainty for both forestry and the Cooperative. The uncertainty concerning future markets for Northwest forest products has cast doubts on the wisdom of continued investments in forestry beyond the bare essentials. There have also been significant changes in land ownership, and many landowners now have different funding priorities, especially with respect to research.

The Cooperative has clearly shown that we can expect an economic growth response to nitrogen application on Douglas-fir over a range of soil and site conditions. However, some areas do not follow this pattern and therefore our understanding is incomplete. Proper nutrition of forest trees results from many processes within the tree and the soil systems. We still have many research challenges to obtain information on elemental deficiencies and give precise recommendations to forest managers.

A final important consideration about the Cooperative is the massive, long-term database. Throughout my entire research career I have consistently heard of the need for such a data base in order to answer questions related to the long-term nature of forests. Many questions now being asked of foresters about cumulative effects, acid rain, and air pollution can only be answered through long-term records.

In summary, the RFNRP continues to make important contributions to Northwest forestry. The record shows that cooperatives are a very effective and efficient way to carry on forestry research. Even with 17 years of effort, all forest nutrition questions have not been answered. Because of the dynamic nature of forests and forest management, we must continue to seek answers.

S. P. Gessel, Professor Emeritus

INTRODUCTION

The Regional Forest Nutrition Research Project continued to change and grow during 1984-1986. New directions undertaken during the biennium, including the initiation of a new five-year research plan (Phase V) are balanced by the ongoing long-term data collection and analysis efforts. Changes in Project staff and in the faculty of the College of Forest Resources provide new directions, interests, and expertise. These elements of change and continuity direct the evolution of the Project and provide new opportunities for developing information on growth of northwest forests in relation to nutrition. The accomplishments of the past two years are outlined in this Biennial Report.

During 1984-1986, measurement, fertilization, and other treatments continued on the extensive base of RFNRP field trials. As of June 1986, there were 128 active installations in western Oregon and Washington. Included in this total are plots with 16 years of growth measurements and four fertilizer applications, and newly-established screening trials established in Spring 1986. During the biennium, remeasurements were discontinued on most of the older second-growth Douglas-fir installations; remeasurement interval was extended on the remainder. Remeasurements were discontinued on all empirical trials in western hemlock. A brief status report on RFNRP fertilization trials is included in this report. The RFNRP database has been continually upgraded and documented, and a number of new features are in place in the database management system.

Increased emphasis has been placed on RFNRP data analysis efforts, with particular attention to providing site-specific response information. The principal objective of the Phase V plan is to improve selection criteria for Douglas-fir fertilization prescriptions and analyses to exploit the RFNRP database are guided by that objective. Many of the results from these analyses are summarized in this report. Ongoing analysis efforts are involved with responses to multiple applications of fertilizer, responses in young stands and for recently planted seedlings, growth and response as affected by geographic province, correlation of growth response with properties of the forest floor and surface soil, and relationship of stand density and structure to fertilization responses.

Results from RFNRP analyses are transmitted to cooperators in a series of internal reports. There have been seven reports produced since the initiation of the RFNRP Report series in 1984, and several more are in preparation and revision. RFNRP Reports are reviewed by the Technical Advisory Committee and other members of the RFNRP community. Other Project publications include the RFNRP Newsletter, published twice a year, and several posters.

A major development during the biennium of significant importance to the RFNRP was the initiation in 1985 of the Stand Management Cooperative (SMC). The SMC was formed to provide an ongoing source of high-quality data on the effects of silvicultural treatments and treatment regimes on tree and stand growth and development and wood quality. The two cooperatives have obvious interrelationships, and five-year plans have been designed to be directly compatible. Administative efficiencies are in place by effective overlaps of project staff and field installations. The SMC comprises two projects dealing with silviculture and wood quality, and synergy between these projects and the RFNRP in terms of fieldwork, data management, and analyses strengthens each effort.

The format of the 1984-86 Biennial Report follows that of the preceding report by presenting summaries and highlights of progress during the past two years. The change reflects the direction of providing results as they become available, through RFNRP Reports and other means, to Project cooperators. This Biennial Report includes summaries of reports presented in 1984-86, abstracts of journal papers and presentations at scientific meetings, a fieldwork overview, reports on RFNRP staff and graduate students, and a listing of reports, publications, and presentations. Detailed results for technical summaries are available in RFNRP Reports and scientific journals.

FOREST FERTILIZATION AND STAND MANAGEMENT: SURVEY UPDATE*

H. N. Chappell and D. Opalach

The RFNRP surveyed member organizations regarding stand management and fertilization practices in September 1983 and again in June 1986. The results of the first survey were distributed as an RFNRP report and briefly summarized in the 1982-1984 Biennial Report. Extensive use of survey results by RFNRP cooperators and others provided the incentive for updating the information. Preliminary results, based on the 1986 survey, are given below. Results will be distributed as an RFNRP Report to Cooperators after further analysis and summarization.

Survey results show that fertilization continues to be an important silvicultural practice used by forest managers in western Oregon and Washington. Current plans for management regimes including fertilization call for multiple applications much more often than a single application. Respondents indicated that 14% of the stands planted today will be fertilized once and 38% will be fertilized more than once.

Eight of 17 respondents applied nitrogen fertilizer to some portion of their timberland in 1985. Preliminary results on area fertilized and fertilization plans for western Washington and Oregon are summarized below.

Area fertilized 1983-1985:	1983	106,050 acres
	1984	183,087
	1985	167,971
Planned fertilization:	1986	127,326
	1987	107,722
	1988	148,170
	1989	174,275
	1990	140,750

Typically, stands selected for fertilization are thinned and unthinned Douglas-fir stands aged 21 years or older growing on intermediate sites. Seven respondents indicated that young Douglas-fir stands (less than 21 years) are considered for fertilization. Other types of stands which receive fertilization priority by at least one organization are Douglas-fir/western hemlock mixtures and noble fir stands.

* *Updates Chappell and Opalach (1984); report in preparation.*

ACID TOLERANCE OF PACIFIC NORTHWEST CONIFERS IN SOLUTION CULTURE:*

I. EFFECT OF HIGH ALUMINUM CONCENTRATION AND SOLUTION ACIDITY

II. EFFECT OF VARYING ALUMINUM CONCENTRATION AT CONSTANT pH

P. J. Ryan, S. P. Gessel, and R. J. Zasoski

GENERAL SUMMARY

Conifers in western Washington occupy specific habitats which are defined by climatic and edaphic variables. One major site difference is the acidity or pH, which varies between sites but also between the forest floor and the mineral soil. In mineral soil low pH is accompanied by relatively high aluminum levels. High aluminum levels are known to be toxic to crop plants; however, the ability of Pacific Northwest conifers to tolerate aluminum is largely unknown. Since high aluminum and low pH occur simultaneously, it is difficult to distinguish the individual effects in soils. In these papers the individual effects of either high aluminum or low pH were investigated in solution culture.

The major findings of this research were:

1. Pacific northwest conifers are quite tolerant of aluminum and low pH.
2. In contrast to western redcedar and Douglas-fir, western hemlock was relatively tolerant of low pH and intolerant of high aluminum.
3. The tolerance of western hemlock to low pH and the tolerance of western redcedar to low pH and high aluminum seems to be related to their ability to tolerate low tissue levels of Mg and Ca and to the ability of western redcedar to accumulate Ca.

From a management and ecological perspective, it appears that the growth of western hemlock in organic rich forest floor or downed woody material would protect it from high aluminum levels. The relatively greater tolerance of Douglas-fir to aluminum is consistent with its pioneering role and mineral soil rooting.

* *Summarized from Ryan, Gessel, and Zasoski (1985) [RFNRP Report No. 4]*

RESPONDING AND NONRESPONDING INSTALLATIONS AS AFFECTED BY DIFFERENCES IN INITIAL PLOT DIAMETER DISTRIBUTIONS*

D. Opalach and C. E. Peterson

The relationship between installation volume growth response to nitrogen fertilizer and the initial diameter distributions of control plots and plots fertilized with 200 lbs N/A was explored for unthinned and thinned Douglas-fir installations. The purpose of the study was to address the following questions: (1) How should the similarity of two stand structures be evaluated? (2) How many installations have initial diameter distributions that differ between treatments? (3) What can be said about the relationship between response estimates and plot diameter distributions? Answers to these questions should help in the derivation of methods which can be used to improve our ability to predict site-specific response.

RESULTS AND CONCLUSIONS

There was a significant ($p < 0.01$) correlation between volume growth response and initial volume difference for unthinned installations (Figure 1). That is, response was larger for those installations where initial volume stocking of fertilized plots was greater than initial volume stocking of control plots.

Using a two-sample Kolmogorov-Smirnov (K-S) test, 42 of 91 installations analyzed were found to have heterogeneous diameter distributions between control and fertilized plots. K-S test results suggest that thinning did not bring about parity in initial diameter distributions: sixteen of 31 thinned installations were found to have heterogenous diameter distributions between control and fertilized plots.

Ten of 91 installations had a negative volume growth response. The control plots in each of these installations had greater initial volume stocking than the fertilized plots. Furthermore, the control plots had diameter distributions that contained more trees in the larger diameter classes. K-S test results indicated that five of these ten installations had significantly different ($p < 0.05$) diameter distributions between treatments (e.g., see Figure 2). Heterogeneous diameter distributions may have also inflated some volume growth responses, since six of the ten installations with the largest responses were found to have significantly different ($p < 0.05$) diameter distributions between treatments.

These results indicate that installation response estimates based on treatment comparisons are suspect for those installations that were found to have significant differences in initial diameter distributions between treatments. In order to improve installation response estimates, "stand structure analysis" can be used. However, prior to using the method, further research is needed to determine the degree of diameter distribution heterogeneity allowable within an installation so valid results are obtained.

