INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE:
A workshop for member organizations.

Theme: Forest Fertilization and Nutrient Management in the Intermountain Northwest

April 12, 1988
University Inn: Best Western, Moscow, Idaho

Agenda

8:00- 9:00 Registration

I. Introduction

9:00- 9:40

Welcome -- Jim Moore, Univ. of Idaho

History of the Cooperative -- Harry Anderson, Washington Department of Natural Resources.

* Information available from the IFTNC - Research Methods/ Experimental Design -- Jim Moore, Univ. of Idaho

II. What the IFTNC has learned to date.

Douglas-Fir Response Results

9:40-10:10 * Response results from the Douglas-fir nitrogen fertilization trials. Jim Moore, Univ. of Idaho.

10:10-10:30 Break

Jim Vander Ploeg Univ. of Idaho

10:30-11:00 * Response results for other species fertilization trials (grand fir, ponderosa pine, western larch). Pat Cochran, USFS, Pacific Northwest Forest Experiment Station.

11:00-11:30 * ~~The~~ effect of site and stand factors on Douglas-fir response to nitrogen fertilization. Peter Mika, Univ. of Idaho.

11:30-12:00 * Distribution of fertilization response across tree size classes. ~~within a stand~~. John Olson, Potlatch Corporation.

12:00- 1:00 Lunch

1:00- 1:40 * Do other nutrients ~~in addition to nitrogen~~ limit tree growth in the Intermountain Northwest? John Shumway, Washington Department of Natural Resources.

* Handouts & outline in booklet

III. Management Implications

1:40- 2:20 A conceptual framework for ~~understanding and~~ applying ~~the~~ results. Kurt Pregitzer, Michigan State Univ.

2:20- 3:00 * Extrapolating the results to management practices: Nutrient management/silvicultural implications. John Mandzak, Champion International Corporation.

3:00- 3:20 Break

3:20- 3:50 * Developing ~~The fertilization decision -- using what we have learned to develop~~ a nitrogen fertilization program. John Olson, Potlatch Corporation.

3:50- ~~4:30~~ Discussion Period -- All participants.

4:30- 4:40 Where the IFTNC is going. Jim Moore, Univ. of Idaho.

INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

Steering Committee

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Champion International Corporation	Jim Runyan
Cominco American Incorporated	Warren Woodward
Inland Empire Paper Company	Dennis Parent
Longview Fiber Company	Dave Bowden
Potlatch Corporation	John Olson
Union Chemicals Division of Union Oil Corporation	Rick Gross
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Pacific Northwest Forest Experiment Station	Pat Cochran
Washington Department of Natural Resources	John Shumway

Staff

Director	Jim Moore
Data Analyst	Peter Mika
Research Associate	Jim VanderPloeg

Information Available from the IFTNC: Research Methods/Experimental Design.

By Jim Moore

Univ. of Idaho

The purpose of this paper is to familiarize participants with the data that support the results discussed in subsequent workshop presentations. The greatest amount of data comes from the Cooperative's Douglas-fir fertilization trials. The overall experiment is a factorial split-plot design. Within each of the IFTNC's six geographic regions (northern Idaho, Montana, central Idaho, northeast Oregon, central Washington, and northeast Washington), stands were selected to provide a range of site quality, age, and density. This selection process resulted in the 94 Douglas-fir installations shown in Figure 1. An installation is comprised of six square or rectangular plots, each at least 1/10th acre in size (Figure 2). A buffer of twenty-five feet on three sides of the plot and fifty feet on the other were included for each plot. The larger buffer on one side provided for destructive sampling of trees without disturbing the plots. Three treatments were randomly assigned to the plots. The treatments consisted of: (1) 200 lb/ac. actual nitrogen, (2) 400 lb/ac. actual nitrogen, and (3) no treatment (Figure 2). Urea was the nitrogen source and the treatments were applied in the fall. Four installations were established in 1980 and forty-five each in 1981 and 1982.

The data collected for each installation included the following:

SITE CHARACTERISTICS

Slope, Aspect, Elevation, Topographic position, Vegetation type, Douglas-fir site index.

TREE CHARACTERISTICS

All trees (≥ 2" dbh): species; diameter breast height; total height; crown ratio; crown class; defect; diameter growth (2 year intervals); height growth (4 year intervals); year and cause of mortality.

Selected trees: breast height age; foliage samples (3rd whorl one year after treatment).

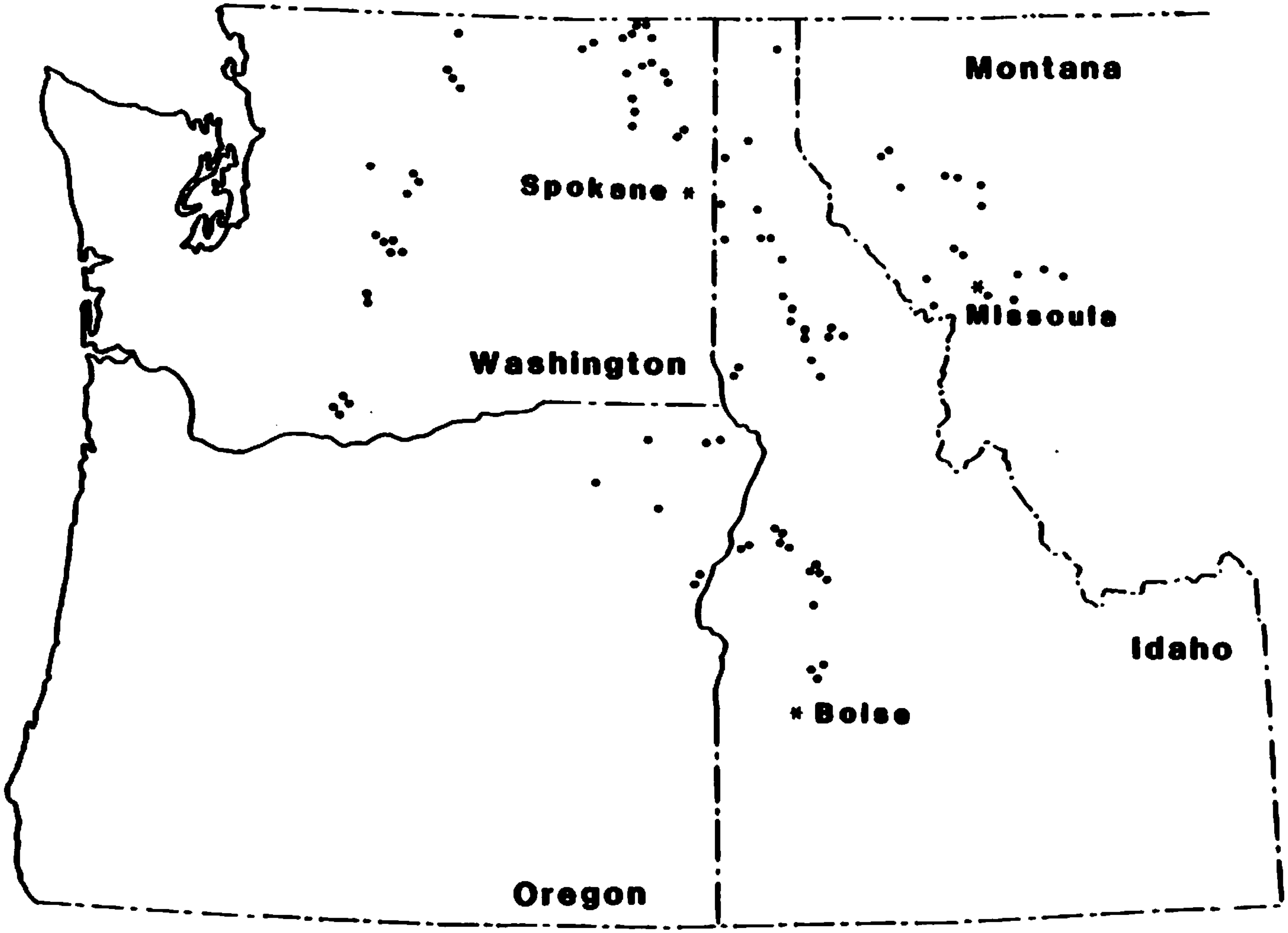

Figure 1 **INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE**

Douglas-fir Fertilizer Trial Locations

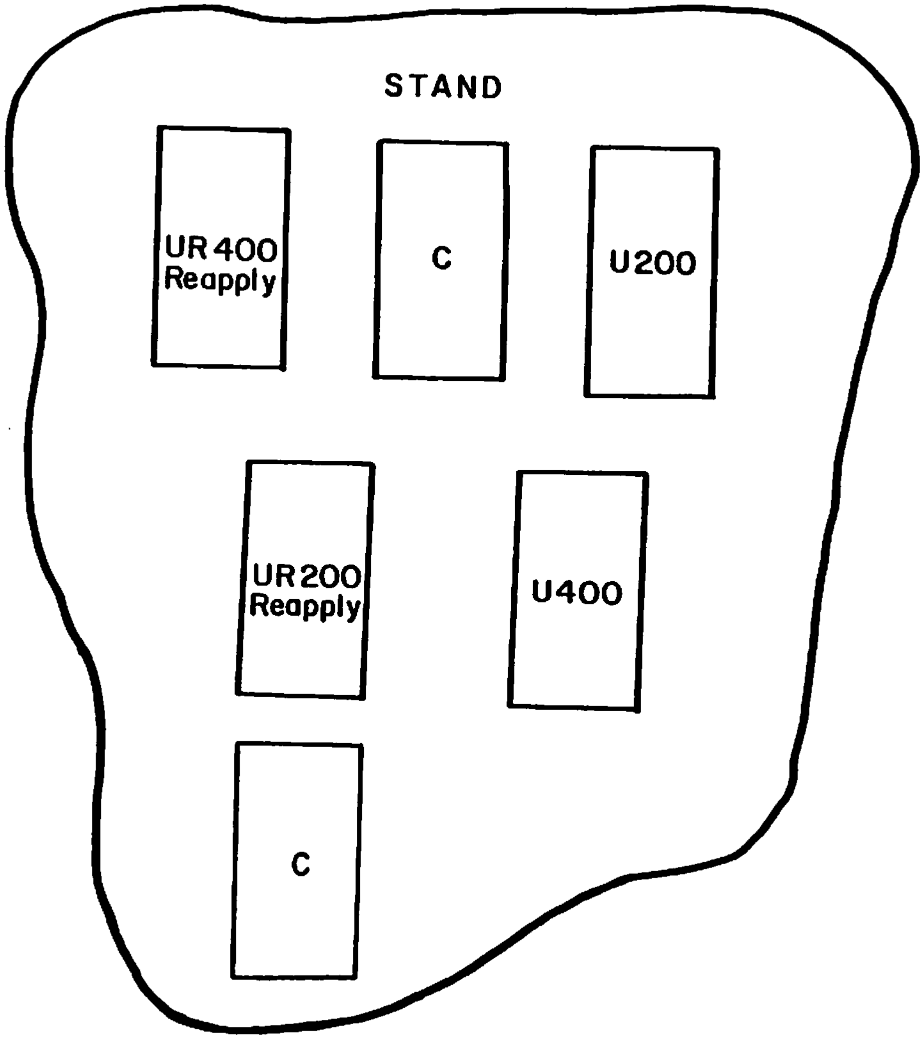

Figure 2. Plot design and layout and applied treatments for a hypothetical installation (stand). Eight stands will be sampled from each major series of each province. Plot size may vary with the distribution of tree species. C = Control; U200 = 224 kg./ha. Urea-N; U400 = 448 kg./ha. Urea-N; UR200 = reapply 224 kg./ha. Urea; UR400 = reapply 448 kg./ha.

SOIL CHARACTERISTICS

Physical properties: parent material; soil depth; ash depth; bulk density; percent coarse fragments.

Chemical properties: p.H.; total nitrogen; total phosphorous; total carbon; mineralizable nitrogen.

FOLIAGE CHARACTERISTICS

Needle weight; content and concentration for the following mineral nutrients: nitrogen, phosphorous, zinc, manganese, boron, iron, magnesium, copper, potassium, calcium.

OTHER VEGETATION

Percent cover of forbs and grasses on each plot; height and percent cover for shrubs on each plot.

In addition, two trees at each plot (from the large buffer or nearby) were felled for stem analysis. This provided about 1200 trees for which the following data were obtained:

total height; total age; dbh age; crown class; diameter inside and outside bark at nine locations along the main stem; annual growth from stem sections removed at breast height, live crown base, and two locations within the live crown; crown length; height growth for each of the past ten years; crown dimensions at live crown base and two locations within the live crown; branch growth and foliage samples at the same locations; defect or damage type and location along the main stem.

The IFTNC also initiated the ponderosa pine phase of the project in 1985. A total of ten installations were established, five each in the northeast Oregon and central Washington regions. Six additional ponderosa pine installations were established in Montana during 1987. The locations of the sixteen IFTNC ponderosa pine installations are shown in Figure 3. These installations have the same design and data collection procedures (except no

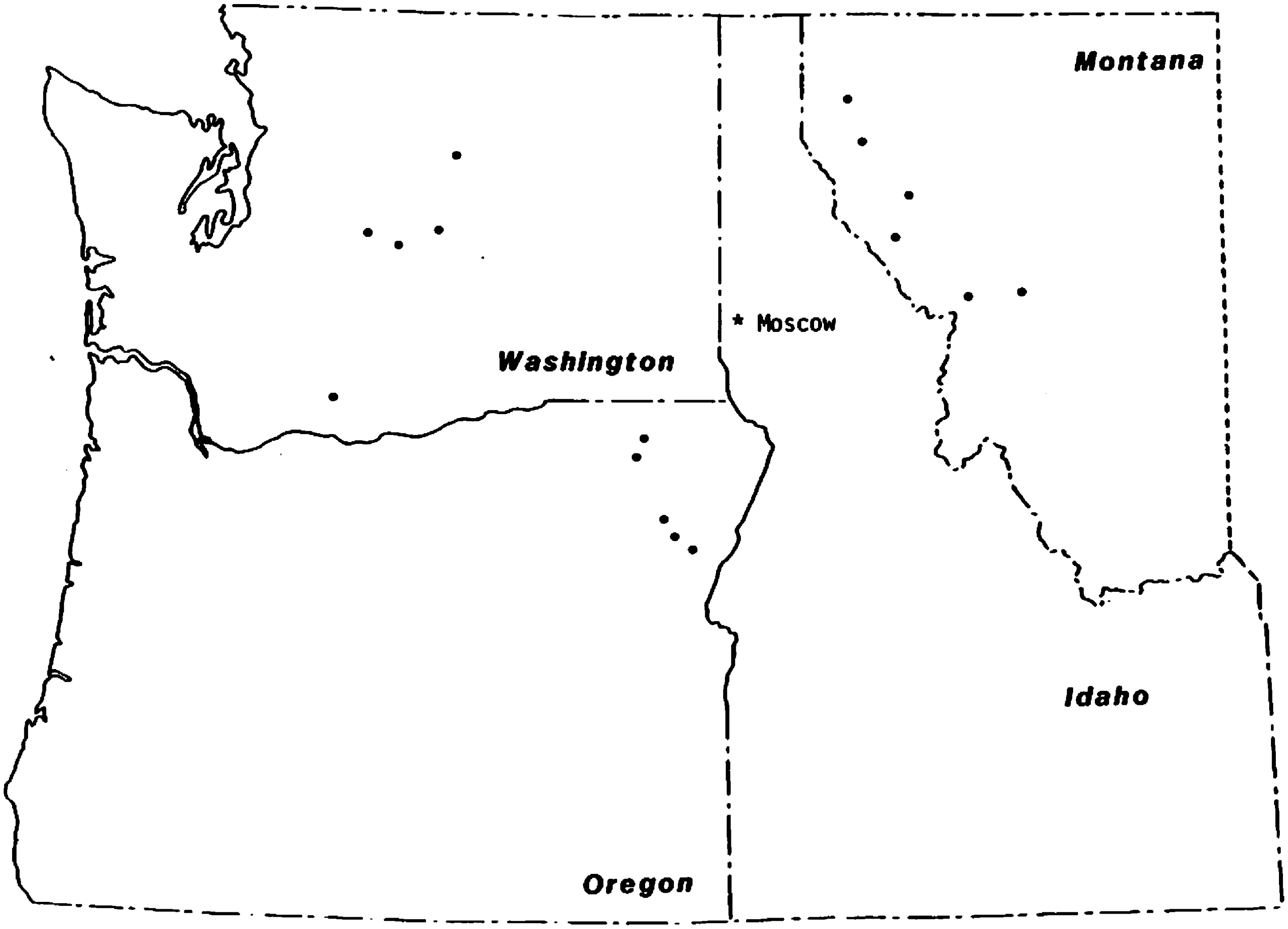

Figure 3 INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE
Ponderosa Pine Fertilizer Trial Locations

stem analysis data have been collected) as previously described for Douglas-fir.