* *Summarized from Opalach and Peterson (1986) [RFNRP Report No.5]*

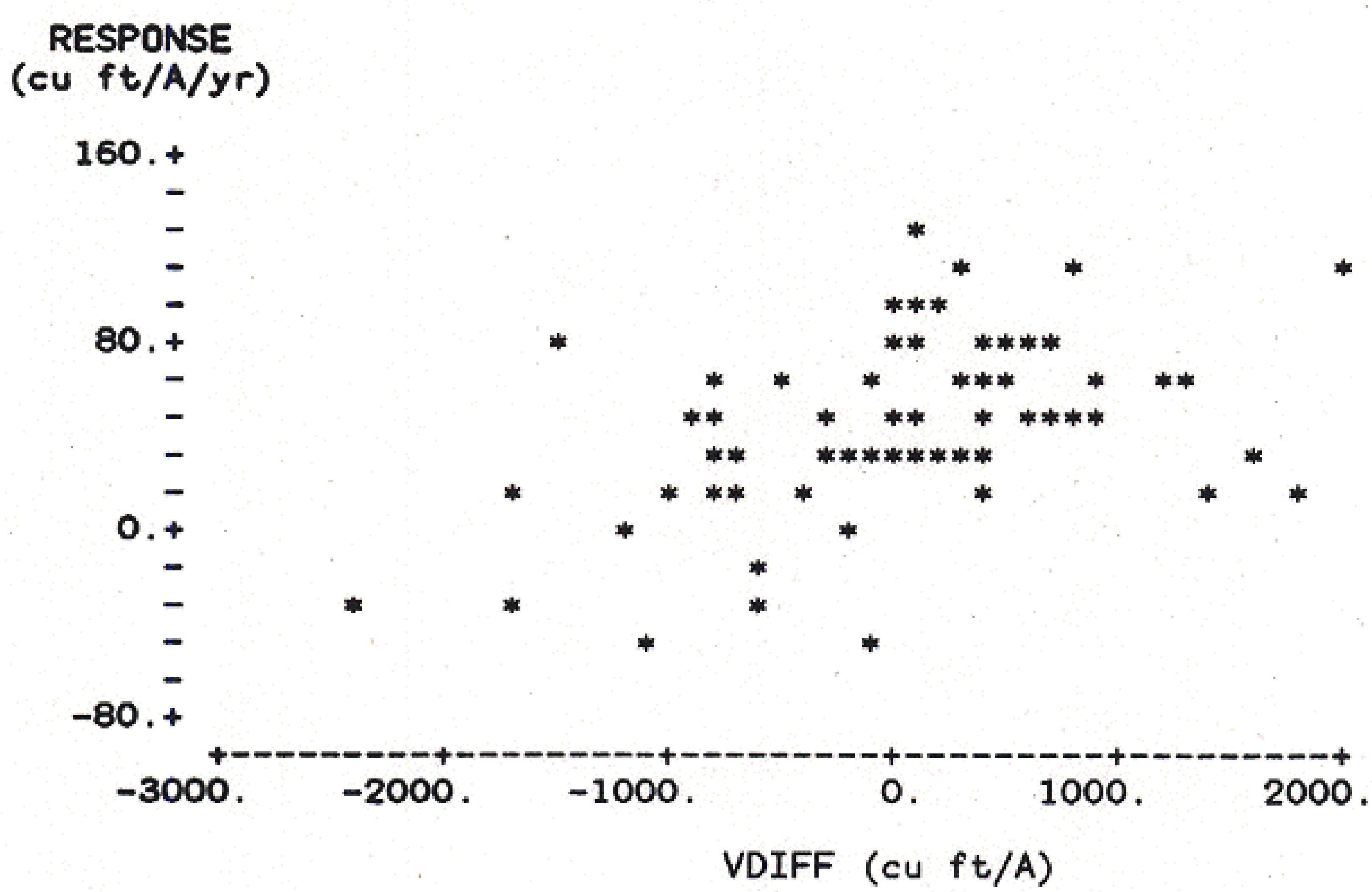

Figure 1. **Volume response plotted against the volume difference between 2N plots and 0N plots for unthinned installations.** The correlation between RESPONSE and VDIFF is 0.469 (df=58, $p < .01$)

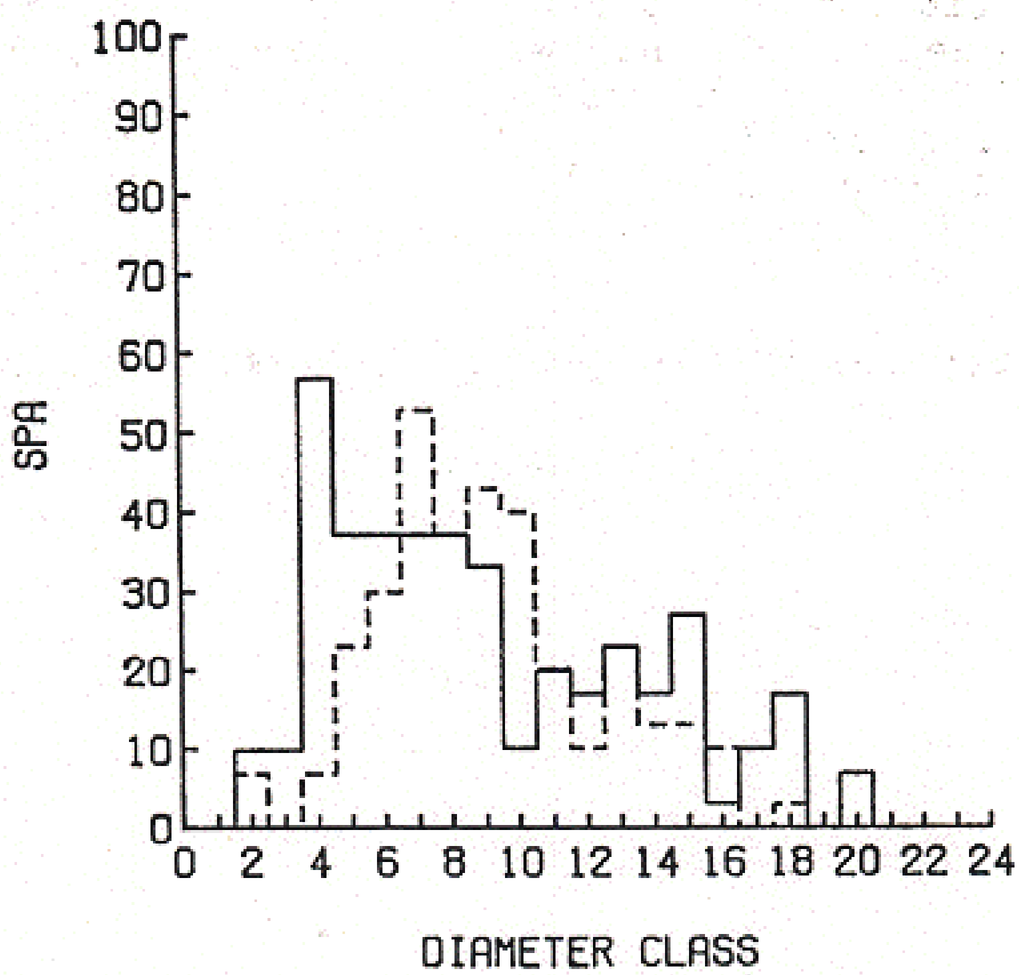

Figure 2. Diameter distributions for combined 0N plots (solid line) and combined 2N plots (dashed line) for installation 115. These diameter distributions were found to be significantly different ($p < .05$) by a two-sample K-S test.

VOLUME GROWTH RESPONSE AFTER FERTILIZATION OF UNTHINNED DOUGLAS-FIR STANDS*

C. E. Peterson and L. S. Heath

Volume growth response to single and multiple nitrogen fertilizer applications in second-growth unthinned Douglas-fir installations was analyzed for six two-year growth periods. The installations contained replicated treatments of 0, 200, and 400 lbs N/A (0N,2N,4N) applied as urea. A second application of 200 lbs N/A (2N refertilization) was applied to one plot of each initial treatment before the fifth two-year growing period. Growth response by two-year growth period is depicted in Figure 3.

Responses to the initial treatments are significant ($p < 0.10$) for the first four two-year periods, and in the final, sixth period (Figure 3). Responses are not significant ($p > 0.25$) in the fifth period. It is possible the nonsignificant responses to the initial fertilization in the fifth period were caused by unusually dry, warm weather. Period 5 encompassed the growing seasons during the years 1978-1980. Average deviations from the normal precipitation and temperature are graphed by calendar year in Figures 4 and 5. These years featured below-normal precipitation accompanied by above-normal temperatures.

Responses to refertilization (responses due solely to the second application of fertilizer) are significant ($p < 0.10$). Growth responses to the refertilization are similar to growth responses in the first two-year period following initial fertilization. However, responses to the refertilization, declined somewhat in the second period following refertilization, while responses to the initial fertilization increased in the second period. This may indicate that refertilization response is of shorter duration than response to one fertilizer application.

Determination of response duration to a single application of nitrogen fertilizer is not easy for the response pattern obtained in this study. Certainly the duration of response for both 2N and 4N treatments is at least eight years. It appeared that unusual weather played a role in the nonsignificant response in the fifth two-year period. Assuming response would have been significant under constant weather conditions, duration of response is at least twelve years for both treatments.

**Summarized from Peterson and Heath (1986) [RFNRP Report No. 6]*

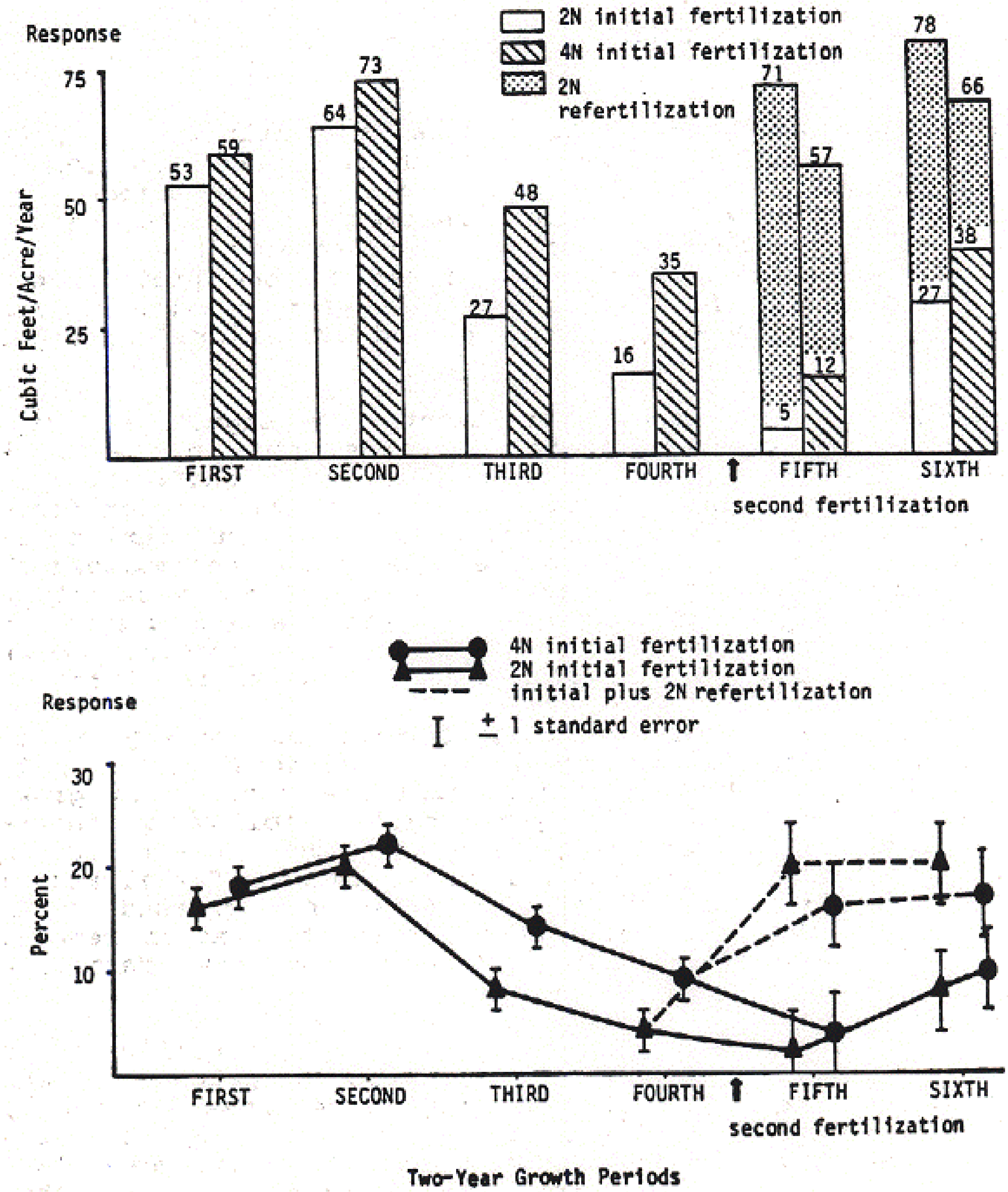

Figure 3. Estimated total gross volume growth response for each two-year growth period for unthinned Douglas-fir ($ft^3/A/yr$; min. dbh = 1.55 in.)

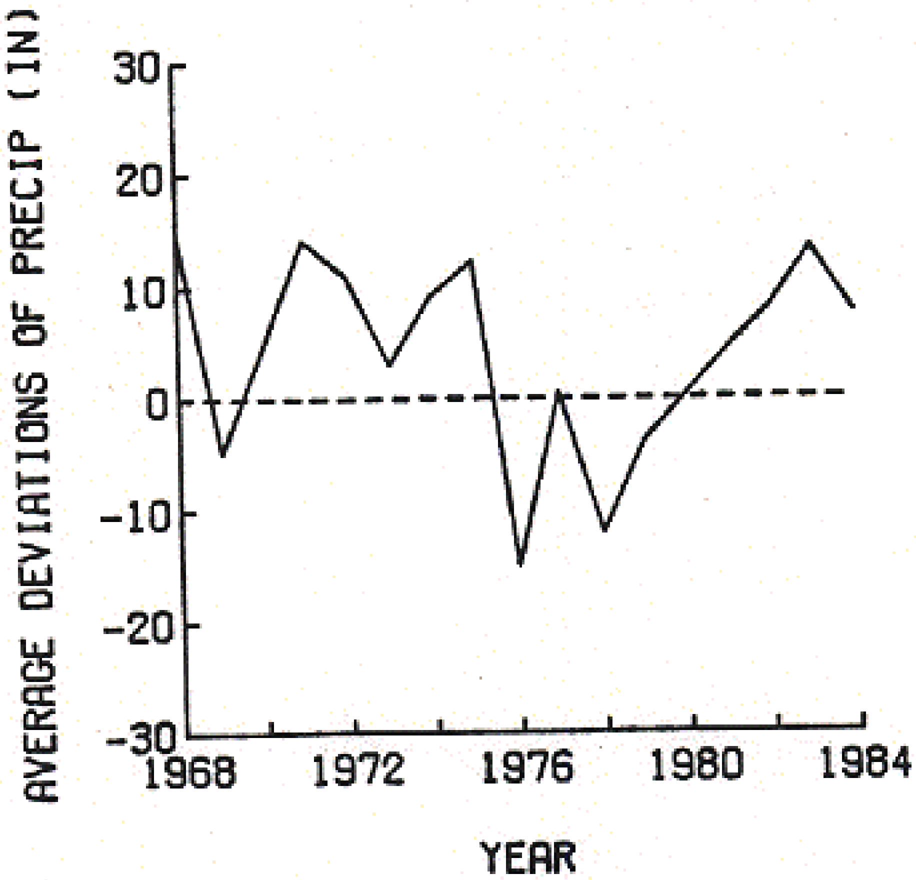

Figure 4. Average deviations by year from the mean precipitation (in.) for January through December.

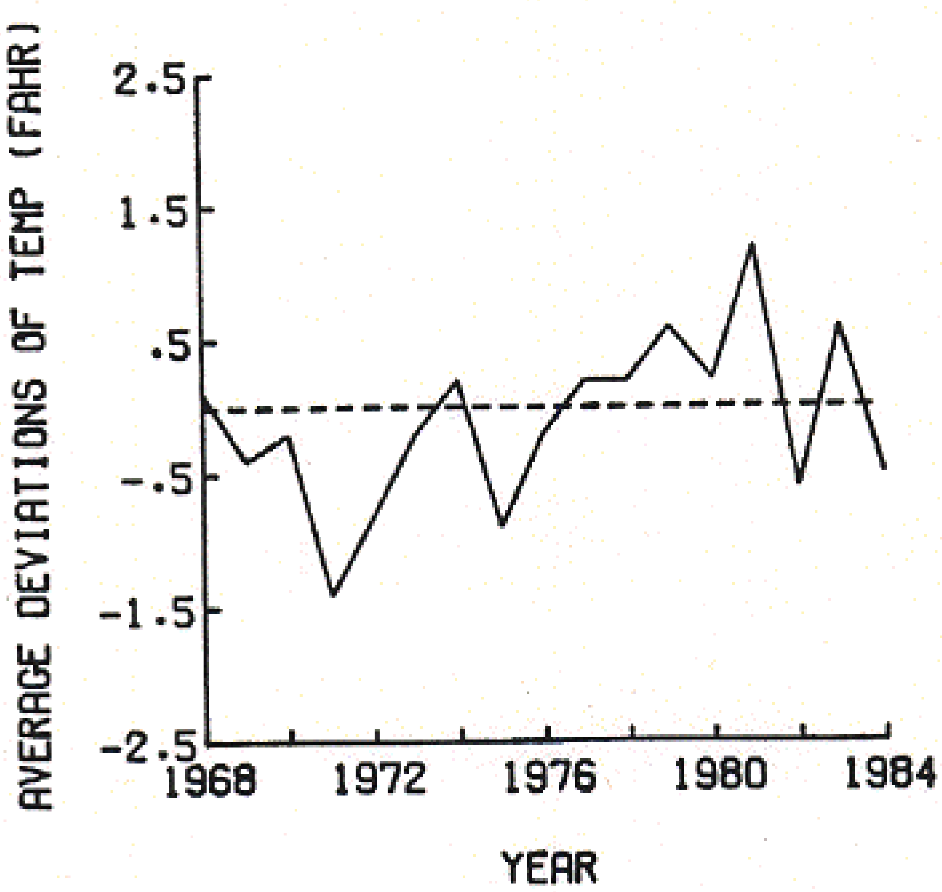

Figure 5. Average deviations by year from the mean temperature (^{o}F) for January through December.

USING NITROGEN FERTILIZER IN MANAGEMENT OF COAST DOUGLAS-FIR*

I. Regional Trends of Response
R.E. Miller, P.R. Barker, C.E. Peterson, and S.R. Webster

II. Future Informational Needs
C.E. Peterson, S.R. Webster, P.R. Barker, and R.E. Miller

SUMMARY

These two papers present an overview of results and conclusions from two large-scale forest fertilization research projects and a discussion of information needs for the future. The first paper presents information on treatments and results from trials in British Columbia, Washington, and Oregon. Results from fertilization and thinning trials established by the B.C. Ministry of Forests and the Regional Forest Nutrition Research Project (in Washington and Oregon) are presented and compared. Principal conclusions are:

1. At least 60% of the Douglas-fir stands responded to N fertilization in fertilizer trials in western British Columbia, Washington, and Oregon.

2. Douglas-fir stands generally proved more responsive to N fertilizer than Douglas-fir/western hemlock mixtures.

3. Fertilization accelerated losses of smaller trees in unthinned stands.

4. Fertilization of thinned stands shortened or even offset the temporary reductions of gross volume production after thinning.

5. Higher priority is recommended for fertilizing thinned stands, although fertilization of unthinned stands is a biologically and economically feasible option.

6. Although further investigation into sources and rate of N fertilizer is needed, the general prescription of 200 lbs N/acre applied as urea is supported.

7. When candidate stands for N fertilization are initially screened, a full range of site qualities and stand ages should be considered. Ranking candidate stands and making final selections, however, should be based on biological and economic considerations specific to the forest and management setting.

The second paper deals with information needs for extensive and intensive forest fertilization programs of the future. For extensive programs, where stands are fertilized once during a rotation, information gaps are considered to be generally minor with the exception of information to improve stand selection. As fertilizer usage shifts to multiple applications, information needs increase. Major information needs for intensive fertilization programs include identification of responsive stands and interactions of fertilization with thinning, particularly with respect to wood quality.

** Summarized from Miller, Barker, Peterson, and Webster (1986), and Peterson, Webster, Barker, and Miller (1986) [RFNRP Report No. 7]*

TABLE 1. Future information needs for fertilization.

Fertilization Program	Extensive	Intensive
Identifying (e.g., N minimum, foliar N, or site index) responsive and nonresponsive stands	Moderate	Major
What nutrients and fertilizer should be applied, at which application (e.g., to deal with induced deficiencies of other elements)? How can the need for elements other than N be predicted or measured? When should other elements be applied?	Minor	Moderate
What are expected volume gains (e.g., additive or diminishing) from fertilization?	Minor	Moderate
Dosage and frequency: How often to apply (e.g., identify declines in response by age, site index, etc.) How much to apply (e.g., varying rates)	Minor	Moderate
Is the relative increase in growth rate from fertilization density dependent?	Minor	Major
Does fertilization affect thinning schedules and vice versa (e.g., when to fertilize in conjunction with PCT or CT)?	Minor	Major
Does fertilization affect wood quality?	Minor	Major
Does fertilization response depend on season of application?	Minor	Minor
Does fertilization affect water quality?	Minor	Minor
Does fertilization affect wildlife?	Minor	Minor
Does fertilization affect disease and insects?	Minor	Minor
Does fertilization affect brush competition?	Minor	Minor

A COMPARISON OF GROWTH RESPONSES TO AMMONIUM NITRATE AND UREA FERTILIZERS IN UNTHINNED DOUGLAS-FIR STANDS

D. Opalach

In 1975, 11 installations (167 to 177) were established by the RFNRP in unthinned Douglas-fir stands to compare growth responses to urea (46% nitrogen [N]) and ammonium nitrate (34% N) fertilizers. Four-year growth responses for these installations were reported in the 1980-1982 RFNRP Biennial Report. Information is now available for eight growing seasons following fertilizer application.