For the remaining geographic regions of the Cooperative (north and central Idaho and northeast Washington) we hope to rely on previously existing ponderosa pine fertilization trials (Scanlin et al. 1978) from the University of Idaho. The locations of these stands are provided in Figure 4.

Similarly, fertilization response information for western larch will come from previously existing trials. One set of larch installations, primarily located in northern Idaho, was established by earlier researchers at the University of Idaho (Scanlin et al. 1978). Three larch installations in northeastern Washington were contributed by Region 6 of the USDA Forest Service. These installations were established, remeasured, and analyzed by the Regional Forest Nutrition Research Project at the University of Washington through a contract with the Colville National Forest. These locations are also shown in Figure 4.

Growth response estimates to nitrogen fertilization for grand fir are provided from a project contributed to the IFTNC by Potlatch Corporation to analyze a combination of previously established thinning and fertilization experiments in grand fir stands (Figure 5). These data include the longest period of growth response after fertilization available in the region, up to fourteen years.

The study designs, sampling methods, and fertilization treatments were different for the previously existing fertilization studies; but all contained at least control plots and a 200 lbs./ac. of nitrogen treatment. However, detailed foliage and soil nutrient information is lacking in all the previously existing fertilization trials.

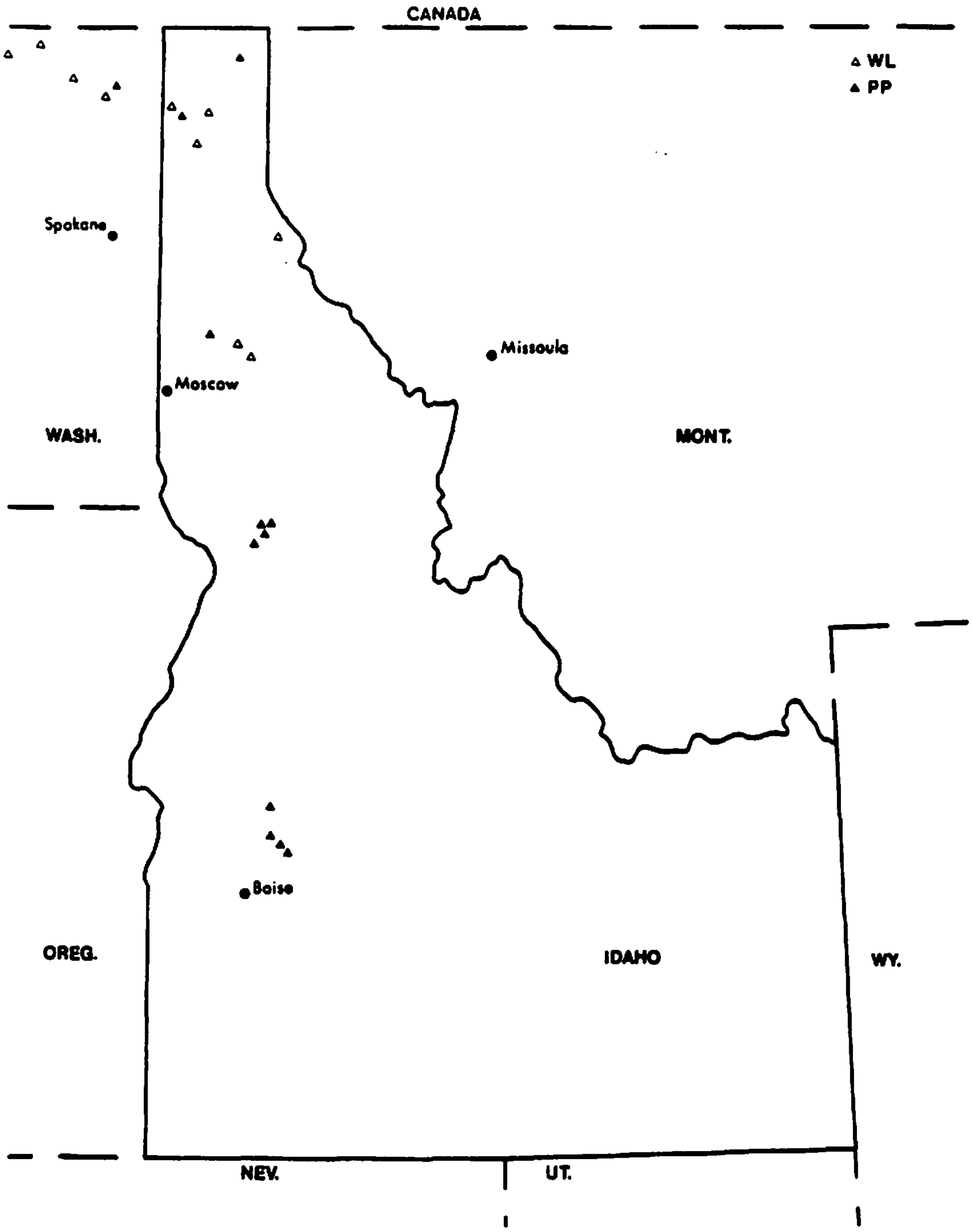

Figure 4 **Existing Ponderosa Pine and Western Larch Fertilizer Trial Locations**

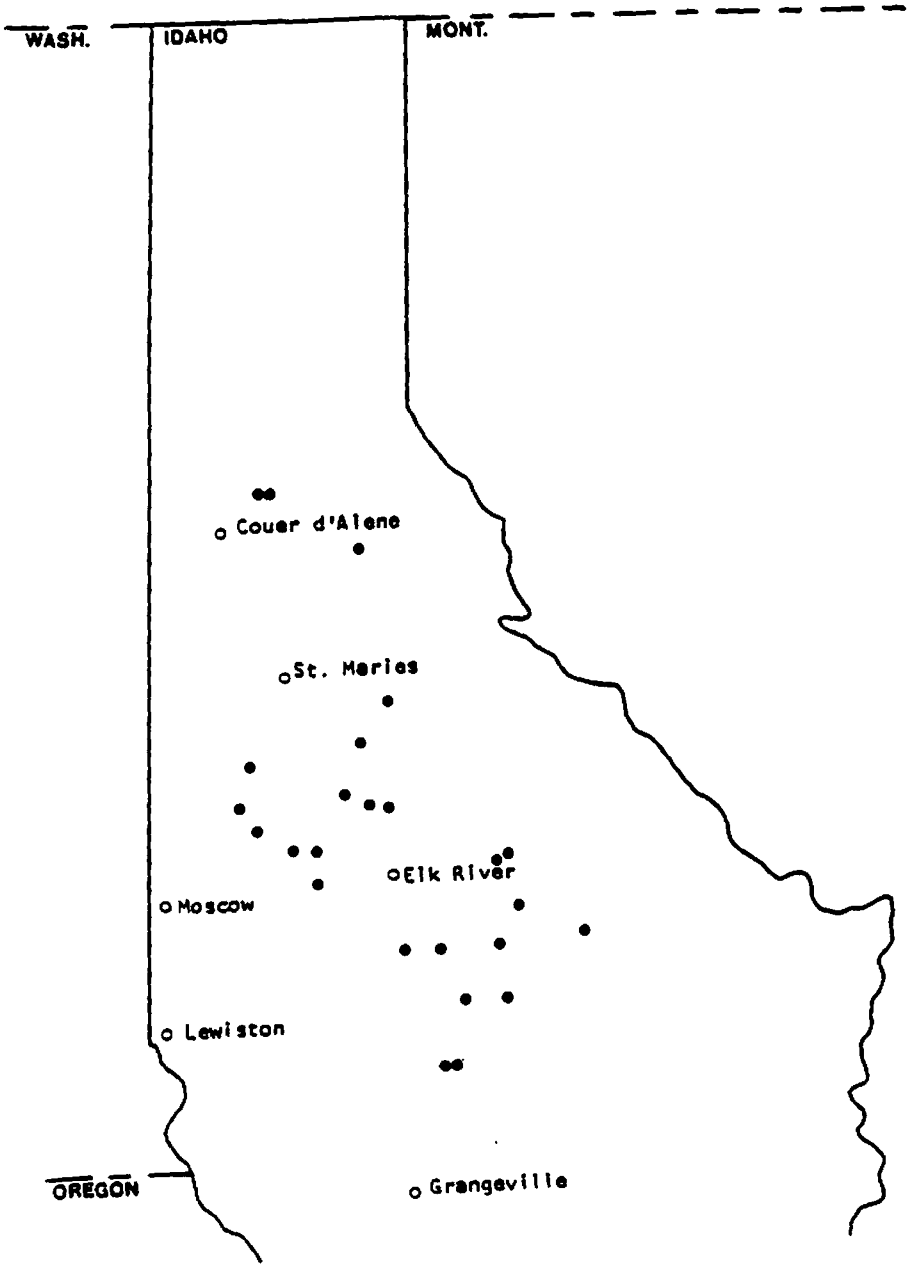

Figure 5 Existing Grand-fir Fertilizer Trial Locations

Response Results from the Douglas-fir Nitrogen Fertilization Trials

By

Jim Moore
University of Idaho

Four-year Growth Response of all Douglas-fir Test Sites:

General Description of the Analysis

Ninety-four installations were established in managed Douglas-fir stands (45 in both 1981 and 1982, and 4 in 1980). The distribution of these installations by geographic region and selected mensurational characteristics were provided to cooperators in previous annual reports. Each installation includes six plots, each plot a minimum of one-tenth acre in size. Nitrogen fertilization treatments were assigned to the plots randomly and applied in the fall. The treatments consisted of: (1) two plots with applications of 200 pounds per acre actual nitrogen, (2) two plots with applications of 400 pounds per acre actual nitrogen, and (3) two control plots. Urea was the nitrogen source. The diameters of all sample trees were measured before treatment and again after two and four growing seasons.

Four-year height increments and total heights were measured for all sample trees after the fourth growing season. Mortality was recorded by cause at each measurement period. Therefore, the following analyses are based on volume growth for four years after treatment. Volume equations used are from the prognosis model for total cubic foot volume.

Experimental design models:

The design models took the form:

INC = f (region, installation within region, block within installation, treatment, BA, BA^2)

where INC = the growth occurring in 4 years;

Region = the geographic region of the cooperative;

Treatment = the level of nitrogen fertilizer applied;

BA = the basal area (ft^2/A at the time of treatment).

Table 1. Average four-year net and gross cubic foot volume growth response by region and treatment.[1]

		Net Volume Increment			Gross Volume Increment		
		Total	Increase over control		Total	Increase over control	
Region	Treatment	ft^3/acre	ft^3/acre	percent	ft^3/acre	ft^3/acre	percent
Northern Idaho	Control	868			849		
	200 # N	983	115	13.3	1033	184	21.7
	400 # N	1008	140	16.1	1085	236	27.9
Montana	Control	436			475		
	200 # N	465	29 NS	6.8	564	88	18.6
	400 # N	462	26 NS	6.1	558	83	17.4
Central Idaho	Control	635			651		
	200 # N	745	110	17.3	752	101	15.6
	400 # N	717	82	12.9	754	103	15.9
Northeast Oregon	Control	546			584		
	200 # N	541	-5NS	-0.9	640	56	9.5
	400 # N	540	-6 NS	-1.0	658	74	12.6
Central Washington	Control	654			660		
	200 # N	840	185	28.3	850	190	28.9
	400 # N	922	268	40.9	944	284	43.0
Northeast Washington	Control	548			718		
	200 # N	759	111	17.1	822	104	14.6
	400 # N	667	19 NS	2.9	825	107	14.9
Overall	Control	646			669		
	200 # N	748	102	15.7	799	130	19.5
	400 # N	748	102	15.8	830	161	24.1

[1] Averages are adjusted to a common initial basal area of 150 ft^2/A.

NS = Not Significant
(α = .1)

Growth responses reported here are smoothed estimates. The estimates are adjusted for initial basal area as indicated by the statistical model shown above and described in more detail in reports to Cooperators.

Volume Growth Response:

The results for net and gross volume growth response are similar to those for basal area growth. The net and gross volume growth estimates by region and treatment are given in Table 1 and shown in Figure 1. The gross volume per acre increments for both nitrogen treatments are significantly greater than the controls across all geographic regions. Only in central Washington and northern Idaho is the gross volume growth for the 400 lb treatment significantly greater than the 200 lb treatment.

There is no statistical difference in net volume increment for the 400 lb treatments and the controls in northeast Washington, and no difference between either fertilizer treatment and the controls in Montana and northeast Oregon. Central Washington showed the greatest net volume growth response to both nitrogen treatments (200 lb N = 185 ft^3, 28.3%; 400 lb N = 268 ft^3, 40.9%). The net volume growth for the 400 lb treatment is significantly greater than the 200 lb treatment in central Washington.