Each installation comprised eight plots. Four replicated treatments were randomly allocated to the plots: control (treatment 0N), fertilization with urea at a rate of 200 lbs N/A (treatment 2N), fertilization with urea at a rate of 400 lbs N/A (treatment 4N), and fertilization with ammonium nitrate at a rate of 200 lbs N/A (treatment 2A). Initial stand conditions based on a sample size of 83 plots[1] were:

	Mean	Range
Site index (feet, base age=50 years)	90	59 - 130
Breast height age (years)	37	8 - 51
Trees/A	1058	340 - 2920
Basal area (ft^2/A)	188	28 - 299
Volume (CVTS, ft^3/A)	4983	206 -10072

Statistical Methods The 8-year period was divided into two 4-year periods for analysis. A separate analysis of covariance was used to estimate growth responses for each 4-year period. Installations were viewed as random blocks and covariates were initial basal area and initial volume, respectively, for computing adjusted basal area periodic annual increment (PAI) and adjusted volume PAI. Response was computed as the difference between adjusted PAI of fertilized plots and adjusted PAI of control plots.

Comparisons between responses were made using an approximate least significant difference multiple comparison procedure. A significance level of 0.10 was used for the procedure.

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1 Data from 83 of the original 88 plots established in the 11 installations were used in this analysis (two plots were destroyed by windthrow, two by harvesting, and one by a pathogen)

Basal Area Growth Response In the first 4-year period following fertilizer application, all three fertilizer treatments produced significant basal area growth responses (Table 2). Basal area growth responses declined in the second period, but remained significant.

Table 2. Gross basal area growth response estimates (± 1 standard error) to ammonium nitrate and urea by 4-year growth period for unthinned Douglas-fir installations, with levels of statistical significance (min. DBH = 1.55 inches).

Response (ft^2/A/yr)	Four-year Growth Period 1	2
Treatment 2A	2.48 ± 0.32	0.98 ± 0.30
percent	46% ± 6%	17% ± 5%
significance	$p < 0.001$	$p < 0.005$
Treatment 2N	2.22 ± 0.32	1.23 ± 0.30
percent	41% ± 6%	22% ± 5%
significance	$p < 0.001$	$p < 0.001$
Treatment 4N	3.10 ± 0.30	2.01 ± 0.28
percent	57% ± 6%	35% ± 5%
significance	$p < 0.001$	$p < 0.001$

Volume Growth Response All three treatments produced significant volume growth responses in the first period (Table 3). In the second period, volume growth responses declined but remained significant.

Table 3. Gross volume growth response estimates (± 1 standard error) to ammonium nitrate and urea by 4-year growth period for unthinned Douglas-fir installations, with levels of statistical significance (min. DBH = 1.55 inches).

Response (CVTS, $ft^3/A/yr$)	Four-year Growth Period 1	2
Treatment 2A	99.4 ± 12.9	48.0 ± 14.1
percent	42% ± 5%	17% ± 5%
significance	$p < 0.001$	$p < 0.005$
Treatment 2N	86.0 ± 12.7	48.6 ± 13.9
percent	36% ± 5%	18% ± 5%
significance	$p < 0.001$	$p < 0.001$
Treatment 4N	113.7 ± 12.2	84.0 ± 13.3
percent	48% ± 5%	31% ± 5%
significance	$p < 0.001$	$p < 0.001$

<u>Comparisons</u> Multiple comparison results for basal area growth responses and volume growth responses are summarized in Tables 4 and 5, respectively. Results indicate that responses to treatments 2A and 2N are not significantly different and, therefore, neither N source can be said to be superior to the other. This conclusion only holds for an application rate of 200 lbs N/A.

Table 4. Basal area growth responses not underscored by the same line are significantly ($p < 0.10$) different.

Period 1	2.22(2N)	2.48(2A)	3.10(4N)
Period 2	0.98(2A)	1.23(2N)	2.01(4N)

Table 5. Volume growth responses not underscored by the same line are significantly ($p < 0.10$) different.

Period 1	86.0(2N)	99.4(2A)	113.7(4N)
Period 2	48.0(2N)	48.6(2A)	84.0(4N)

<u>Summary</u> Ammonium nitrate and urea fertilizers produced similar growth responses over an 8-year period when each was applied at a rate of 200 lbs N/A.

GROWTH RESPONSE TO DELAYED FERTILIZATION IN PRECOMMERCIALLY THINNED DOUGLAS-FIR PLANTATIONS

D. Opalach

In 1975, the RFNRP established three installations in precommercially thinned Douglas-fir plantations to study growth response to delayed fertilization. The primary objective of the study was to answer the question "Does delaying fertilization enhance response in precommercially thinned stands?"

Four- and six-year growth responses for these installations were reported in the RFNRP 1980-1982 Biennial Report and Peterson (1984), respectively. This note summarizes the data obtained from these installations over eight growing seasons following precommercial thinning. The data were analyzed by 2-year growth periods to facilitate comparisons among treatments.

Description of the Data Three replicated treatments were randomly assigned to six 1/10-acre plots in each installation. The treatments were control (treatment 0T), N fertilization concurrent with thinning (treatment 2T), and N fertilization delayed two years after thinning (treatment 2D). Fertilization treatments were 200 lbs N/A applied as urea. Initial stand conditions for these installations were:

	Installation			
	179	182	183	All
Number of plots[2]	6	6	6	18
Age (breast height)	13	12	13	12
Site class	I	I-	II-	
Trees/A	400	398	398	399
Basal area (ft^2/A)	92	61	42	65
Quadratic mean diameter (in)	6.5	5.3	4.4	5.4
Relative density (Curtis)	36	26	20	27
Volume (CVTS; ft^3/A)	1741	913	556	1070

[2] Two plots from installation 179 were dropped from the study in 1982 due to windthrow; only data from 16 plots were available to compute statistics associated with the fourth 2-year growth period.

<u>Statistical Analysis</u> A separate analysis of covariance was used to estimate growth responses for each two-year period. Installations were viewed as random blocks and covariates were initial basal area and initial volume, respectively, for computing adjusted basal area periodic annual increment (PAI) and adjusted volume PAI. Response was computed as the difference between adjusted PAI of fertilized plots and adjusted PAI of control plots. A response was judged to be significant if its p-value was less than 0.10.

<u>Results</u>

Table 6. Gross basal area growth response estimates (± 1 standard error) to concurrent and delayed fertilization by 2-year growth period for precommercially thinned Douglas-fir installations, with levels of statistical significance (min. DBH = 1.55 inches).

Response ($ft^2/A/yr$)	Two-year Growth Period 1	2	3	4
Treat. 2T	2.92 ± 0.82	2.80 ± 1.04	1.16 ± 1.13	0.24 ± 1.06
percent	29% ± 8%	27% ± 10%	11% ± 11%	2% ± 10%
significance	p = 0.071	p = 0.055	p = 0.362	p = 0.829
Treat. 2D	N/A	3.83 ± 1.03	2.70 ± 1.12	1.12 ± 1.04
percent		38% ± 10%	27% ± 11%	11% ± 10%
significance		p = 0.020	p = 0.073	p = 0.344

Table 7. Gross volume growth response estimates (± 1 standard error) to concurrent and delayed fertilization by 2-year growth period for precommercially thinned Douglas-fir installations, with levels of statistical significance (min. DBH = 1.55 inches).

Response ($ft^3/A/yr$)	Two-year Growth Period 1	2	3	4
Treat. 2T	58.8 ± 15.8	55.6 ± 29.0	33.7 ± 36.1	0.1 ± 52.9
percent	22% ± 6%	18% ± 9%	9% ± 10%	0% ± 14%
significance	p = 0.065	p = 0.128	p = 0.404	p = 0.999
Treat. 2D	N/A	69.8 ± 29.0	55.2 ± 36.1	-0.4 ± 52.9
percent		22% ± 9%	15% ± 10%	-0% ± 14%
significance		p = 0.074	p = 0.201	p = 0.995

<u>Delayed vs Concurrent Fertilization</u> Results (Tables 6 and 7) from this limited sample indicate that concurrent and delayed fertilization produced similar response trends over time. Two conclusions follow from these results:

(1) Delaying fertilization did not enhance growth response.

(2) A forest manager may not have to fertilize at the time of precommercial thinning to maximize a young stand's growth response to fertilizer. If necessary, the forest manager might delay fertilization up to two years without incurring a reduction in response.

It must be emphasized that these conclusions are based on a weak sample and should be applied accordingly.

FERTILIZER EFFECTS ON PROPORTIONAL GROWTH RELATIONSHIPS*

C. E. Peterson

Nitrogen fertilization has become an important silvicultural option to increase timber and fiber production of Douglas-fir. There is ample evidence in the forestry literature that fertilization increases increment, but there is little information available on how this response is distributed between major volume components of height and basal area. This paper examines proportional growth relationships in fertilized (200 lbs N/A) and unfertilized young spaced plantations through the use of proportions.

Assume the relationship between volume (V) and height (H), basal area (B), and cylindrical form factor (F) of a tree to be V=BHF. Using this equation and assuming a nonsignificant change in form factor and very small contributions from the product of 2 or more proportions over a short period, the proportional growth in volume (P_v) is approximately equal to the sum of the proportional growth in basal area (P_b) and the proportional growth in height (P_h).

Proportional growth relationships of P_v, P_b, and $P_b + P_h$ for unfertilized plots are shown in Figure 6. It can be inferred from this graph that P_b is the principal component of P_v, and (P_b+P_h) improves as an approximation of P_v with increasing stand age. The effect of fertilization on each of the growth components is illustrated in Figure 7. The proportionate increase in volume growth after fertilization is significant. Most of this increase is due to the increase in P_b. The fact that the ratio of P_b to P_h is significantly increased by fertilization could mean a change in form factor.

Jenkins (1975. The contribution of basal area and height increment to volume increment. Unpublished research paper. Coll Forest Resour, Univ Washington) found that P_b, P_h, and the ratio P_b/P_h were all inversely related to site index in older (30 years b.h. age) stands of unthinned and unfertilized Douglas-fir (Figure 8). Furthermore, after fertilization, the P_b/P_h ratio of the same stands was increased across the range of site index. Although this ratio is lower for stands older than those in the current study, the impact of fertilization on this lower ratio was similar to the results from fertilizing young plantations. Thus, it appears that volume growth on fertilized stands of a given site index is not proportionately distributed as would be expected for unfertilized stands of higher site index. In other words, these results show that volume gains for a fertilized stand cannot be predicted by simply raising the site index of that stand.