Variation in Growth Response to Nitrogen Fertilization Across Installations

So far in the discussion of results we have been comparing average responses by treatment and geographic region. This approach is useful for drawing general conclusions, but averages tell us nothing about the variation in response to nitrogen fertilization between installations. In every region some stands responded well to nitrogen fertilization and others did not respond at all. The variation in treatment response across the entire

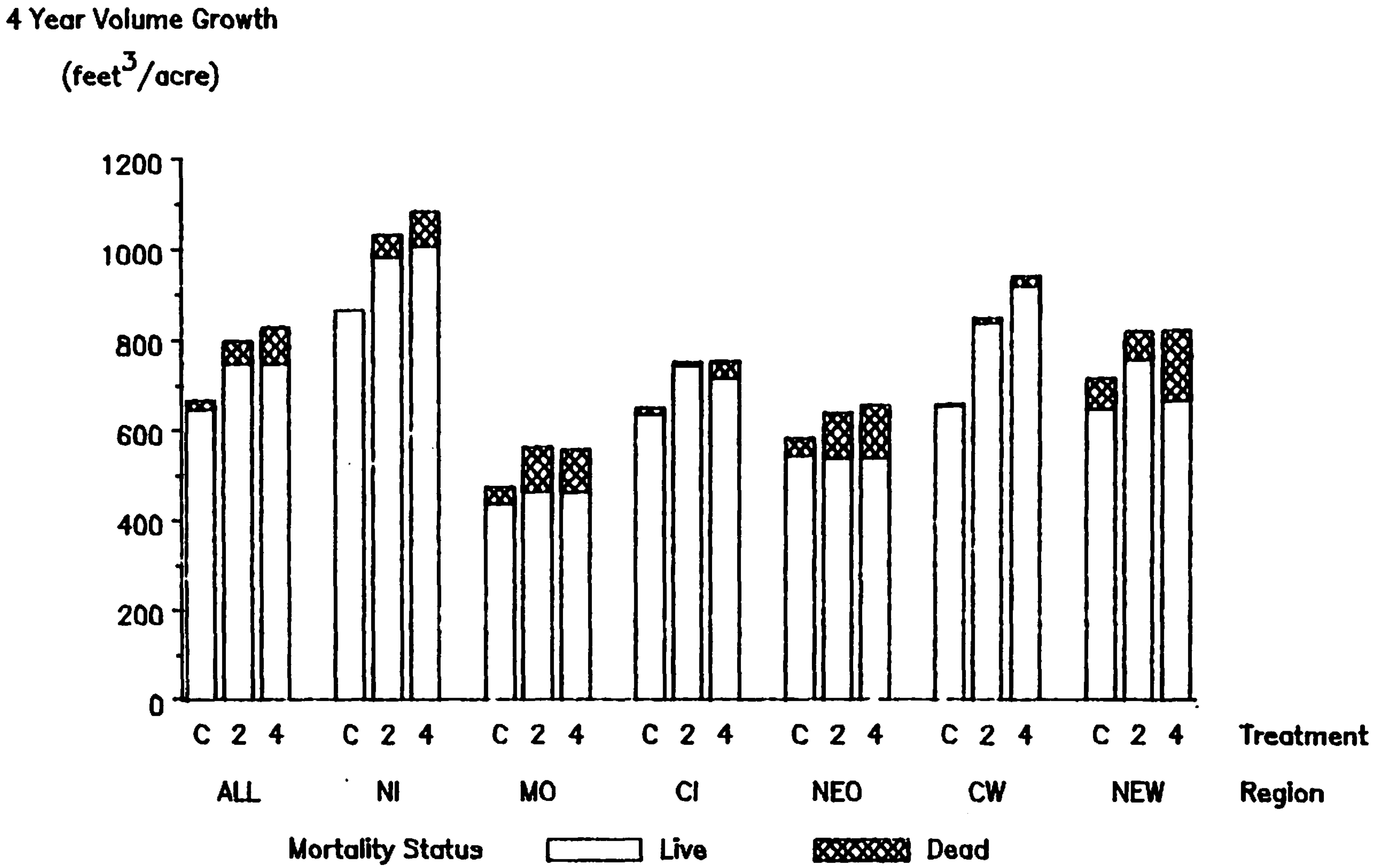

Figure 1. FOUR-YEAR VOLUME INCREMENT BY REGION AND TREATMENT PARTITIONED INTO LIVE (NET) AND DEAD COMPONENTS.

experiment is shown in Figure 2. This figure is the cumulative distribution of net four-year volume growth response to the nitrogen treatments. This information can be potentially useful to cooperators. For example, if an organization specified 100 ft^3/A (25 ft^3/A/yr.) (or any specified amount) as the minimum treatment response required to make an acceptable return on investment, then Figure 2 can be used to estimate the probability of obtaining at least this response for the population of managed Douglas-fir stands represented by our sample. The solid vertical line in Figure 2 is located at 100 ft^3/A. Our data indicate that about 52 percent of the stands would produce a response greater than 100 ft^2/A for the 200 lb nitrogen treatment. Similarly for the 400 lb treatment the probability is about 57 percent. One of the IFTNC's objectives is to explain the variation in response to nitrogen fertilization so that operational treatments can be targeted at those stands with a high probability of "substantial" response. We can now explain much of the variation in response, at least preliminarily based on four-year results. The following example illustrates this process. We know that response to nitrogen fertilization is significantly different by geographic region. The probability of obtaining the previously specified response of 100 ft^3/A varies significantly by region and in some cases by nitrogen treatment. This is summarized in Table 2. The chances of obtaining at least this response to the 200 lb treatment are very good in central Washington, good in northern Idaho, and very small in Montana.

We also know that stand density and soil characteristics significantly affect response to nitrogen treatments. Within each region we can further refine the likelihood of obtaining the specified 100 ft^3/A response by using soil parent material as a predictor variable. These results are given in

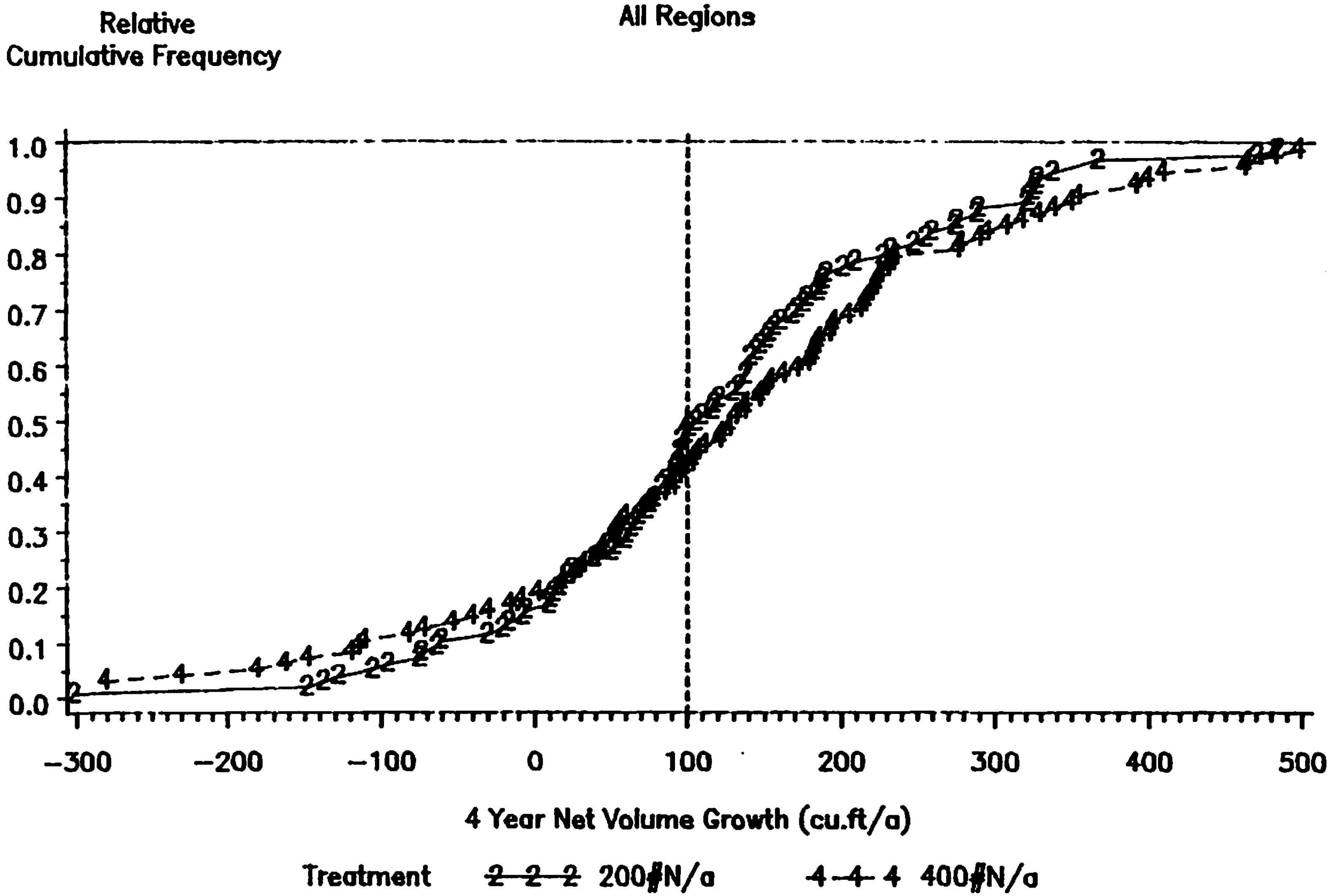

Figure 2. THE CUMULATIVE DISTRIBUTION OF NET FOUR-YEAR VOLUME GROWTH RESPONSE TO THE NITROGEN TREATMENTS FOR THE ENTIRE DOUGLAS-FIR EXPERIMENT.

Table 2. The Probability of Obtaining a four-year Net Volume Response Greater than 100 Cubic feet per Acre by Geographic Region and Treatment.

Region	200#N	400#N
Northern Idaho	75%	78%
Montana	12%	20%
Central Idaho	36%	50%
Northeast Oregon	22%	33%
Central Washington	80%	84%
Northeast Washington	59%	40%
Overall	50%	55%

Table 3. In northern Idaho, the only installations (4) not producing a response greater than 100 ft^3/A are on ash/metasediments. Obviously, the likelihood of a substantial four-year response to fertilization with 200 lbs of nitrogen in northern Idaho is very high. Conversely, in Montana the chances of such a response is low. However, the probability would be improved somewhat by only fertilizing glacial tills and valley fill soils. For central Idaho, basalts are more likely to respond to nitrogen fertilization than granitic soils, and the same situation is true for northeast Oregon. In central Washington 80 percent of the installations produced a net volume response greater than 100 ft^3/A. All ten of the stands located on basalt and sandstone soils responded more than 100 ft^3/A in four years to 200 lb of nitrogen. For northeast Washington, nearly all installations are on glacial tills, so there is no real improvement over the region's cumulative distribution (Table 2). As a point of interest, in the "other" category in northeast Washington, the responding stand was on a basalt soil and the non-responder on granite.

The process we have been going through in this section of the report attempts to "screen-out" non-responding installations (i.e., those < 100 ft^3/A in four years). This is one of the major goals of the cooperative. The results suggest that we are fairly successful in the screening process using region and parent material. Naturally the average response to nitrogen fertilization is much higher for the responding stands in the population than for the overall average response. This is shown in Table 4, which gives the average net volume response by region for responding illustrations in a region. The purpose of the data in Table 4 is to illustrate what might be gained by applying what we know to "screen-out" non-responding stands.

Table 3. The Number of Installations Producing a Net Volume Response of More than 100 ft^3/A to the 200 lb Nitrogen Treatment by Region and Parent Material.

Region	Parent Material	Number of Responding Stands (>100 ft^3/A)	Total Number of Stands	Percent of Stands Responding
Northern Idaho	Ash-loess	5	5	100%
	Ash/metasediments	8	12	67%
	Others	2	2	100%
Montana	Glacial till	1	4	25%
	Valley fill	1	4	25%
	Others	0	8	0%
Central Idaho	Granite	2	8	25%
	Basalt	3	6	50%
Northeast Oregon	Basalt	2	7	29%
	Others	0	2	0%
Central Washington	Basalt & Sandstone	10	10	100%
	Glacial till	3	5	60%
	Others	2	4	50%
Northeast Washington	Glacial till	9	15	60%
	Others	1	2	50%

Table 4. Average four-year net cubic foot volume growth response to the 200 pound nitrogen treatment for responding and all installations by region.

Region	Responding Installations 1] (>100 ft^3/A) ft^3/A	All Installations 1] ft^3/A
Northern Idaho	228	159
Montana	159	35
Central Idaho	229	113
Northeast Oregon	164	56
Central Washington	254	202
Northeast Washington	207	126
Overall	226	124

1] These responses are adjusted to individual installation average basal area rather than the overall average basal area of 150 ft^2/A.

The Relationship Between Other Mineral Nutrients and the Response to Nitrogen Treatments:

The post-treatment foliar nitrogen levels are given by region in Table 5. These values are derived from all 90 Douglas-fir installations established in 1981 and 1982. The average foliar nitrogen concentration for the untreated control plots is only 1.1 percent. This is very low compared to results from studies in other regions. It has been suggested by some studies that significant response to nitrogen can be expected if foliar N levels are below 1.6 percent. Notice that the foliar N levels for the 200 lb nitrogen treatment, while significantly greater than the controls, do not reach 1.6 percent. It is only with the 400 lb treatment that we approach this level. Why then wasn't the two-year growth response to the 400 lb treatment significantly greater than the 200 lb treatment based on all 90 installations? In the cases where additional nitrogen did not produce additional increment, it is likely some other factors limited growth. Central Washington produced the greatest response to both nitrogen treatments, and the 400 lb treatment was significantly greater than the 200 lb treatment. This is the kind of response pattern we would expect from a nitrogen limited forest system. However, the foliar nitrogen concentration values for the control plots in other regions were even lower than central Washington. This suggests that nitrogen also limits growth in the other regions. Central Washington is not the most productive of our IFTNC regions based on comparing untreated control height and volume increments. Central Washington ranks behind northern Idaho and northeast Washington and about the same as central Idaho in terms of productivity. Why does central Washington respond so well to nitrogen fertilization? One clear difference between central Washington and the other

Table 5. Average foliar nitrogen concentration by geographic region.

Region	Control	Nitrogen Percent 200 lb	400 lb
North Idaho	1.10	1.35	1.86
Montana	1.11	1.37	1.84
Central Idaho	1.02	1.32	1.67
Northeast Oregon	1.21	1.24	1.47
Central Washington	1.20	1.44	1.81
Northeast Washington	1.13	1.41	1.67

regions is in foliar potassium (K) concentrations before and after nitrogen fertilization. The average foliar K concentrations by region and treatment are given in Table 6. Central Washington control plots have foliar K concentrations well above the other regions and the K concentrations remain about the same after nitrogen treatments. Northern Idaho, Montana, and northeast Washington control plots are low in foliar K and show a noticeable drop in K concentrations after nitrogen treatments. In northern Idaho and Montana, the average values are at or below an estimated inadequate foliar K concentration of 6000 ppm (Webster & Dobkowski, 1983). Even though the installations in central Idaho and northeast Oregon do not exhibit the pattern of decline in foliar K after nitrogen treatments, the values are low and are well below the estimated marginal K concentration of 8000 ppm (Webster & Dobkowski).

Another way to analyze nutrient status is to examine balances between nutrients. Ingestad (1966) proposed a set of "standards" for nutrient ratios. In this approach other nutrients are expressed as a percent of nitrogen concentration in the foliage. These potassium/nitrogen ratios are given by region and treatment in Table 7. A ratio of 50 is low, and a value below 40 would be cause for concern. Notice that the average K/N ratios for the 400 lb nitrogen treatments in northern Idaho, Montana, and northeast Washington are all below 40.