* *Summarized from Peterson (1985)*

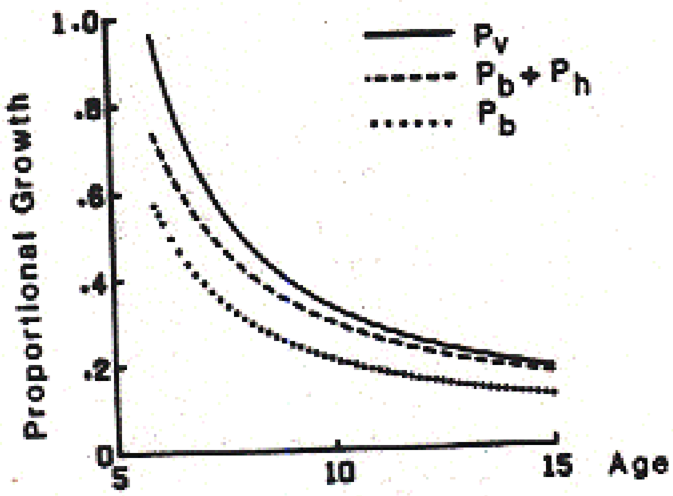

Figure 6. Proportional growth relationships in young untreated Douglas-fir plantations; P_v, P_b, and P_h represent relative growth of volume, basal area, and height, respectively.

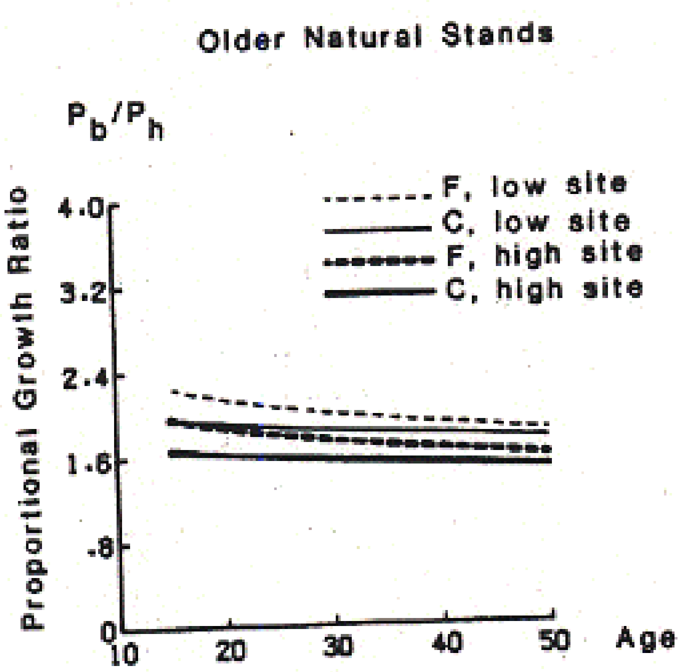

Figure 8. Ratio of proportional basal area growth to proportional height growth for Douglas-fir on older natural stands of low site and high site (after Jenkins, 1975); 0 kg N/ha (C) and 224 kg N/ha (F).

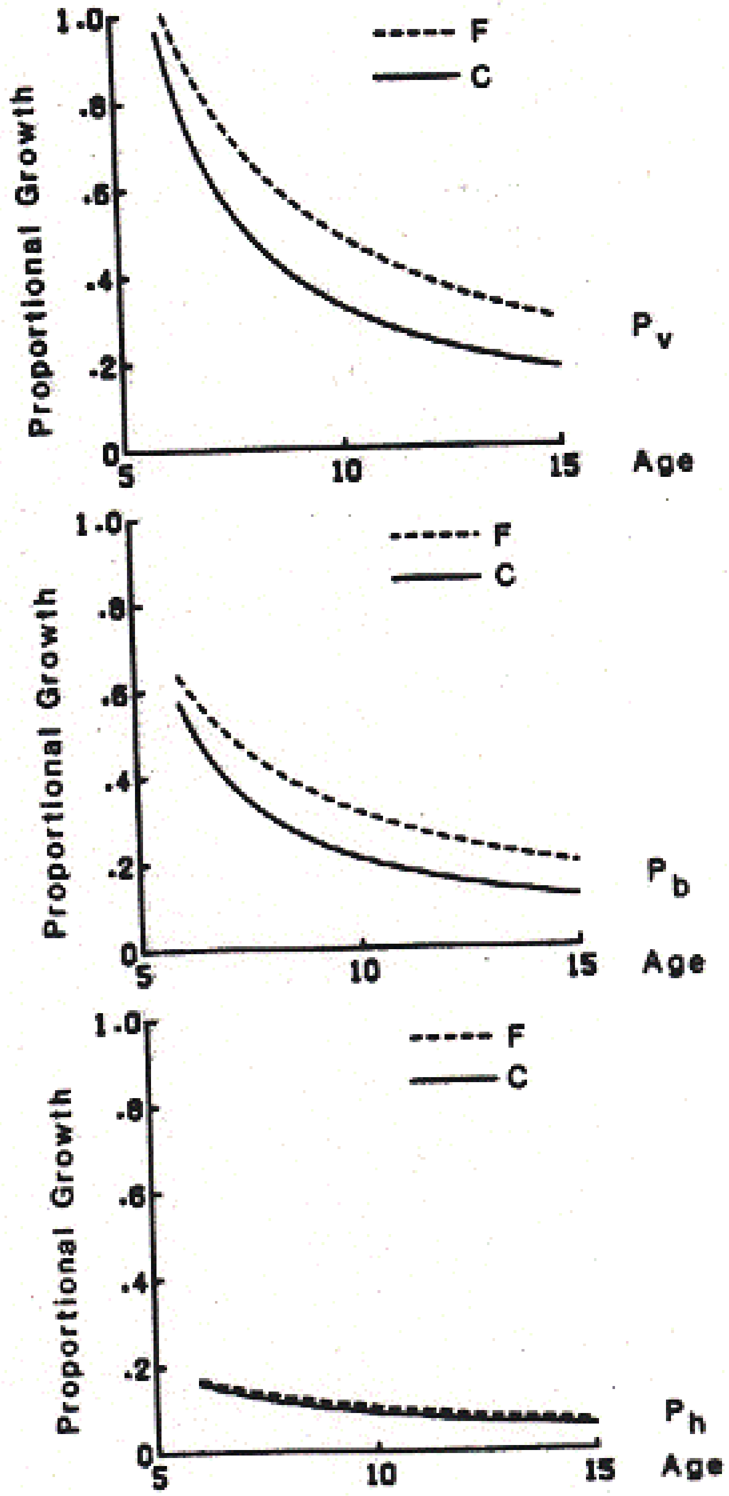

Figure 7. Proportional growth in young Douglas-fir plantations for 0 kg-N/ha (C) and 224 kg-N/ha (F); P_v, P_b, and P_h represent relative growth of volume, basal area, and height, respectively.

RESPONSES TO SULFUR IN NITROGEN FERTILIZED DOUGLAS-FIR*1

J. I. Blake, S. P. Gessel, and S. R. Webster

Three experiments were initiated to quantify the growth response of N fertilized Douglas-fir to S supplements and to identify the nutritional conditions which relate to S deficiencies. Seedlings grown for seven months in a pot trial showed a significant increase in stem caliper and weight to N and N plus S. Sulfur enhanced growth at soil levels below 14 mg kg^{-1} SO_4-S by Morgan's extract. In stands, S improved basal area response to 336 kg ha^{-1} of urea N at surface soil SO_4-S levels of 20 mg kg^{-1}. Separation of responsive sites was improved by the inclusion of age weighted subsoil SO_4-S. The growth increase with N plus S was identical to the relative growth increase on non-S deficient plots receiving N alone. At five intensively studied plantations, differential responses to N plus S were not clearly related to pretreatment soil or foliage S levels. Foliage analysis is used to suggest a rationale for the observed results. Sulfur interactions with litter-humus decomposition, enhanced N uptake due to S and the potential influence of calcium and aluminum on soil available S are believed to influence these results. Genuine S deficiencies may occur when foliage SO_4-S is less than 80 to 100 mg kg^{-1}.

WESTERN HEMLOCK PRODUCTIVITY IN RELATION TO STAND AND SOIL VARIABLES*2

C. E. Peterson and R. J. Zasoski

Replicated samples of forest floor and surface soil (0-15 cm) were obtained from control plots at 30 installations of western hemlock located in western Washington and Oregon. Growth and fertilizer response data form thinned and unthinned installations treated with 0, 224, and 448 kg N/ha as urea-N were examined with respect to stand parameters and properties of the forest floor and surface soil. The periodic annual increment (PAI) from controls demonstrates a linear relationship with several soil variables such as %N, %C, C/N, and base saturation, particularly in thinned stands. Growth responses to fertilizer were also related to soil properties. However, both the control PAI and associated fertilizer responses also strongly correlated with initial stand parameters such as age and stocking. Response to fertilizer addition was strongly correlated with PAI of the controls. Western hemlock productivity (with and without fertilizer) is related to stand and soil variables and both must be considered in the soil-site evaluations.

*1 *From Blake, Gessel, and Webster (1985).*
*2 *From Peterson and Zasoski (1985).*

RESPONSE OF DOUGLAS-FIR AND HEMLOCK SEEDLINGS TO N, P, AND N+P APPLICATIONS[*3]

H. J. Porada and R. J. Zasoski

A fertilizer trial was established in spring 1984 on coastal Washington soils of low pH, low base saturation, and high exchangeable Al to determine whether application of N, P, and N+P at planting to Douglas-fir and western hemlock seedlings could increase foliar nutrient levels and increase productivity. A complete factorial with two levels of N and P (plus control) was established with fertilizer spot applied. Height measurements were carried out each fall; foliar samples were collected spring and fall each year and nutrient concentrations determined. The two species did not respond similarly. After two years' growth, Douglas-fir showed a consistent (>30%) height response to P and N+P, while hemlock height response was variable for all treatments. Data from growth measurements and foliar analyses indicate that application of P or N+P at planting will greatly increase height growth of Douglas-fir on these soils. Additions of other elements in conjunction with P or N+P, particularly Fe and B, appear necessary to obtain a hemlock height increase.

TISSUE NUTRIENT STATUS AND DRIS AS INDICATORS OF OUTPLANTED DOUGLAS-FIR AND WESTERN HEMLOCK GROWTH[*4]

R. J. Zasoski and H. Porada

Plug-1 seedlings of Douglas-fir and western hemlock were planted at four locations in western washington and treated with N and P in factorial combinations. A complete treatment (N, P, Ca, Mg, S, and trace elements) was also included. Two locations had been burned after harvest and two were unburned. Height and diameter growth for the first and second growing season along with tissue analysis allowed for evaluation of seedling performance in relation to nutrient status. Two years after planting tissue levels of N, Ca, Mg, Cu, Fe, and Zn were decreased relative to concentrations at planting. Although critical levels for Douglas-fir and western hemlock are not known with certainty for all elements, Fe and Zn appear to be below critical levels. Tissue Zn and Fe are lower in western hemlock than in Douglas-fir. In addition to low Fe both species had tissue Mn levels that ranged from 400 to 1500 ppm resulting in very low Fe:Mn values. Interpretations of these results in relation to DRIS (Diagnosis and Recommendation Integrated System) are discussed.

*3 *From Porada and Zasoski (1986).*
*4 *From Zasoski and Porada (1986).*

FERTILIZATION RESPONSES IN THE PACIFIC SILVER FIR ZONE*

Because of successful fertilization programs in Douglas-fir stands and increased management of upper-slope Cascade forests, interest has developed for information on potential fertilization responses in upper-slope forest types. About 12% of the timberland ownership of RFNRP cooperators is in true fir/hemlock forest types, a significant factor when considering PNW forest productivity. RFNRP objectives in Phase V include initiation of a limited effort to examine response to fertilization in this important forest type.

Fertilization screening trials began in Spring 1986 in pure and mixed stands of true firs (Abies spp.) in the Pacific silver fir (Abies amabilis) zone of Oregon and Washington. Study objectives are:

1. To evaluate growth responses of managed stands in the Pacific silver fir zone to nitrogen fertilization.

2. To examine differences in growth and response after fertilization with urea and ammonium nitrate.

3. To examine growth responses to application of other nutrient elements (P,S) alone and in combination with N.

A two-stage approach will be used for this study. In the initial stage, growth and foliar responses of individual trees will be monitored for four growing seasons after fertilizer application. Results from this stage will be used to develop sampling and treatment regimes for fixed-area treatment plots used in the second stage.

Young stands of Noble fir and Pacific silver fir are being selected for the first-stage effort. Candidate area criteria and forms are available from RFNRP. Fertilization treatments include N (ammonium nitrate and urea) alone and in combination with P, S, and micronutrients. Current foliage will be sampled after one growing season and analyzed along with growth measurements to rank treatment responses. Diameter and height growth will also be measured after two and four growing seasons. First-stage installations will be established in 1986-87, and preliminary results reported in early 1988.

Six trials were established in the Washington Cascades in Spring 1986, and candidate stands are being evaluated for trials to be established in Spring 1987. Establishment data and one-year growth data has been entered into the RFNRP database; foliar samples are being analyzed.

* *Summarized from "Fertilization responses in true fir stands in the Pacific silver fir zone," RFNRP study plan on file.*

WESTERN HEMLOCK COOPERATIVE DATABASE PROJECT

There has been increasing interest in recent years in growth and yield projections for managed western hemlock stands. In early 1985, an effort was initiated to assemble a cooperative regional database for managed stands of western hemlock in western Oregon, Washington, and British Columbia. The RFNRP joined with eight other organizations to pool data and form a single dataset with uniform format. Weyerhaeuser Company staff coordinated the project and compiled the data. Each cooperating organization received a complete copy of the pooled dataset in late 1985.

The master dataset contains data from 1298 plots (302 from RFNRP) with a total of 514,843 diameter and height measurements (151,445 from RFNRP plots). In addition to the tree measurement data, the database includes plot descriptions, notes on other measurements taken, and descriptions of fertilization and thinning treatments.

The cooperative database project greatly increases the amount of western hemlock data available for RFNRP analyses. In addition to providing more measurements from plots similar to RFNRP installations, the dataset includes measurements from plots that have received more thinnings, plots that have been measured over longer periods of time (up to 31 years), and plots that have received different fertilization treatments.

Analyses planned jointly by the RFNRP and the Stand Management Cooperative include comparisons of fertilization treatments and evaluation of other aspects of western hemlock growth and yield. The RFNRP also joined with 15 other organizations in a cooperative venture to analyze the growth and yield of western hemlock using the pooled dataset. The analysis was conducted by Dr. James Arney of Applied Biometrics and resulted in an upgrade of the Stand Projection System (SPS) model. These cooperative efforts hold significant promise for providing better information on western hemlock.

RESPONSE ANALYSIS BY SIZE CLASS

Efforts are now underway to evaluate response by size class. Two approaches are being employed to perform the analysis. One approach is based on analysis of growth rates of individual trees from control and treated plots. Preliminary results indicate that response by diameter class varies considerably between unthinned and thinned stands (compare Figures 9 and 10). In unthinned stands, diameter increment response appears to be similar for all diameter classes except the largest. In the largest classes, response tapers off quickly. However, due to the small sample sizes in the larger diameter classes it is not possible to place a high degree of confidence in the estimates associated with these classes. In thinned stands generalizations about diameter increment response are complicated by an unusual bulge in the diameter increment curves (Figure 10). However, it can be seen that fertilization benefitted trees in all diameter classes. In addition to diameter increment, basal area increment and volume increment are also being analyzed over diameter classes.

The second approach is based on an analysis of the potential crop tree component of the stand (e.g., the largest 100 trees per acre). In this approach, data from each plot are used to determine the basal area growth and volume growth of the crop tree component. Regression analysis is then used to (1) determine the growth response of the crop tree component and (2) determine if the growth response of the crop tree component is a function of stand variables such as age, site index, and basal area. Results from this analysis will be compared to previous RFNRP results for the total stand to determine what proportion of the total growth response accumulated on the largest trees.

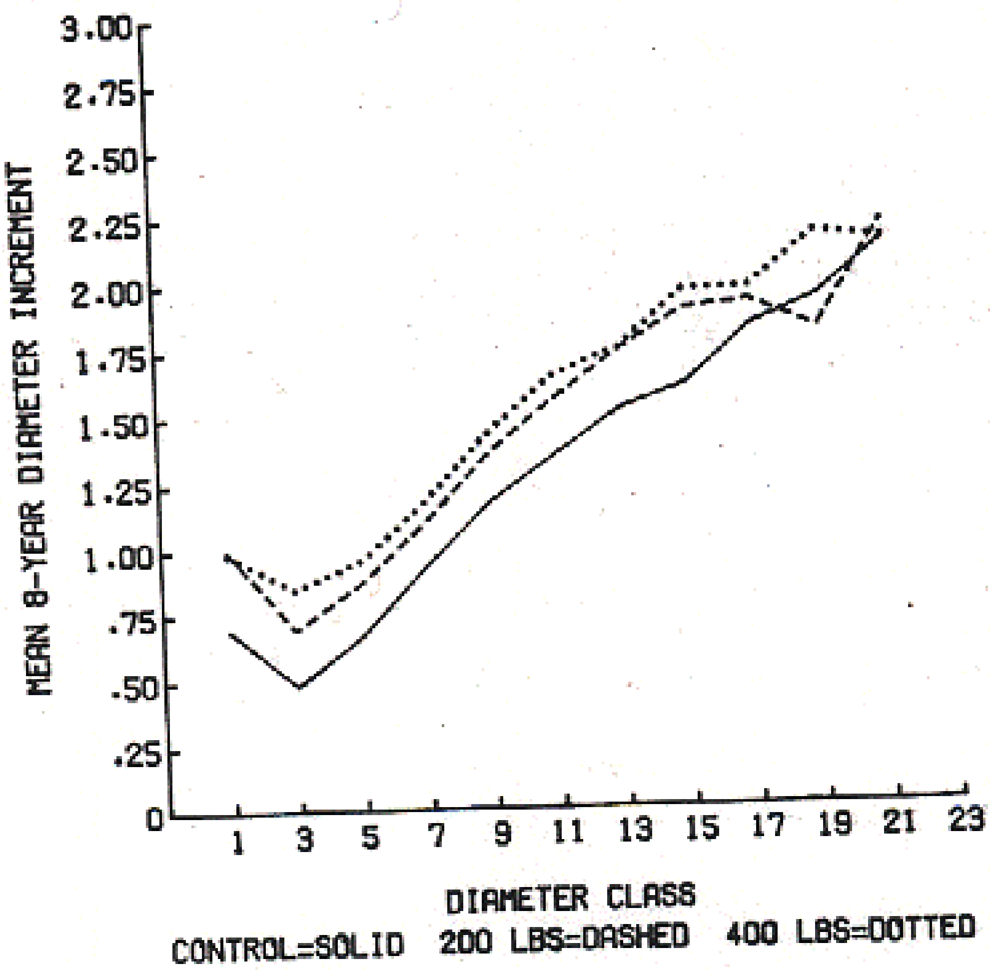

Figure 9. Mean 8-year diameter increment by diameter class and treatment for Douglas-fir trees in unthinned installations (min. DBH = 1.55 in.)

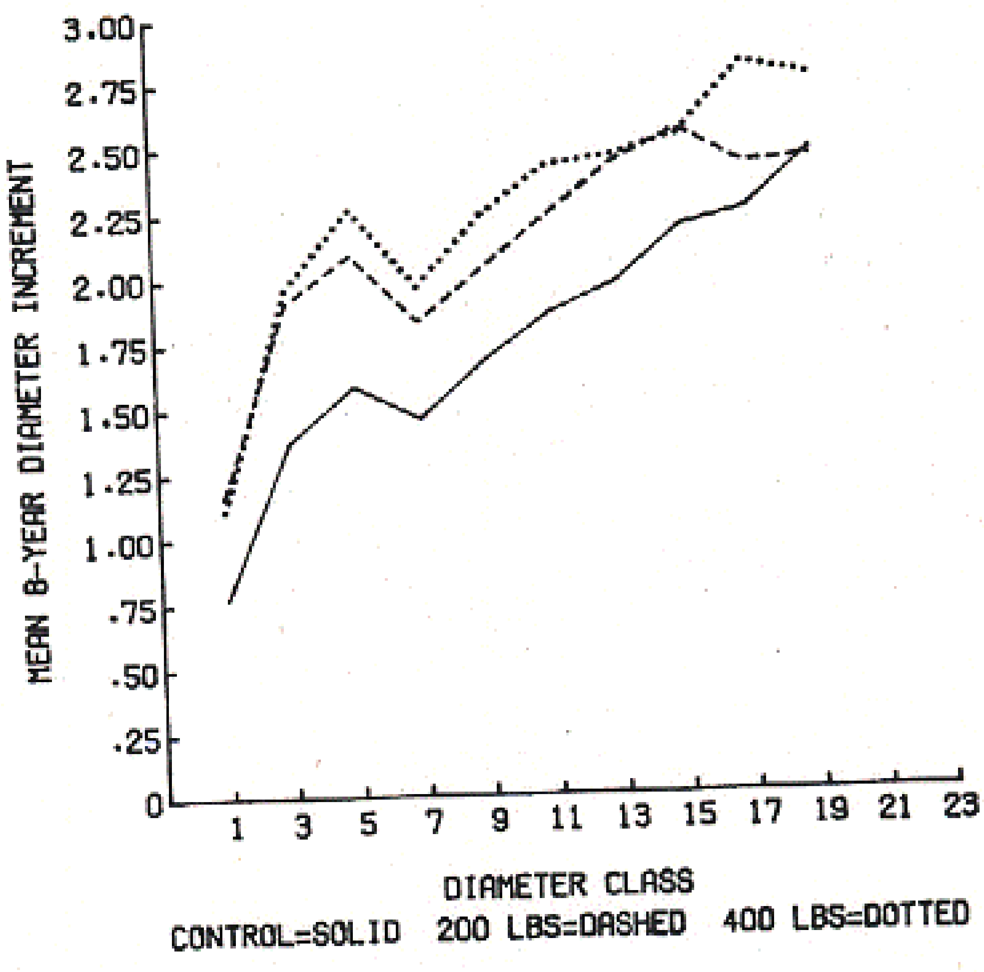

Figure 10. Mean 8-year diameter increment by diameter class and treatment for Douglas-fir trees in thinned installations (min. DBH = 1.55 in.)