The trends in foliar K concentrations and K/N ratios by nitrogen treatments are even more noticeable when compared by soil parent material. Average foliar K concentrations by soil parent material and nitrogen treatment are provided in Table 8. Ash-loess, glacial tills, ash/metasediments, and colluvium soils all begin with low K concentrations (the control plots) and

Table 6. Average foliar potassium concentration by geographic region and treatment.[1]

Region	Potassium concentration (PPM)		
	-Treatment-		
	Control	200lb.N	400lb.N
Northern Idaho	6316	6049	5625
Montana	6249	6056	6081
Central Idaho	6092	5928	6645
Northeast Oregon	6630	6823	6800
Central Washington	7210	7317	7248
Northeast Washington	6880	6297	6132
Overall	6568	6390	6366

[1] Estimated marginal foliar K concentration is 8000ppm.
Estimated inadequate foliar K concentration is 6000ppm.

Table 7. Average ratios of foliar potassium and nitrogen concentrations by geographic region and treatment.[1]

Region	Ratio (K/N*100) -Treatment- Control	 200 lb N	 400 lb N
Northern Idaho	58	45	32
Montana	57	45	35
Central Idaho	60	46	41
Northeast Oregon	59	57	47
Central Washington	60	53	43
Northeast Washington	61	45	37
Overall	59	48	38

[1] Ingestad suggests that 65 is "optimal" and 50 is "marginal".

Table 8. Average foliar potassium concentrations by soil parent material and treatment.[1]

Parent Material	Potassium concentration (PPM) -Treatment- Control	 200lb.N	 400lb.N
Granite	5881	6345	6583
Ash-loess	6149	5704	5310
Basalt	6918	6634	6824
Glacial till	6680	6319	6202
Ash/metasediments	6524	6289	6111
Valley fill	6199	5571	6704
Colluvium	5985	6064	5369
Alluvium	6653	6778	6714
Sandstone	8127	8574	8381
Overall	6568	6390	6366

[1] Estimated marginal foliar K concentration is 8000ppm.
Estimated inadequate foliar K concentration is 6000ppm.

show noticeable decreases with the nitrogen treatments. This is particularly true for ash-loess and colluviums given the 400 lb nitrogen treatments. The average K concentrations are well below the suggested inadequate level of 6000 ppm. The K decline for glacial tills would be even greater if the glacial till soils in central Washington were excluded; none of them showed a large decrease with nitrogen treatments! The other parent materials generally were low for the untreated control plots but remained at about the same level after nitrogen treatments. Granites and valley fills (for the 400 lb nitrogen treatment) increased in foliar K concentrations after nitrogen treatments. The foliar K levels for sandstone soils are the highest we sampled in the study and remain high for all treatments (they are even above the suggested marginal concentration of 8000 ppm). Perhaps it is not a coincidence that these soils produced the highest average absolute and relative response to the nitrogen treatments in the entire experiment.

The average K/N ratios by parent material and nitrogen treatment (Table 9) clearly show the foliar K decreases after nitrogen fertilization. The nitrogen treatments produced a noticeable decrease in the foliar K/N ratios for all parent materials. The decrease is largest for ash-loess, ash/metasediments, glacial till, valley fill, and colluvium soils. The foliar K/N ratios remained at "acceptable" levels after nitrogen treatments for sandstone.

We have carefully examined the foliar concentrations and Ingestad ratios for the following other mineral nutrients: phosphorous, calcium, magnesium, zinc, manganese, boron, iron, and copper. Except for a few cases for boron and iron, none of the other nutrients suggested the kind of potential problem we may have with potassium.

Table 9. Average ratios of foliar potassium and nitrogen concentrations by parent material and treatment.[1]

Parent Material	Ratio (K/N*100) -Treatment- Control	200 lb N	400 lb N
Granite	58	50	42
Ash-loess	57	43	29
Basalt	61	49	43
Glacial till	61	47	37
Ash/metasediments	57	46	34
Valley fill	52	39	37
Colluvium	57	46	32
Alluvium	61	50	38
Sandstone	59	61	49
Overall	59	48	38

[1] Ingestad suggests that 65 is "optimal" and 50 is "marginal".

The following is an interesting paraphrase taken from Jorgensen and Wells (1987): . . . . unlike nitrogen, the effects of potassium can persist over a longer time because it can be recycled with few leaching losses.

LITERATURE CITED

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Jorgensen, J.R. and C.G. Wells. 1987. A loblolly pine management guide: Foresters primer in nutrient cycling. U.S.D.A. For. Serv. GTR SE-37, 42p.

Webster, S.R. and A. Dobkowski. 1983. Concentrations of foliar nutrients for trees and the dosage and frequency of fertilizer trials. Weyerhaeuser Res. Rpt. No. 1, 25p.

SOME RESPONSE RESULTS FOR LODGEPOLE PINE, GRAND FIR, WESTERN LARCH AND PONDEROSA PINE

by
Pat Cochran
and
Jim Vander PLoeg

Direct and Indirect Response:

When a positive response to fertilization occurs, growth is influenced both directly and indirectly. First there is an immediate change in the nutritional status of the tree which allows increased crown production, higher rates of photosynthesis, more rapid root development and more bole wood growth. As time since fertilization increases, increased growth rates result in higher stocking levels and perhaps other changes in stand structure. Thus increased growth rates over nonfertilized portions of the same stand are due in part to increased stocking levels.

An example of the effect of stand density on growth rates for white fir is illustrated by plotting the percent of gross periodic annual increments at full stocking as a function of percent of full stocking (fig. 1). Notice that at the lower stocking levels there is a rapid increase in growth of basal area and volume as stocking levels are increased. When stocking levels reach 50 to 60 percent of full stocking, rates of growth taper off as stocking levels continue to increase. The figure shows that it is possible to capture nearly all of the potential growth with stocking levels that are 75% of normal or below. Treatments such as fertilization which would speed the development of stocking levels in heavily thinned stands toward 60% of full stocking would increase growth while concentrating this growth on fewer stems than unthinned stands.

Lodgepole pine:

The relative importance of increased tree nutrition and increased stocking levels on rates of growth changes with time since fertilization. This is illustrated by a fertilization study in thinned lodgepole pine which was remeasured 4, 8, and 13 years after application. In this study (fig. 2) percent increases in growth were calculated using the formula shown. For the second and third periods percent increases in growth were calculated two different ways. For one set of percentages - the ones in parenthesis - the initial value in the numerator was the value at the time of fertilization. For the other set of percentages the

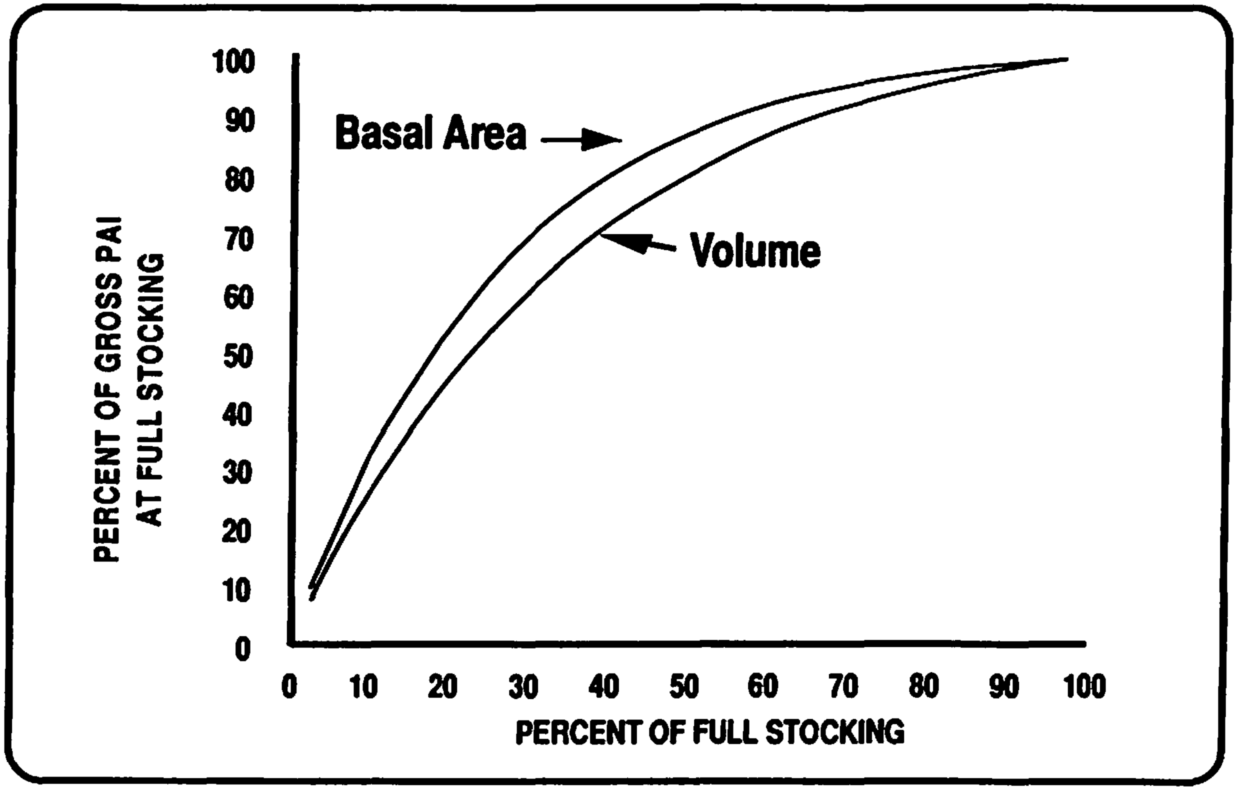


Figure 1: Effect of stand density on growth rates for white fir.

$$\% \text{ Increase} = \frac{(\text{Final Value} - \text{initial Value})\,100}{(\text{Initial Value})(\text{number of growing seasons})}$$

Period	Percent Increase in Growth			
	Volume		Basal Area	
	Fertilized	Control	Fertilized	Control
1	11.6	5.5	9.9	4.7
2	10.9 (15.9)	7.1 (8.8)	8.3 (11.7)	5.3 (6.4)
3	6.2 (13.2)	6.3 (10.0)	4.7 (9.0)	4.4 (6.6)

Figure 2: Percent increases in growth of lodgepole pine for direct and indirect response to fertilization.

initial value in the numerator was the value at the start of each period (Initial value in the denominator is always the value at the beginning of the period and number of growing seasons refers to the period). Note that for period two, percentages calculated in both ways are higher for the fertilized treatments. For period three the percentages calculated using values at the start of the period as initial values are not significantly higher for the fertilized treatment. However at the start of period three, stocking levels for the fertilized plots are now higher than for the control treatments, so percentages calculated using values at the start of the study as initial values in the formula continue to be higher. This is further illustrated by looking at gross volume PAI as a function of basal area at the start of each period (fig. 3). Note that the regression lines for the fertilized plots are significantly higher than the regression lines for the control plots for the first two periods. However, for the third period the regression lines merge indicating that at the same level of basal area, growth rates for both treatments were the same for 9th through the 13th growing seasons after treatment. Figure 4 gives the adjusted means for this study for two different analyses of covariance. For one set the covariate was the basal area at the start of the study for each of the three periods. For the other set the covariate was the basal area at the start of the period as shown in fig. 3. Results are the same as with the use of percentages calculated in two different ways.

Grand fir:

Let's now consider some growth rates of grand fir in response to fertilization and thinning (fig. 5). Notice that in the first two year period since treatment, thinning decreased growth rates per acre and fertilization increased growth rates per acre. As time goes by the difference in growth rates between the thinned and control treatments narrows - an indication that the thinned plots are rapidly building stocking levels. Plots that were both fertilized and thinned grew more than the other treatments in periods three and four, indicating both the importance of increased tree nutrition and increased levels of stocking. Figure 6 shows height growth response for the same study.
The most interesting aspect of this study is the influence of treatment on tree size (fig. 7). There is little difference in net volumes between treatments but a great difference in tree size, indicating the drastic influence of treatments on stand composition. Thinning concentrates growth on fewer stems/acre while fertilization projects a responsive stand forward in time.

Growth rates of grand fir as influenced by thinning and fertilization are also evident in the results of another

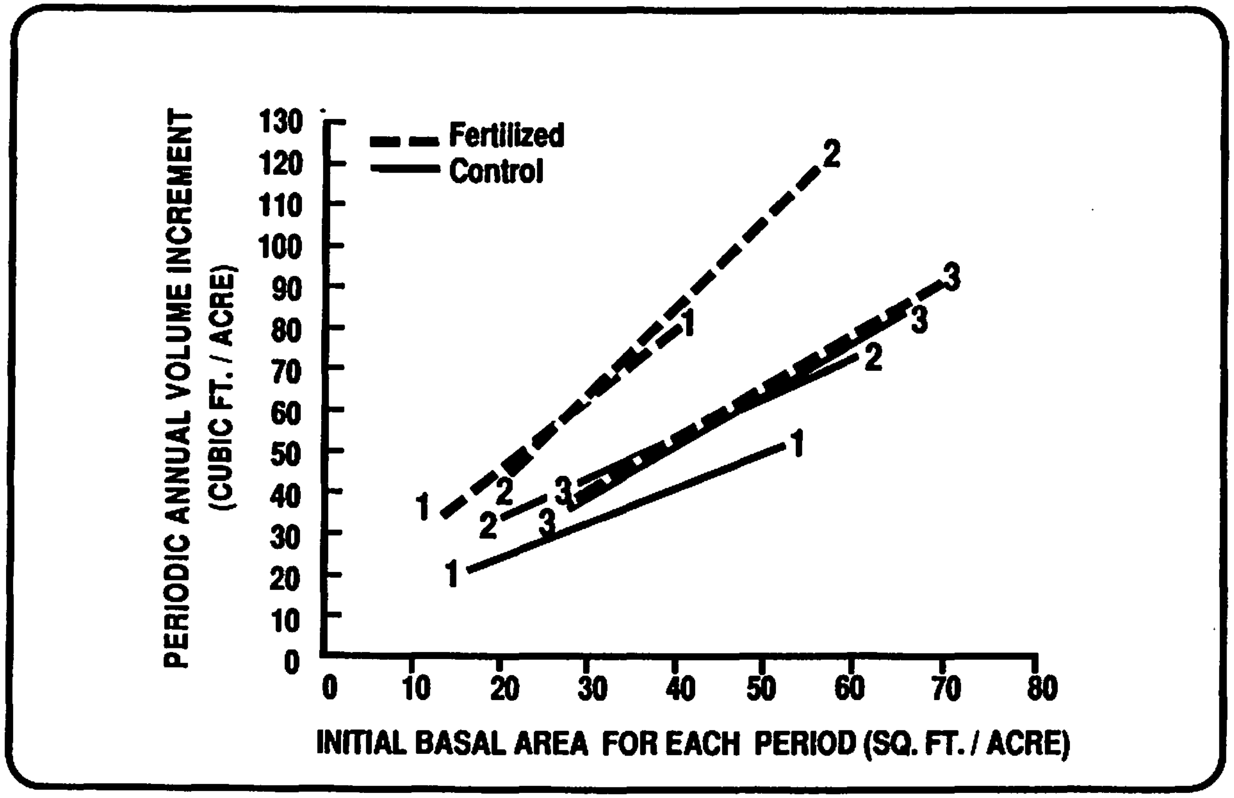


Figure 3: Gross volume PAI for lodgepole pine as a function of basal area at the start of each period.