FIELDWORK OVERVIEW

During 1984-86, measurements and treatments continued on the extensive base of RFNRP field trials. A number of installations have now completed 16 growing seasons after initial treatment, and a subset of these have been fertilized a total of four times. Scheduled remeasurements for these installations have been extended to 4-year intervals; other RFNRP installations are measured on 2-year intervals.

RFNRP trials have been established in a number of phases, and reference to these phases is common practice to identify a particular subset of the field installations. The phases are:

Phase I — Natural, unthinned stands of Douglas-fir and western hemlock; established 1969-70.

Phase II — Natural, thinned stands of Douglas-fir and western hemlock; established 1971-72.

Phase III — Young thinned plantations of Douglas-fir and western hemlock; low site quality stands of Douglas-fir; established 1975.

Phase IV — Precommercially thinned plantations of Douglas-fir and western hemlock; Douglas-fir stands of naturally low stocking; established 1980.

The fertilization schedule for Phase I and II Douglas-fir installations is summarized below.

Douglas-fir Phase I & II Fertilization Schedule

Plot	Initial fertilization	After 8 growing seasons	After 12 growing seasons	After 16 growing seasons
	-------------	lbs N/acre as urea	----------------	
1	0	0	0	0
2	0	200	200	200
3	200	0	0	0
4	200	200	200	200
5	400	0	0	0
6	400	200	200	200

Status of Field Trials

The RFNRP has established over 270 research installations since 1969. Six to 35 permanent growth plots make up an installation, for experimental designs used in Phases I-IV and contract installations. Recent screening trials established in the Pacific silver fir (PSF) zone are on individual trees. Active RFNRP trials are listed below; other installations are inactive (no remeasurements are scheduled) or dropped (no further measurements are possible, e.g. plots have been logged, windthrown, etc.). Remeasurement of all western hemlock trials has been discontinued.

Establishment Year	Installation Type	Number Established	Number Active 6/86
1969	Phase I	57	13
1970	Phase I	60	12
1971	Phase II	16	9
1972	Phase II	27	22
1973	Contract (BLM)	6	0
1975	Phase III	29	22
1975	Contract (USFS)	4	0
1976	Contract (USFS)	2	0
1977	Contract (USFS, BLM)	16	3
1978	Contract (USFS)	5	0
1979	Contract (SUDIC)	3	3
1980	Phase IV	34	34
1980	Contract (SUDIC)	2	2
1983	Contract (MCI)	3	3
1984	Contract (USFS)	3	3
1985	Phase V PSF	6	6
	TOTALS	273	128

GRADUATE STUDENTS

John Blake completed his Ph.D. thesis in 1985 and accepted a post-doctoral position at Auburn University. His thesis is entitled "Characterization of soil nitrogen and sulfur availability in relation to volume response of Douglas-fir in western Oregon and Washington". Rachel Friedman-Thomas completed requirements for the M.S. degree in 1986 (thesis: "Effects of nitrogen fertilization on fine root and mycorrhizal biomass in a second growth Douglas-fir stand in western Washington"). Abstracts of both theses are included at the end of this section.

Hans Porada is completing data analysis and interpretation for his Ph.D. degree, under the direction of Dr. Robert Zasoski. His project deals with nutrition and fertilizer response of Douglas-fir and western hemlock seedlings on coastal Washington sites.

Dan Opalach assumed much of the responsibility for RFNRP data analysis in 1985, and continues to make progress on his Ph.D. program. The working title of Dan's dissertation is "A Diameter Distribution Yield Model for Managed Even-Aged Stands." The generalized model uses a probability density function (pdf) to characterize the diameter distribution of even-aged stands. Stand projection is accomplished by predicting changes in the pdf parameters with a system of differential equations. Management practices incorporated into the generalized model are thinning and nitrogen fertilization. RFNRP data will be used to develop a specific model for managed second-growth Douglas-fir stands.

Linda Heath is also a Ph.D candidate involved with data analysis for RFNRP. Her current work includes investigating alternative methods for estimating growth responses to fertilization with Dan, and analyzing response in young stands. Her dissertation is tentatively titled "Optimization of a Stochastic Projection System."

Other graduate students have been associated with the RFNRP during 1984-86. Tom Gower, Mark Redlin, and Dan Vogt are working with Drs. Charles Grier and Kristiina Vogt on projects examining carbon allocation in relation to mineral nutrition for above- and belowground portions of Douglas-fir stands. Tom Hsiang has worked with Dr. Robert Edmonds on an evaluation of carbon:nitrogen ratios as possible diagnostic criteria for fertilization prescriptions.

CHARACTERIZATION OF SOIL NITROGEN AND SULFUR AVAILABILITY IN RELATION TO VOLUME RESPONSE OF DOUGLAS-FIR (PSEUDOTSUGA MENZIESII [MIRB.] FRANCO) IN WESTERN OREGON AND WASHINGTON

John I. Blake

Volume response to urea nitrogen was examined on fifty-one Douglas-fir installations in western Oregon and Washington. Response was significantly related to stand and soils variables at each location. Site index was negatively related and age was positively related to response. The correlation between response and mineralizable nitrogen from incubation tests was low. It was significantly improved by adjusting the test for gravel content of the soil and the mean annual air temperature at the site. The adjusted mineralization values were also shown to significantly improve the prediction of the net live foliage biomass increment in the control plots. The best predictive model of nitrogen response included site index, mineralizable nitrogen and sulfur indices. The sulfur indices consisted of A horizon sulfate sulfur, age weighted subsoil sulfate sulfur, and the ratio of sulfur to nitrogen in the soil. Canonical analysis demonstrated that age was strongly associated with mineralizable nitrogen (negative) and sulfur availability (positive).

Sulfur availability was examined further in three separate experiments. Douglas-fir seedlings showed sulfur responses in greenhouse trials on soils with less than 14 mg kg^{-1} using Morgan's solution. Relative basal area responses in paired fertilization plots of nitrogen only and nitrogen plus sulfur were correlated significantly to indices using sulfate sulfur in the A horizon and the subsoil. Field trials with nitrogen and sulfur were established in a range of young Douglas-fir plantations. Growth responses and foliage analysis after treatment suggest that complex interactions with litter-humus immobilization of sulfur may strongly affect responses at specific locations. Genuine sulfur deficiencies appeared to occur when sulfate sulfur in the foliage was reduced below 80 to 100 mg kg^{-1}.

EFFECTS OF NITROGEN FERTILIZATION ON FINE ROOT AND MYCORRHIZAL BIOMASS IN A SECOND GROWTH DOUGLAS-FIR STAND IN WESTERN WASHINGTON

Rachel Friedman-Thomas

Short-term effects of nitrogen fertilization on the below- and above-ground biomass of a second-growth Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) stand were estimated. Total fine root and mycorrhizal biomass in the plots treated with 448 kg N ha^{-1} decreased within four months following fertilization by 35% of the control plots. This decrease occurred mainly in the <1 mm mycorrhizal root and <5 mm angiosperm root categories. Another short-term response to nitrogen fertilization was shown for the conifer root tip biomass and density. The greatest change in conifer root tips was observed in the A horizon which showed the highest proportional increase in availability of mineral nitrogen. Fertilizer effects were also shown for the above-ground component with increases in new foliage and new twig biomass on fertilized plots. Results of this study pointed out the relationships between nutrient amendment and carbon allocation to roots and shoots four months after fertilization.

RFNRP PERSONNEL

Dr. H. N. Chappell, Director
Mr. Robert Gonyea, Program Manager
Mr. William Bennett, Database Manager
Mr. Dan Opalach, Mensurationist
Mr. Michael Rinehart, Field Supervisor
Mr. Michael Johnson, Field Technician

Several personnel changes occurred in RFNRP and the College of Forest Resources during 1984-86. Charley Peterson, Project Mensuration Director, completed his Ph.D. degree in 1985 and accepted a position with Northrop Services in Corvallis, Oregon. Dan Opalach, RFNRP Research Assistant since 1983, assumed much of the responsibility for data analysis. Rick Ells, Database Manager for the past three years, accepted a position with the UW Academic Computing Service in September 1986. Bill Bennett took over the data management role in January 1987. Both Charley and Rick maintain close ties to the RFNRP.

Although Dr. Stan Gessel officially retired in 1983, he continues to be a RFNRP mainstay. Stan's energy and knowledge continue to guide and inspire us all. Nick Chappell was named Project Director in 1984, and was appointed Director of the Stand Management Cooperative in 1985.

Faculty participation in RFNRP continues to be a Project asset. Drs. Bruce Bare, Dale Cole, Robert Edmonds, Charles Grier, Douglas Maguire, James Newberry, and Robert Zasoski have devoted considerable time to the Project. Chuck Grier, whose work on forest productivity complemented RFNRP projects, accepted a position at Northern Arizona University in 1985. Jim Newberry worked with Project staff on a number of analyses during 1985 before leaving to assume duties as Forest Biometrician with Potlatch Corporation in Lewiston, Idaho. Doug Maguire accepted the faculty position in growth and yield in September 1986 and has become involved in a number of projects. Also in September 1986, Bob Zasoski joined the soils faculty at the University of California, Davis; Bob continues to be involved, albeit at long range, in a number of RFNRP studies. Faculty interest and participation strengthens the RFNRP, and graduate students supervised by these faculty members provide for research on basic and applied topics beyond the scope of the core RFNRP effort.

Fieldwork in 1984-86 has been accomplished with the assistance of Messrs. Bob Bollander, Pete Hasselberg, Ron Kent, and Larry Maechler. Thanks are due Mrs. Kathi Grier, who left the College in 1985, and Mrs. Dolores Batayola, who retired in 1986, for their excellent handling of Project secretarial and publication tasks. Appreciation is also due Ms. Margaret Lahde and Mrs. Veronica Gallardo for their secretarial and word processing duties.