Adjusted Means

Period	Volume		Basal Area	
	-----ft³/ac/yr-----		-----ft³/ac/yr-----	
	Fertilized	Control	Fertilized	Control
1	61.8	30.7	2.8	1.4
2	82.3 (88.3)	50.8 (48.3)	3.2 (3.3)	2.0 (1.9)
3	63.3 (70.4)	62.3 (55.3)	2.4 (2.5)	2.1 (2.0)

Figure 4: Adjusted means for lodgepole pine fertilization study for two different analysis of covariance.

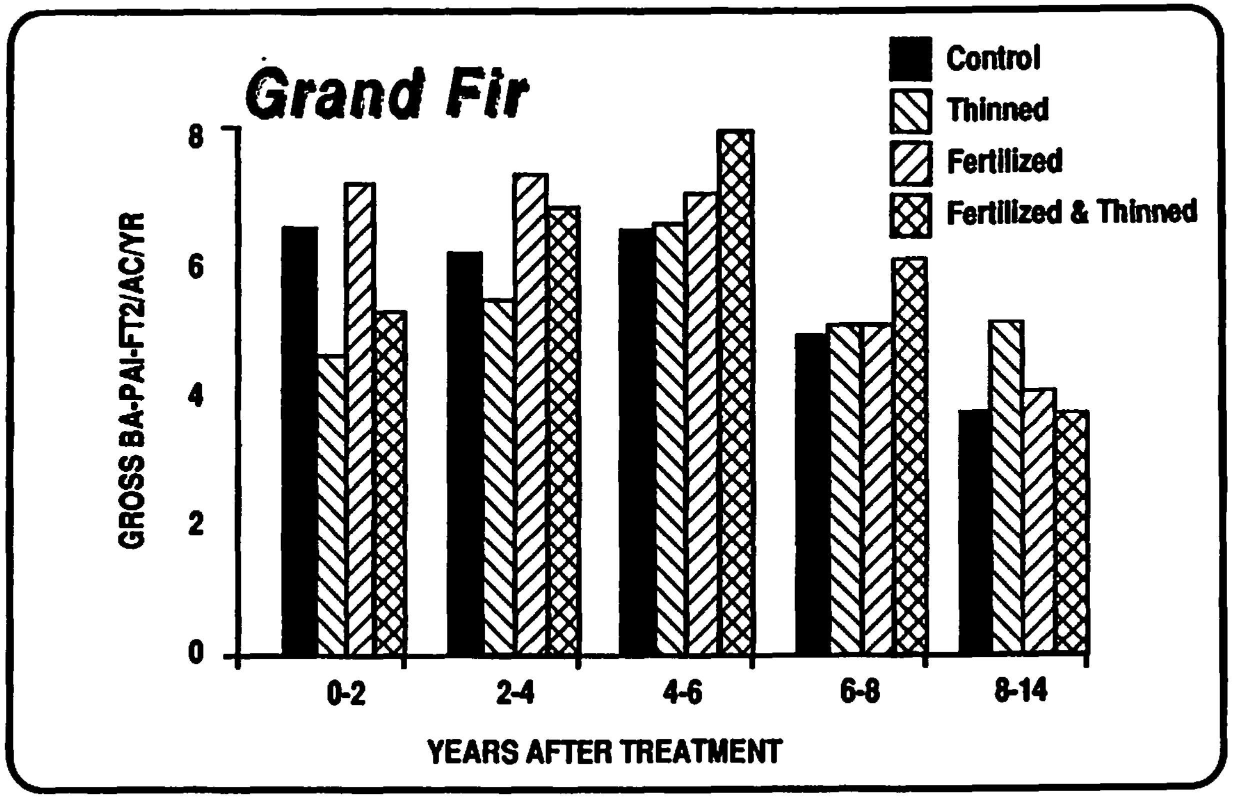


Figure 5: Gross basal area growth rates of grand fir in response to fertilization and thinning.

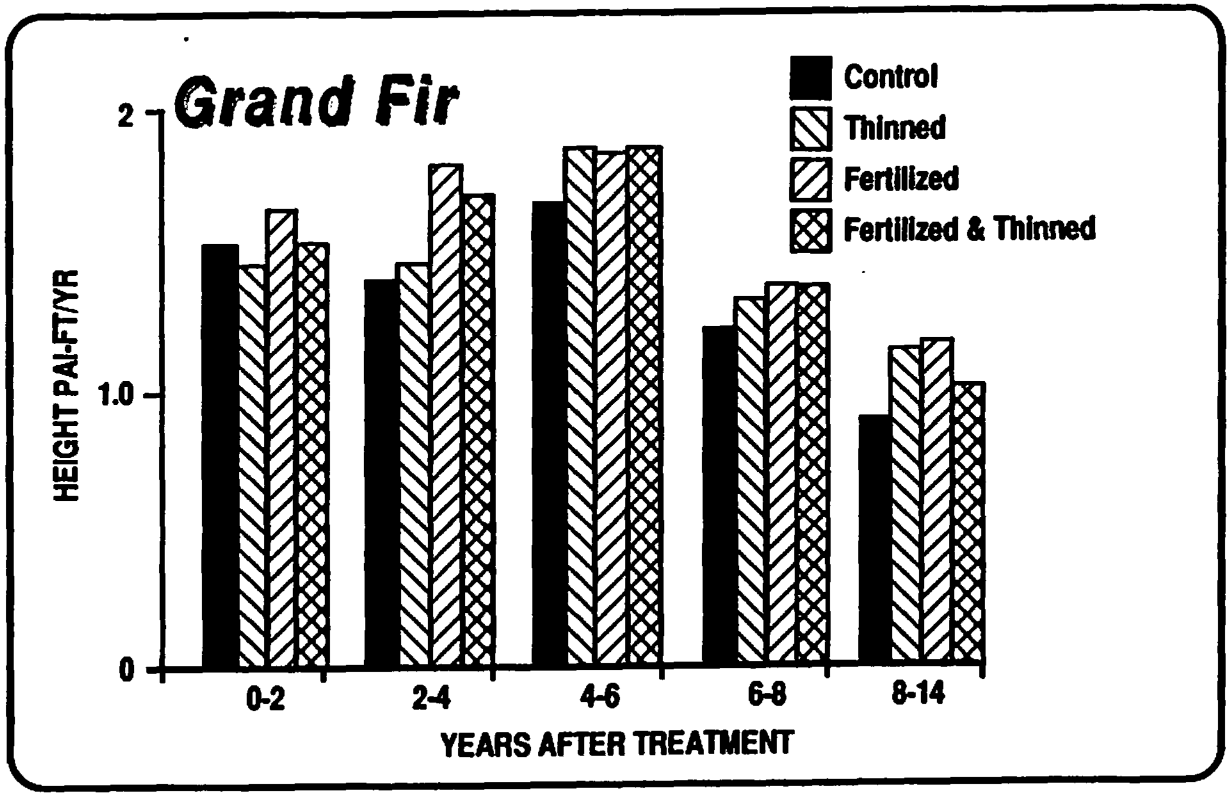
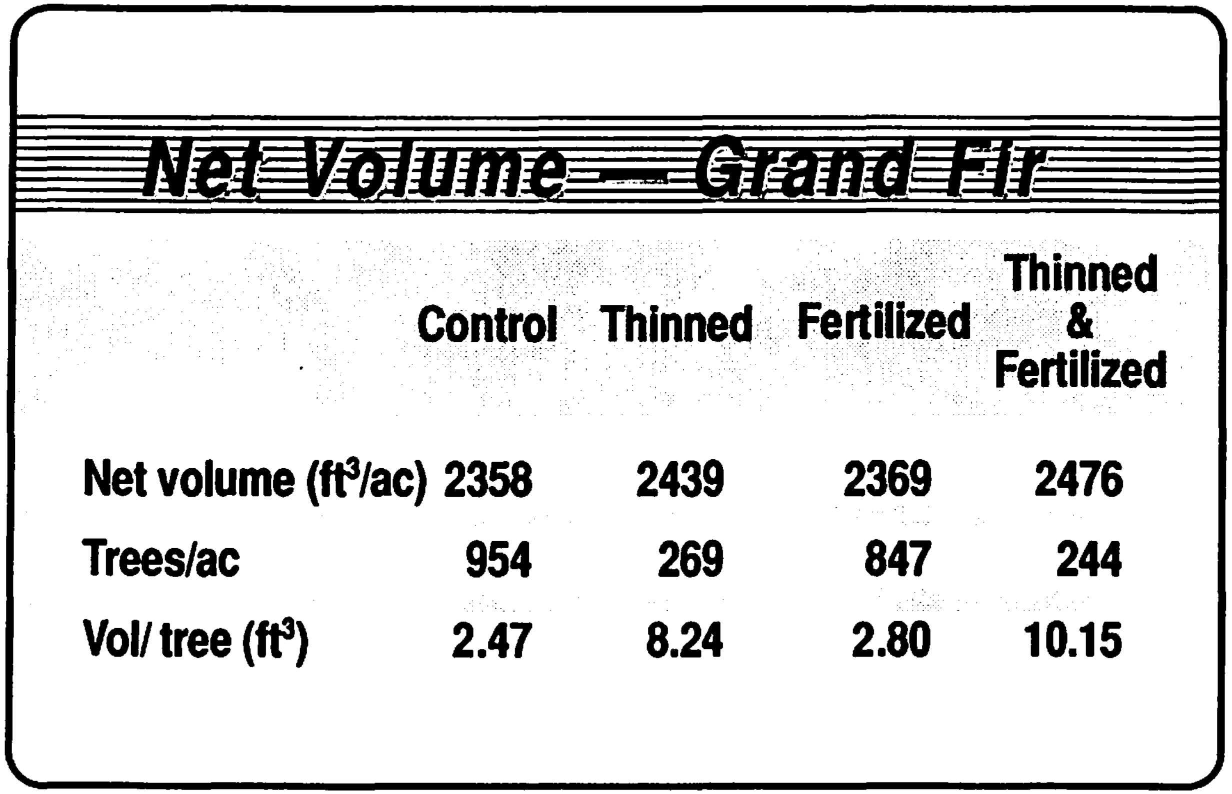


Figure 6: Height increment of grand fir in response to fertilization and thinning.



Net Volume — Grand Fir

	Control	Thinned	Fertilized	Thinned & Fertilized
Net volume (ft^3/ac)	2358	2439	2369	2476
Trees/ac	954	269	847	244
Vol/ tree (ft^3)	2.47	8.24	2.80	10.15

Figure 7: Average fourteen-year net cubic volume per acre, trees per acre, and cubic volume per tree of grand fir in response to fertilization and thinning.

study (fig.8). Here unthinned plots were fertilized with 100, 200 and 400 pounds N/acre while thinned plots were fertilized with 200 pounds N/acre. This figure shows that thinning only reduced growth for a short period of time but by the third period the fertilized and thinned treatments were growing as well as the other treatments.

Western larch:

Data for western larch are limited but fertilization in one study with 200 and 400 pounds N/acre applied to thinned plots did produce increased basal area growth (fig. 9). and volume growth (fig. 10). There was no difference in gross volume growth rates between the 200 and 400 pound treatments (fig.11) and the 200 pound treatment had the highest net growth.

Ponderosa pine:

Several studies in ponderosa pine are being monitored and the results vary. In one study in southwestern Idaho fertilization increased basal area and volume growth in three out of four installations (figs. 12 & 13). In installations scattered across eastern Washington, northeast Oregon and northern Idaho a summary of the results suggests an increase in growth with application of 200 pounds/acre of N and a slight additional increase with 400 pounds N/acre (fig. 14). However, results from individual installations are quite varied (as shown by the lines across treatment bars), ranging from no response to either rate, a response to 400 pounds N but not to 200 pounds N, a response to 200 pounds N/acre but not to 400 pounds N/acre, a near linear relationship with increasing amounts of nitrogen and no difference in response between the 200 and 400 pound treatments.

Summary:

This brief discussion of results from specific studies of the response of other species to nitrogen fertilization suggests that:

1) All species investigated (lodgepole pine, grand fir, western larch and ponderosa pine) showed significant positive response to nitrogen fertilization at some locations.
2) Fertilization has a direct effect by changing the nutritional status of the stand and an indirect effect of increasing stocking levels by projecting the stand forward in time.

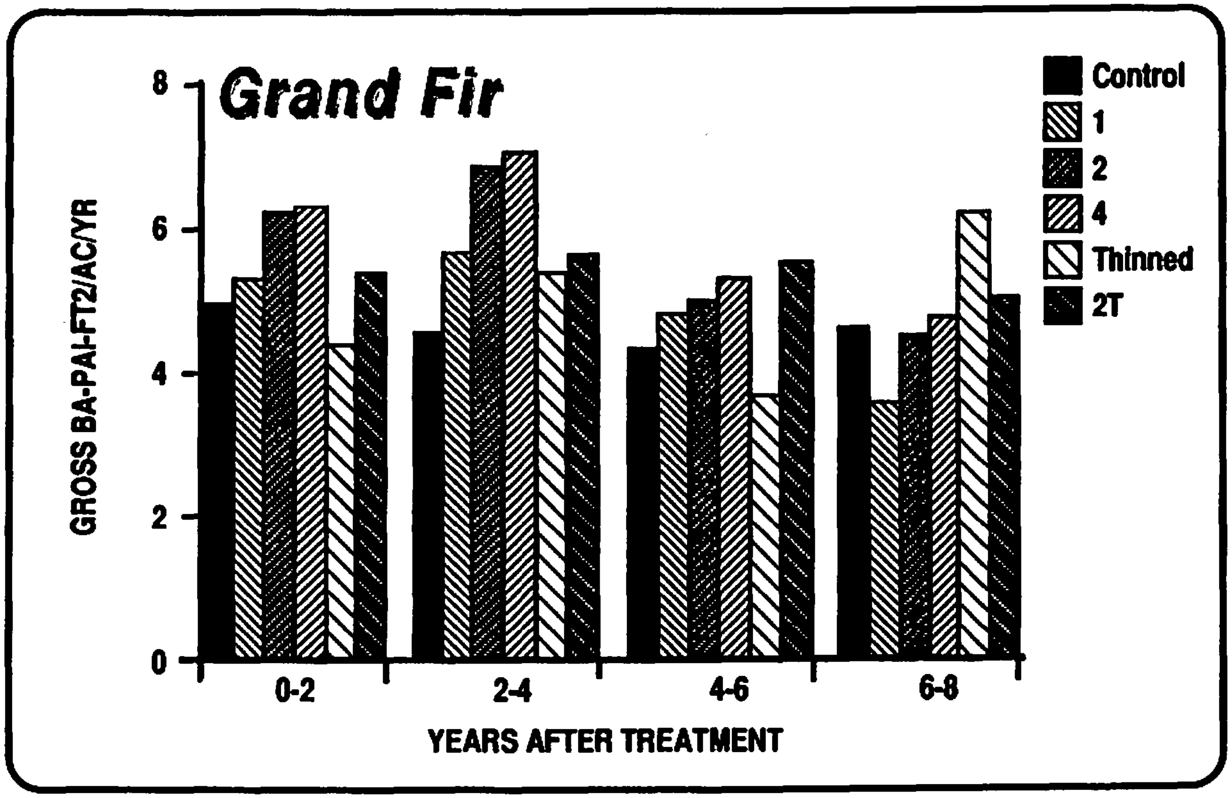


Figure 8: Gross basal area growth rates of grand fir in response to fertilization and thinning for three levels of nitrogen fertilizer treatments.

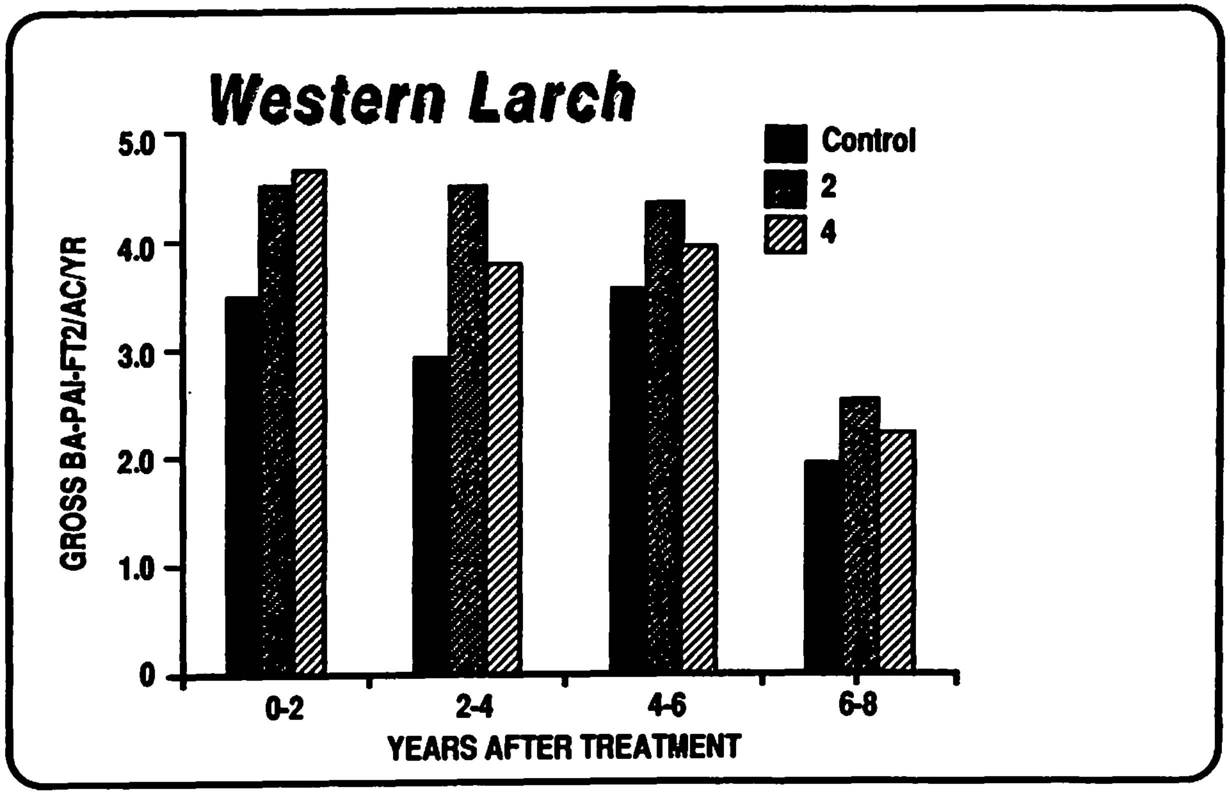


Figure 9. Gross basal area growth of western larch in response to nitrogen fertilization.

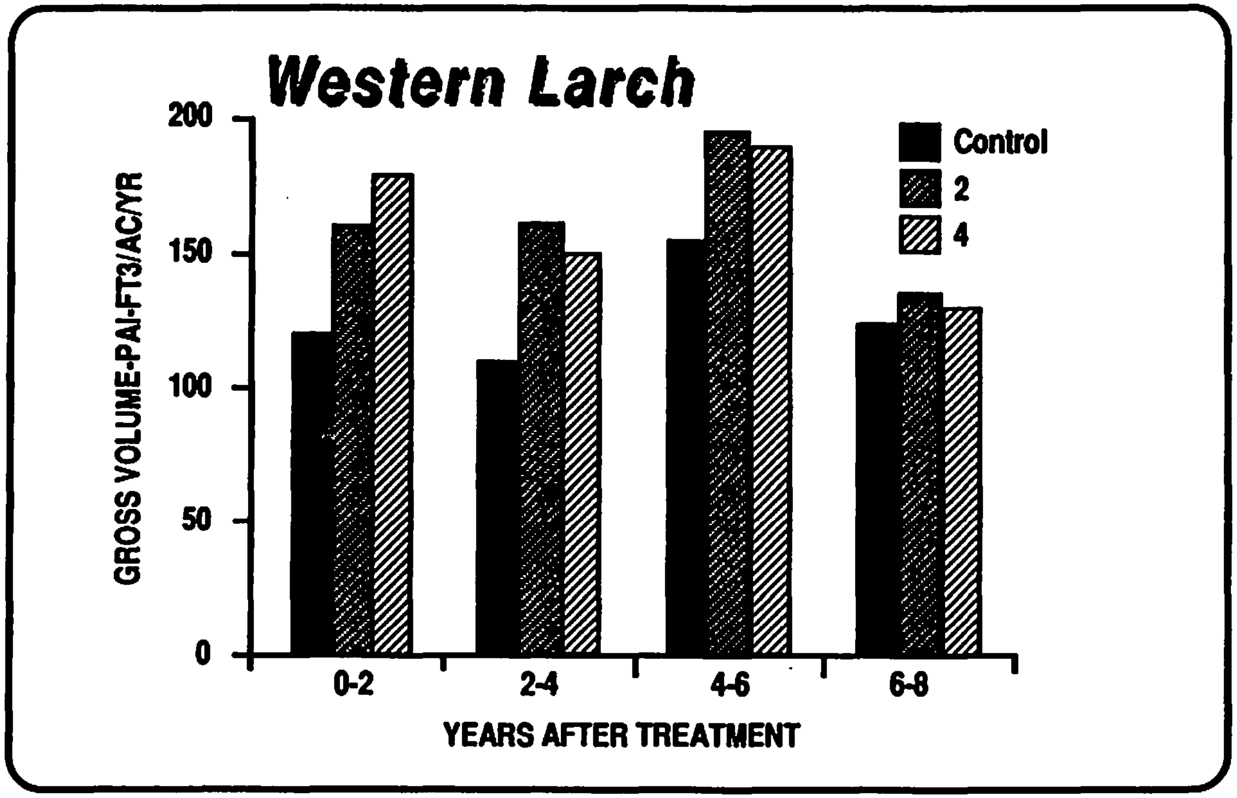


Figure 10: Gross volume growth of western larch in response to nitrogen fertilization.

Western Larch

	PERIODIC ANNUAL INCREMENTS Basal Area --- *ft^3/ac/yr* --- Gross	Net	Volume --- *ft^3/ac/yr* --- Gross	Net	HEIGHT INCREMENT *ft/yr*
Control	3.0	2.0	127	105	1.1
200N	4.0	3.2	161	146	1.3
400N	3.7	2.2	162	128	1.3

Figure 11: Periodic Annual Increments in basal area, volume and height of western larch in response to nitrogen fertilization.

Figure 12: Gross basal area growth of four ponderosa pine stands in southwestern Idaho in response to nitrogen fertilization.

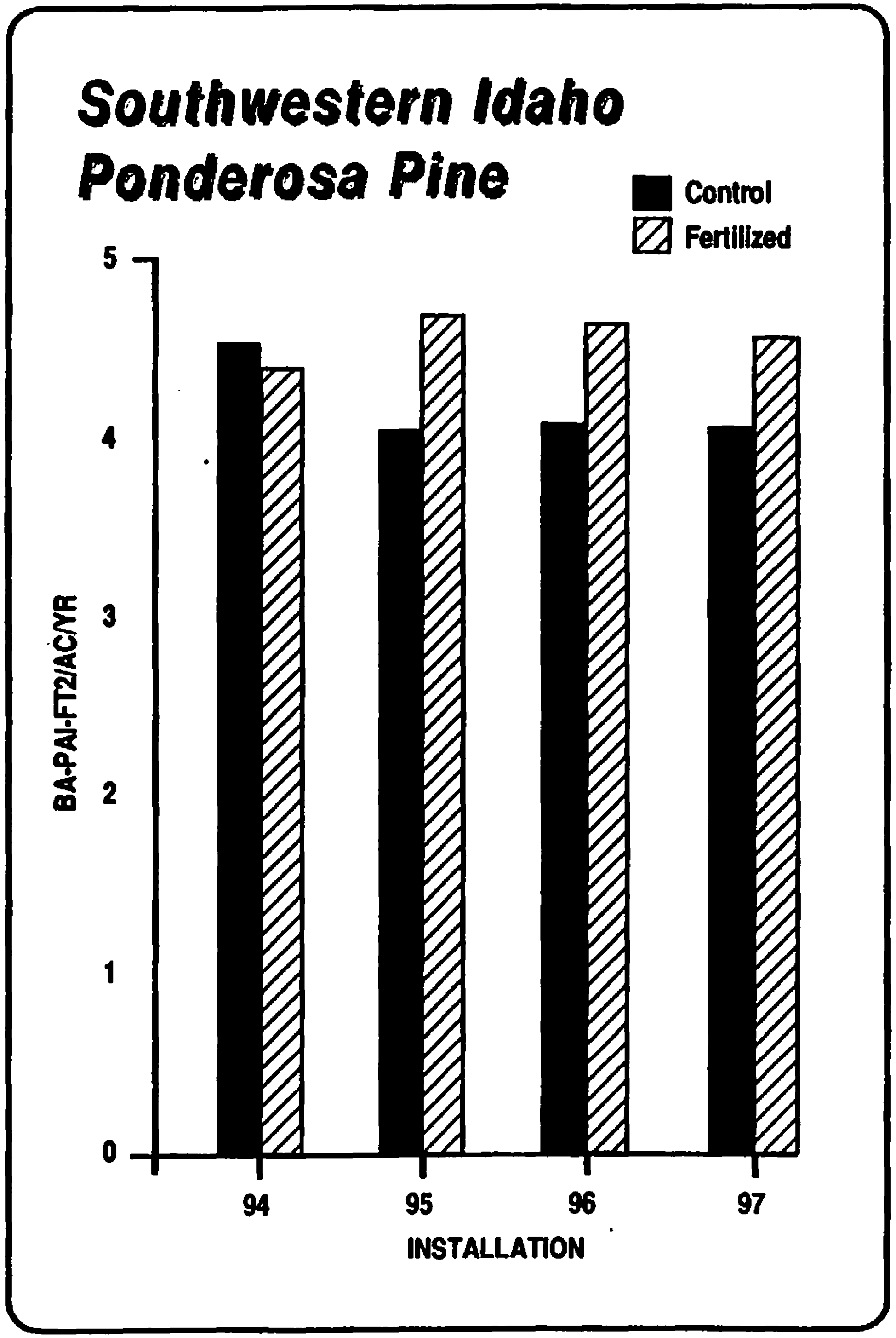
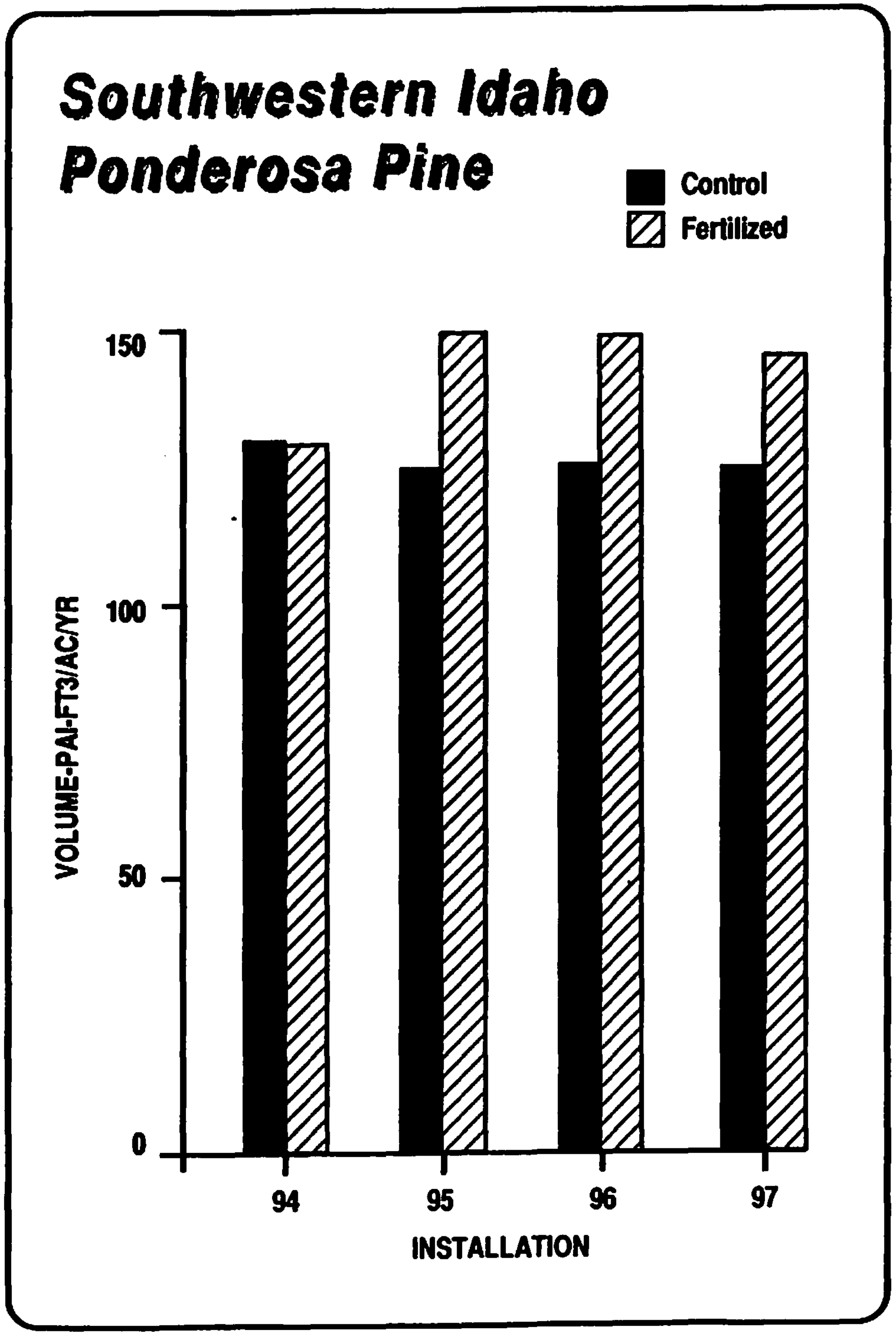


Figure 13: Gross volume growth of ponderosa pine stands in southwestern Idaho in response to nitrogen fertilization.