COOPERATORS' LIAISON COMMITTEE

Jack Barringer	**Barringer and Associates, Inc.**
E. C. Scheider	Boise Cascade Corporation
Byron Thomas	**Bureau of Land Management**
Jeff Madsen	Champion International Corporation
Newton Hawkinson	**Chevron Chemical Company**
Warren Woodward	**Cominco American, Inc.**
William Atkinson	Crown Zellerbach Corporation
Charles Brown	Fruit Growers' Supply Company
Ted Deer	Georgia-Pacific Corporation
Russell Ellwood	Giustina Brothers Lumber & Plywood Co.
Dennis Creel	**Hampton Tree Farms, Inc.**
Greg Johnson	**International Paper Company**
David Bowden	**Longview Fibre Company**
Ronald Eckfield	Menasha Corporation
William Voelker	**Oregon Department of Forestry**
Bruce Beckett	**Plum Creek Timber Company**
Alan Steege	Quinault Indian Nation
Gerry Hawkinson	**CPEX Pacific** (formerly Reichhold Chemicals)
Philip Hahn	**Rex Timber Company**
Kurt Munnich	Scott Paper Company
Cal Poe	Simpson Timber Company
Loren Hillman	**UNOCAL Chemicals**
Donald Connett	**U. S. Forest Service**
Harry Anderson	**Washington Dept. of Natural Resources**
Steve Webster, William Scott	**Weyerhaeuser Company**
Morris Bergman	**Willamette Industries, Inc.**

Organizations listed above participated in RFNRP during 1984-86. Organizations in **boldface** continue participation in Phase V.

TECHNICAL ADVISORY COMMITTEE

The RFNRP Technical Advisory Committee (TAC) provides review and counsel on Project reports and plans. RFNRP study plans, research proposals, manuscripts, and field and laboratory studies benefit from the active participation of TAC members. TAC review is also an important step in production of the RFNRP Report series. The willingness of TAC members to contribute their time and expertise is a key factor in the continued success of the Project. TAC participants during 1984-86 were:

Harry Anderson	Washington Dept. of Natural Resources
William Atkinson	Crown Zellerbach Corporation
Russ Ballard	Weyerhaeuser Company
Tim Ballard	University of British Columbia
Paul Barker	British Columbia Ministry of Forests
Albert Becker	Georgia-Pacific Corporation
George Bengtson	Oregon State University
Peter Farnum	Weyerhaeuser Company
John Hazard	U.S. Forest Service, PNW Station
Paul Heilman	Washington State University
Denis Lavender	Oregon State University
David McNabb	Oregon State University
Robert Meurisse	U.S. Forest Service, PNW Region
Richard Miller	U.S. Forest Service, PNW Station
James Moore	University of Idaho
Charles Peterson	Northrop Services
Robert Powers	U.S. Forest Service, PSW Station
Larry Promnitz	Crown Forest Industries
John Shumway	Washington Dept. of Natural Resources
Robert Strand	Crown Zellerbach Corporation
Byron Thomas	Bureau of Land Management
Steve Webster	Weyerhaeuser Company
Gordon Weetman	University of British Columbia
Robert Zasoski	University of California, Davis
Larry Zuller	Georgia-Pacific Corporation

1986 Opalach, D. and C. E. Peterson. Responding and non-responding installations as affected by differences in plot stand structures. Unpublished, RFNRP Report 5. 28 p.

1986 Peterson, C. E. The effect of nitrogen fertilizer on proportional growth relationships on Douglas-fir. p. 74-79 In D.S. Solomon and T.S. Brann, eds., Proc. IUFRO Environmental Influences on Tree and Stand Increment, Sept 22-27, 1985, Durham, NH. Maine Ag Exp Sta Misc Publ 691, Univ Maine, Orono.

1986 Peterson, C. E. and L. S. Heath. Volume growth and volume growth response after fertilization of unthinned Douglas-fir stands. Unpublished, RFNRP Report 6. 22 p.

1986 Peterson, C. E., S. R. Webster, P. R. Barker, and R. E. Miller. Using nitrogen fertilizer in management of coast Douglas-fir: II. Future informational needs. p. 304-309 In C. D. Oliver et al, eds., Douglas-fir: Stand management for the future. Proc Sympos held June 18-20, 1985, Seattle. Inst Forest Resources Contrib No 55, Univ Washington, Seattle (Also compiled in RFNRP Report 7. 1986. [unpublished])

1986 Porada, H. J. and R. J. Zasoski. Response of Douglas-fir and western hemlock seedlings to N, P, and N+P applications. Agron Abstr 1986: 265.

1986 Ryan, P. J., S. P. Gessel, and R. J. Zasoski. Acid tolerance of Pacific Northwest conifers in solution culture: I. Effect of high aluminum concentrations and solution acidity. Plant and Soil 96: 239-257. (Also compiled in RFNRP Report 4. 1985. [unpublished])

1986 Ryan, P. J., S. P. Gessel, and R. J. Zasoski. Acid tolerance of Pacific Northwest conifers in solution culture: II. Effect of varying aluminum concentration at constant pH. Plant and Soil 96: 259-272. (Also compiled in RFNRP Report 4. 1985. [unpublished])

1986 Zasoski, R. J. and H. J. Porada. Tissue nutrient status and DRIS as indicators of outplanted Douglas-fir and western hemlock growth. Agron Abstr 1986: 270.

1985 Blake, J.I., S.P. Gessel, and S.R. Webster. Responses to sulfur in nitrogen fertilized Douglas-fir. Agron Abstr 1985:216.

1985 Chappell, H. N., C. E. Peterson, Jr., and L. S. Heath. Growth response after fertilization in thinned and non-thinned Douglas-fir stands. Poster presented at the Society of American Foresters National Convention, July 28-31, 1985, Colorado State Univ, Fort Collins; and at Douglas-fir: stand management for the future, June 18-20, 1985, Univ Washington, Seattle.

1985 Peterson, C.E. and R.J. Zasoski. Western hemlock productivity in relation to stand and soil variables. Agron Abstr 1985:223.

1986 ________. The Regional Forest Nutrition Research Project. (poster)

1986 Bare, B. B. and D. Opalach. Optimizing species composition in uneven-aged stands. Paper presented at the 18th IUFRO World Congress, Sept 7-21, 1986 at Ljubljana, Yugoslavia.

1986 Friedman-Thomas, R. Effects of nitrogen fertilization on fine root and mycorrhizal biomass in a second growth Douglas-fir stand in western Washington. M.Sc. thesis, Univ Washington, Seattle. 120 p.

1986 Gessel, S. P., ed. Forest site and productivity. Martinus Nijhoff, Dordrecht. 270 p.

1986 Gessel, S. P. and H. N. Chappell. University - forest landowners cooperation: the Regional Forest Nutrition Research Project. p. 49-57 In D.P. Burns, compiler, Proc IUFRO Evaluation and planning of forestry research, July 25-26, 1985, Colorado State Univ, Fort Collins. USDA Forest Service Gen Tech Rpt NE-GTR-111.

1986 Miller, R. E., P. R. Barker, C. E. Peterson, and S. R. Webster. Using nitrogen fertilizer in management of coast Douglas-fir: I. Regional trends of response. p. 290-303 In C. D. Oliver et al, eds., Douglas-fir: Stand management for the future. Proc Sympos held June 18-20, 1985, Seattle. Inst Forest Resources Contrib No 55, Univ Washington, Seattle (Also compiled in RFNRP Report 7. 1986. [unpublished])

1984 Peterson, C. E., P. J. Ryan, and S. P. Gessel. Response of northwest Douglas-fir stands to urea: correlations with forest soil properties. Soil Sci Soc Am J 48:162-169. (Also presented at 1982 American Society of Agronomy meeting, Anaheim, CA; Agron Abstr 1982:264.)

1984 Radwan, M. A., D. S. DeBell, S. R. Webster, and S. P. Gessel. Different nitrogen sources for fertilizing western hemlock in western Washington. Can J For Res 14:155-162. (Also presented at 1982 American Society of Agronomy meeting, Anaheim, CA; Agron Abstr 1982:263.)

1984 Radwan, M. A. and J. S. Shumway. Site index and selected soil properties in relation to response of Douglas-fir and western hemlock to nitrogen fertilizer. p 89-104 In E. L. Stone, ed, Forest Soils and Treatment Impacts. Proc Sixth North Amer Forest Soils Conf, Knoxville, Tenn.

1984 Shumway, J. S. Mineralizable nitrogen as a guide to fertilizing Douglas-fir stands. Agron Abstr 1984:265.

1984 Strand, R. F., compiler. Nitrogen assessment workshop, May 19-20, 1982. Unpublished, RFNRP Report 2. 84 p.

1984 Walker, R. B., S. P. Gessel, and R. E. Miller. Greenhouse/ laboratory evaluation of three "problem" soils from Rogue River forest sites. Northwest Sci Assoc Abstr 1984:202.

1985 Bare, B. B. and R. Loveless. An overview of the Regional Forest Nutrition Research Project. p. 52-61 In C.D. Risbrudt and P.J. Jakes, compilers, Forestry research evaluation: current progress, future directions, Proc forestry research evaluation workshop, Aug 20-21, 1984, St. Paul, MN. USDA Forest Serv Gen Tech Rep NC-104.

1985 Beckman, T. Elements of a successful fertilization program. p 183-207 In USDA Forest Service, Timber Management Group, compiler, Proc National Silviculture Workshop, May 13-16, 1985, Rapid City, South Dakota.

1985 Blake, J. I. Characterization of soil nitrogen and sulfur availability in relation to volume response of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) in Western Oregon and Washington. Ph.D. dissertation, Univ Washington, Seattle. 132 p.

RFNRP PUBLICATIONS, REPORTS, AND PRESENTATIONS 1984-1986

This is a list of publications, reports, and presentations by Project personnel, and those which are results of research using the Project database.

1984 Chappell, H. N. and D. Opalach. Forest fertilization and stand management in western Oregon and Washington: Status and prospect. Unpublished, RFNRP Report 1. 23 p.

1984 Ells, R. The Regional Forest Nutrition Research Project information management system. Unpublished, RFNRP Report 3. 45 p.

1984 Gertner, G. Z. Localizing a diameter increment model with a sequential Bayesian procedure. Forest Sci 30:851-864.

1984 Gessel, S. P. Position paper: site productivity. p. 433-439 In D.C. Grey et al, eds., Proc IUFRO Sympos on Site and Productivity of Fast Growing Plantations, April 30-May 11, Pretoria and Pietermaritzburg, South Africa.

1984 Gessel, S. P. and W. A. Atkinson. Use of fertilizers in sustained productivity and Douglas-fir forests. p. 67-87 In E.L. Stone, ed., Forest Soils and Treatment Impacts. Proc Sixth North Amer Forest Soils Conf, Knoxville, Tenn.

1984 Grier, C. C., K. M. Lee, and R. M. Archibald. Effect of urea fertilization on allometric relations in young Douglas-fir. Can J For Res 14:900-904.

1984 Hazard, J. W. and C. E. Peterson. Objectives and analytical methods of the Regional Forest Nutrition Research Project. Institute of Forest Resources Contrib 53, Univ Washington, Seattle. 23 p.

1984 Peterson, C. E. Fertilization of Douglas-fir plantations in the Pacific Northwest RFNRP cooperative. p. 637-645 In D.C. Grey et al, eds, Proc IUFRO Sympos on Site and Productivity of Fast Growing Plantations, April 30-May 11, Pretoria and Pietermaritzburg, South Africa.