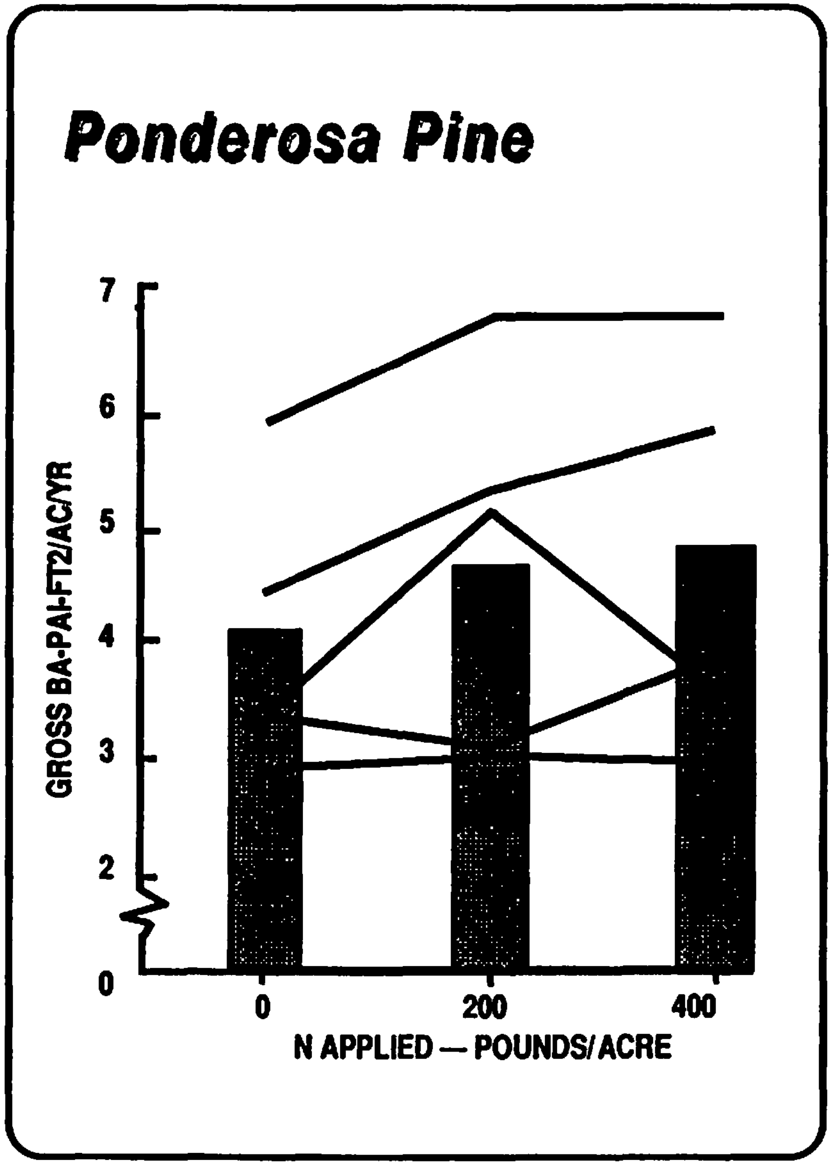


Figure 14: Gross basal area growth of ten ponderosa pine stands in northeast Oregon and eastern Washington in response to nitrogen fertilization.

3) Ponderosa pine exhibited the most variation in fertilizer response, due possibly to differences in soils. Laboratory analysis of foliage and soil samples already collected should help explain some of the response variation.
4) Additional growth response data is needed to evaluate long term fertilizer effects on stocking levels and possible changes in stand structure.

Additional Comments:

The data base for the studies just discussed was compiled over a long period of time from several different organizations. Although they provide invaluable data, differences in experimental design and remeasurement schedules due to the lack of a single controlling agency resulted in information gaps and irregularities. Also, because of the relatively limited extent of the majority of the individual projects in terms of geographical range and sample size, operational guidelines and recommendations are less reliable. These are only part of the reasons that the Intermountain Forest Tree Nutrition Cooperative was formed. Due to its unified structure and extensive data base the cooperative enjoys many advantages over some of the individual fertilizer research projects discussed above, of which a few are:

(1) Examination of responses over wide geographic ranges.
(2) Determination of reasons for the varied responses.
(3) Development of diognostic tests to predict response.
(4) Determination of duration of responses and the separation of the effects due to increased tree nutrition and changes in stocking levels.
(5) Collection of growth and mortality data.

Ecosystem management:

In addition, the work of the coop has further implications involving ecosystem management and long term productivity. Soil genesis, nutrient cycling and net primary productivity can be viewed as a series of processes involving additions, subtractions, transformations and translocations. Forest managers are being pressured to show that their operations are not subtracting more than is being added and that their management practices are not interfering with the transformation and translocation processes vital in maintaining or enhancing long term productivity. This coop is providing information on nutrient managememt and stand development essential to assessing long term productivity and management practices to maintain or enhance it.

The Effect of Site and Stand Factors on Douglas-fir Response to Nitrogen Fertilization:

Development of a Prediction Model

Peter G. Mika
University of Idaho

April 12, 1988

When the IFTNC was established, one objective identified was to allow prediction of response potential on sites by evaluating associations between response estimates and site and stand characteristics. Thus a large amount of information was collected in addition to that needed to estimate fertilizer response. Development of a prediction model relating this additional information to response was the means decided on to achieve the objective.

Successful development of such a model would serve two purposes:

1) We would refine our estimates of expected response for particular conditions and identify those most likely and least likely to respond. Given this information, those considering a fertilization program could stratify their inventory into expected response classes and better estimate the likely return from various fertilization alternatives.

2) By studying the associations found between response and different measures of the environment, we could better understand the biological mechanisms controlling such response and the basic nutritional requirements of forest in our area. Then we could determine why some installations failed to respond or why many plots treated with 400 pounds per acre of nitrogen did not grow more than those treated with 200 pounds.

Because of this dual purpose for modeling response, a stepped analysis approach was used. Potential predictor variables were grouped into four categories, as shown in the accompanying table, based on their ease of acquisition. The first category contains measures that should be readily available from existing inventory data. The second group consists of variables for classifying soil features; if not already available, these could

Table 1. Information available for predicting response sorted by ease of acquisition.

1. Basic site and stand condition measures

    - Elevation
    - Slope
    - Aspect
    - Vegetation series
    - Douglas-fir site index
    - Mensurational characteristics
    - Species composition
    - Region

2. Soil classification variables

    - Parent material

      Alluvium, Ash/Loess, Ash/Metasediments, Basalt, Colluvium, Glacial Till, Granite, Sandstone, Valley Fill

    - Soil depth to parent material

      Shallow (<12 in.), Medium (12-24 in.), Deep (>24 in.)

    - Ash mantle depth

      Deep (>12 in.), not deep

3. Soil physical and chemical characteristics

    - Moisture holding capacity
    - Bulk density
    - pH
    - Percent carbon
    - Total nitrogen and phosphorus
    - Available phosphorus
    - Mineralizable nitrogen

4. Foliar nutrient levels

    Concentration and content for Douglas-fir foliage (dormant season, current year, third whorl) from control and fertilized plots one year after treatment. Nutrients sampled include N, P, K, Ca, Mg, Mn, Zn, Fe, B, and Cu.

be obtained by simple field reconnaissance. The third and fourth categories contain variables requiring field sampling and laboratory analysis. Any model likely to be useful for applied prediction of response would involve variables from only the first two groups.

Unfortunately the ease of acquisition of information is probably inversely proportional to its ability to directly measure biological factors controlling response. Thus we hoped that models including variables from the last two categories, while lacking applied utility, would offer some hypotheses on limits to response.

Standard multiple regression techniques were used in analysis. The dependent variable was four year gross volume response, calculated as the difference between actual volume growth on the treated plot and similar growth on the control adjusted to the initial basal area of the treated plot. At each step all variables from a particular category were added to the model and least significant variables were progressively dropped. An alpha level of 0.05 was used for variable retention.

Separate models were fit with and without geographic region. Although we suspected that regional differences would be useful in obtaining better predictions, the biological meaning of such differences was unclear. Regional differences would likely include changes in climate, topology, geology, soils, associated vegetation, and genotype. Thus, it would be difficult to sort out the biological relationships represented in models including region.

Model 1 includes those variables from the first category, with exception of geographic region, that showed a statistically significant relationship to response. The model does not have great predictive power; however, the

Prediction Models

- Site and Stand Conditions

  <u>Model 1</u> R-SQ = 0.2066 CV = 83.02%

  -Treatment

  -Elevation

  -Vegetation series

  -Average crown ratio

  -Initial volume

  -Gross volume pai on control

  -% basal area in grand fir

implied relationships of response to site and stand conditions are of interest.

Treatment Adding more nitrogen does produce more response, but not twice as much as 200 pounds per acre.

Elevation The trend likely reflects broad climatic differences, with conditions more favorable to growth and, hence, permitting greater response found at lower elevations. This is strictly a broad scale trend as elevational differences within regions were not related to response.

Vegetation Series Sites on grand fir, cedar, and western hemlock vegetation series responded more than those on Douglas-fir types. More mesic, milder sites are capable of sustaining more growth when nutrient limitations are removed.

Average Crown Ratio Stands with deeper crowns were able to respond more. Trees increase growth following fertilization in two ways: by increasing the photosynthetic efficiency of older needles and by increasing production of new foliage. The greater existing foliar biomass associated with deeper crowns would enhance both of these reactions.

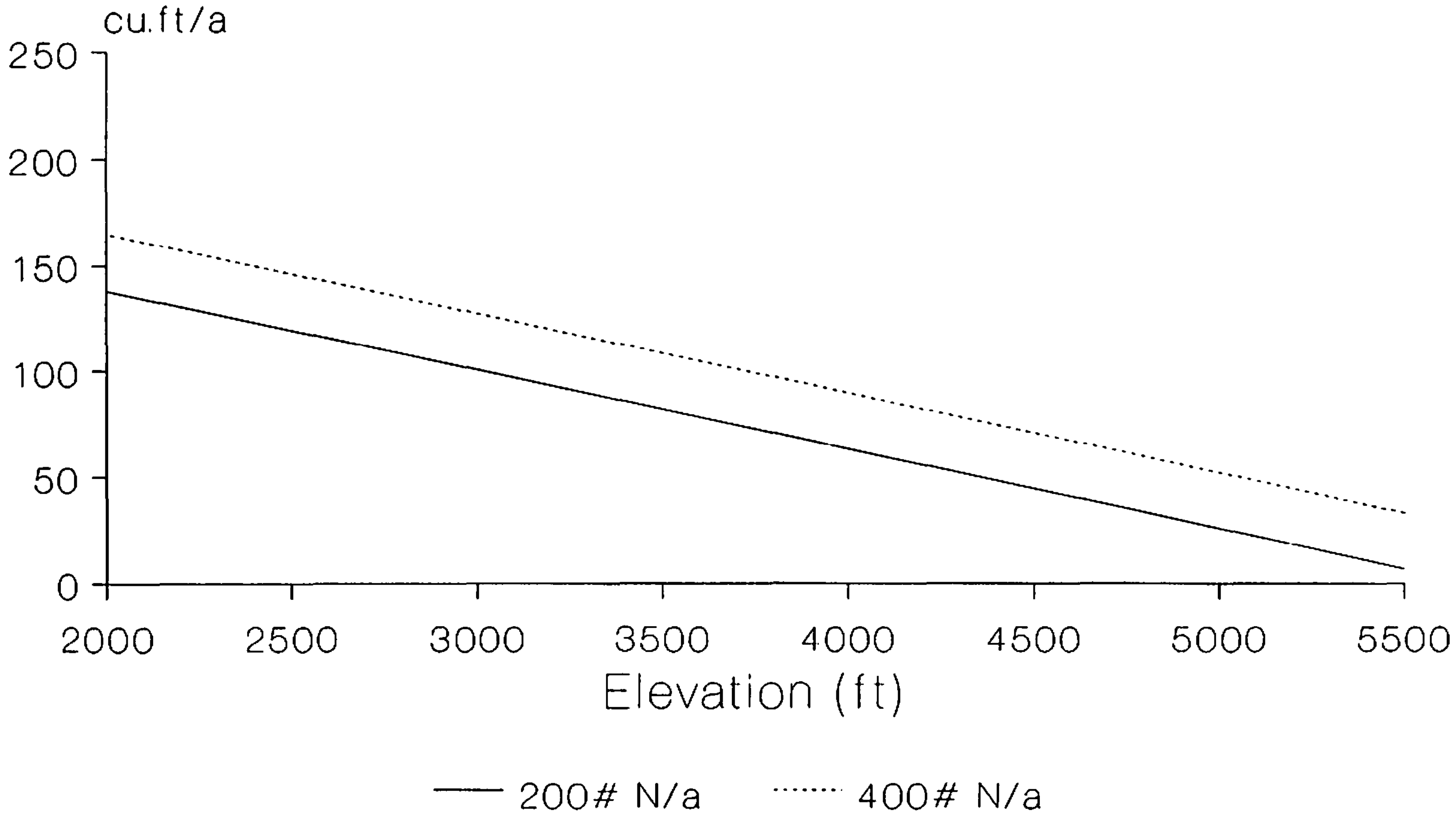
Initial Volume At density below where intense competition takes place, the more live biomass you have on the site to respond, the more growth response you will get.

Gross Volume PAI Stands that are already growing at a fast rate have adequate nutrients.

Percent Basal Area in Grand Fir Several possible interpretations exist: 1) mixed stands can utilize the added nutrients more effectively;

Gross Volume Response

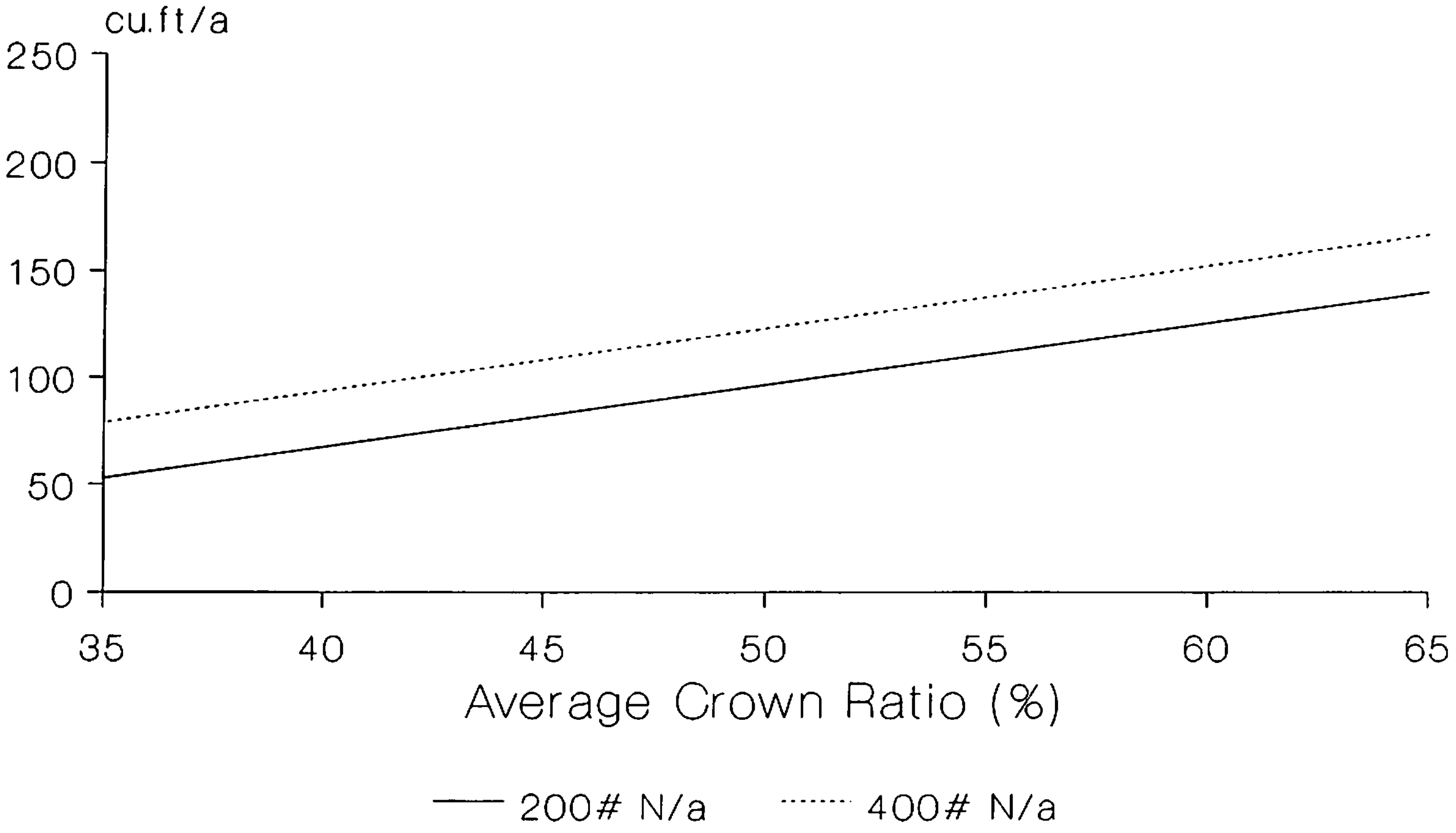
By Treatment



CR=45, V=3500, VI=175, %GF=0, DF series

Gross Volume Response

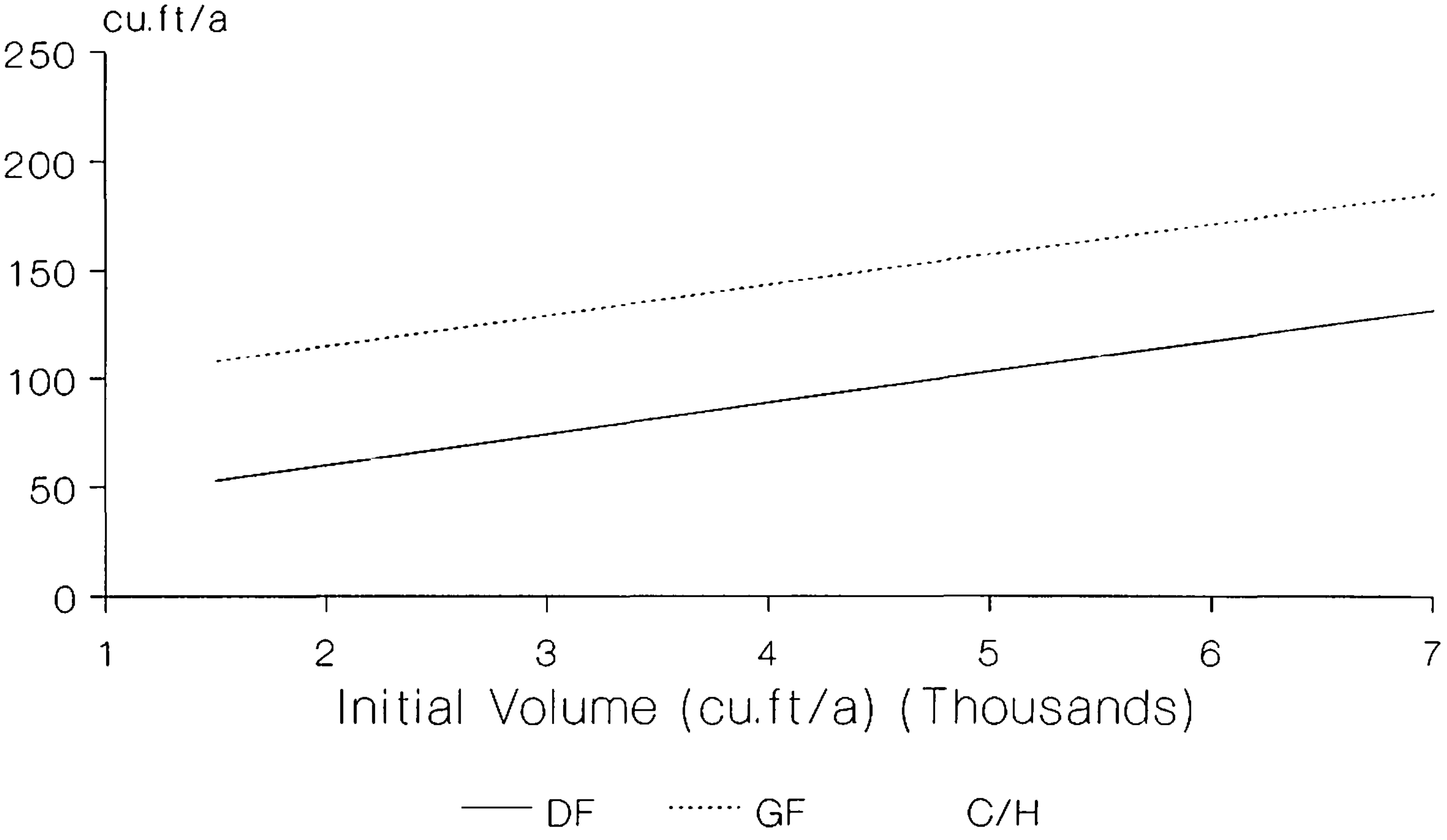
By Treatment



E=3500, V=3500, VI=175, %GF=0, DF series

Gross Volume Response

By Vegetation Series



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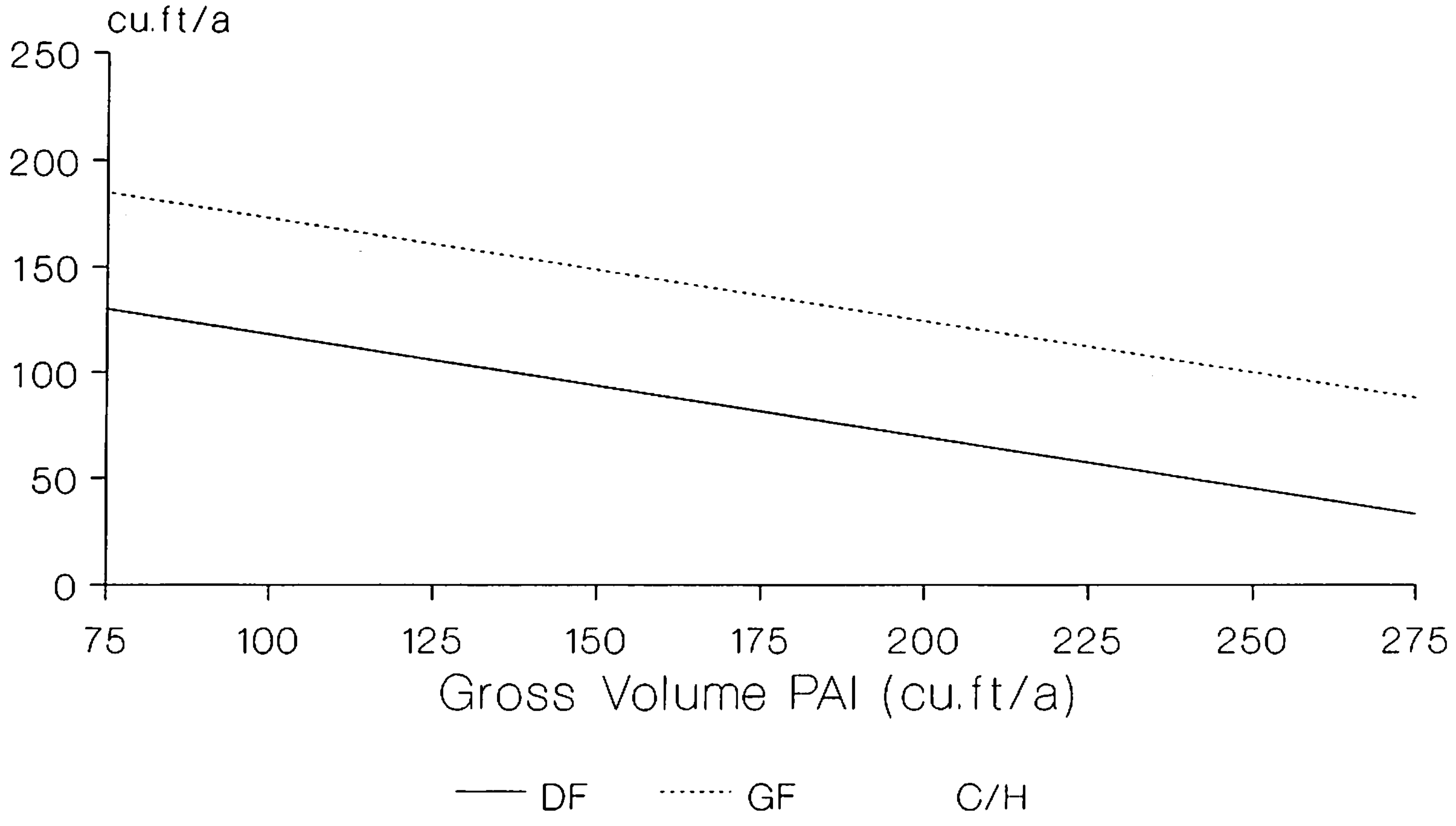
Gross Volume Response

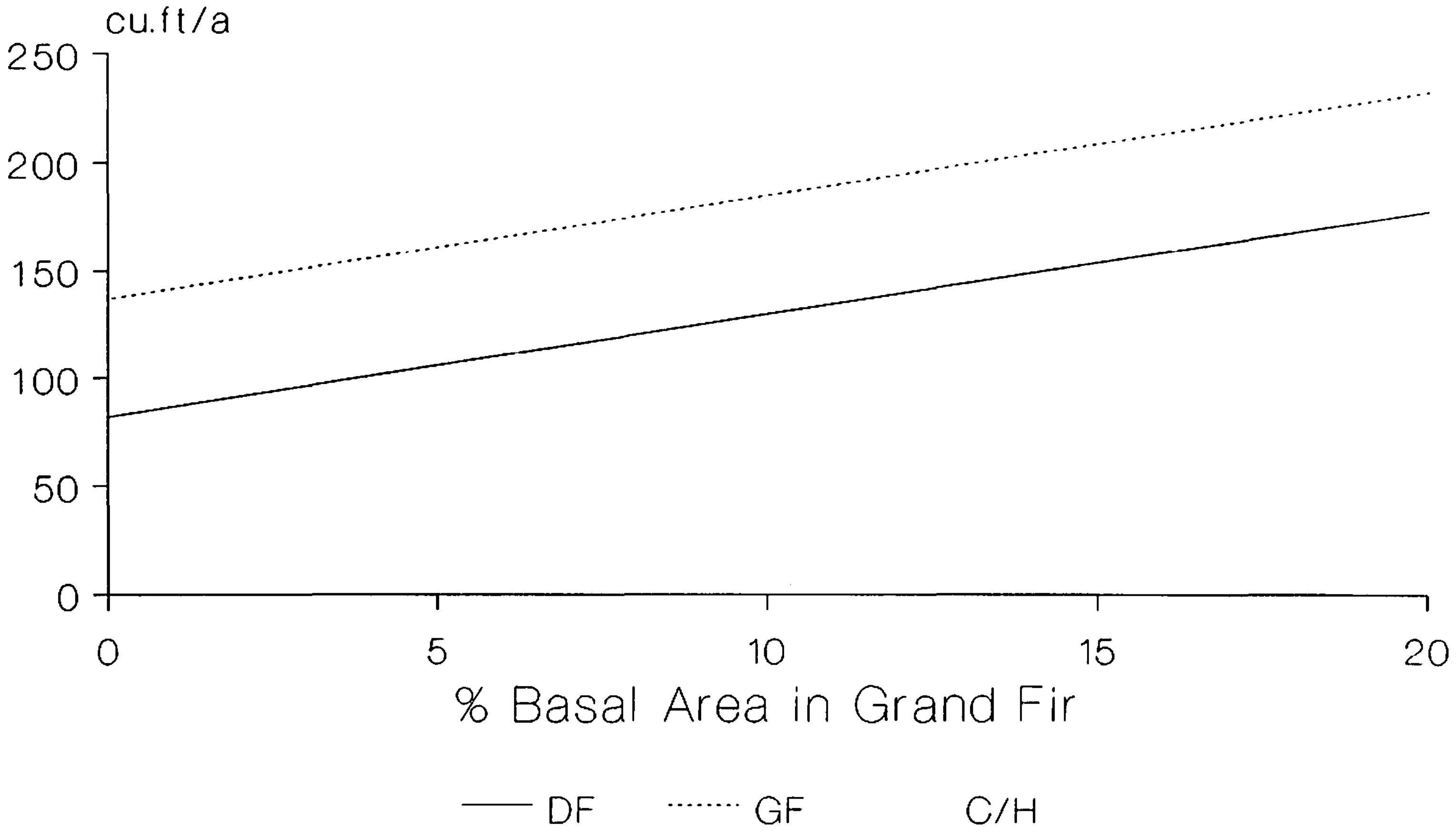
By Vegetation Series



E=3500, CR=45, V=3500, %GF=0, 200# N

Gross Volume Response

By Vegetation Series



E=3500, CR=45, V=3500, VI=175, 200# N

2) grand fir is an indicator of sites capable of sustaining better growth; and/or 3) grand fir responds more than Douglas-fir.

Model 2 includes region which greatly enhances our predictive power. This is the model probably most suited for predicting response in an applied setting. Note that elevation is not included; that variability is now explained by regional differences in response.

Model 3 adds the soil classification variables, parent material, and soil depth to model 1. Vegetation series no longer explains a significant portion of the variability in response and thus has been dropped. Again, while not a particularly good model for prediction, the implied relationships are of interest.

Soil Depth Greater soil depth would permit better root development and should provide a greater reserve of other nutrients required for growth. It may also be indicative of climatic conditions capable of sustaining better response.

Parent Material Large differences were found between average response on different parent materials. These may reflect associated changes in nutrient reserves, allowing different parent materials to support different levels of response, or may only be indicative of certain climatic conditions.

Model 4 adds soil depth to model 2; however, the small gain in predictive power probably does not justify any added effort needed to gain soil depth information. The variability explained by parent material and elevation in model 3 is accounted for by region and vegetation series.

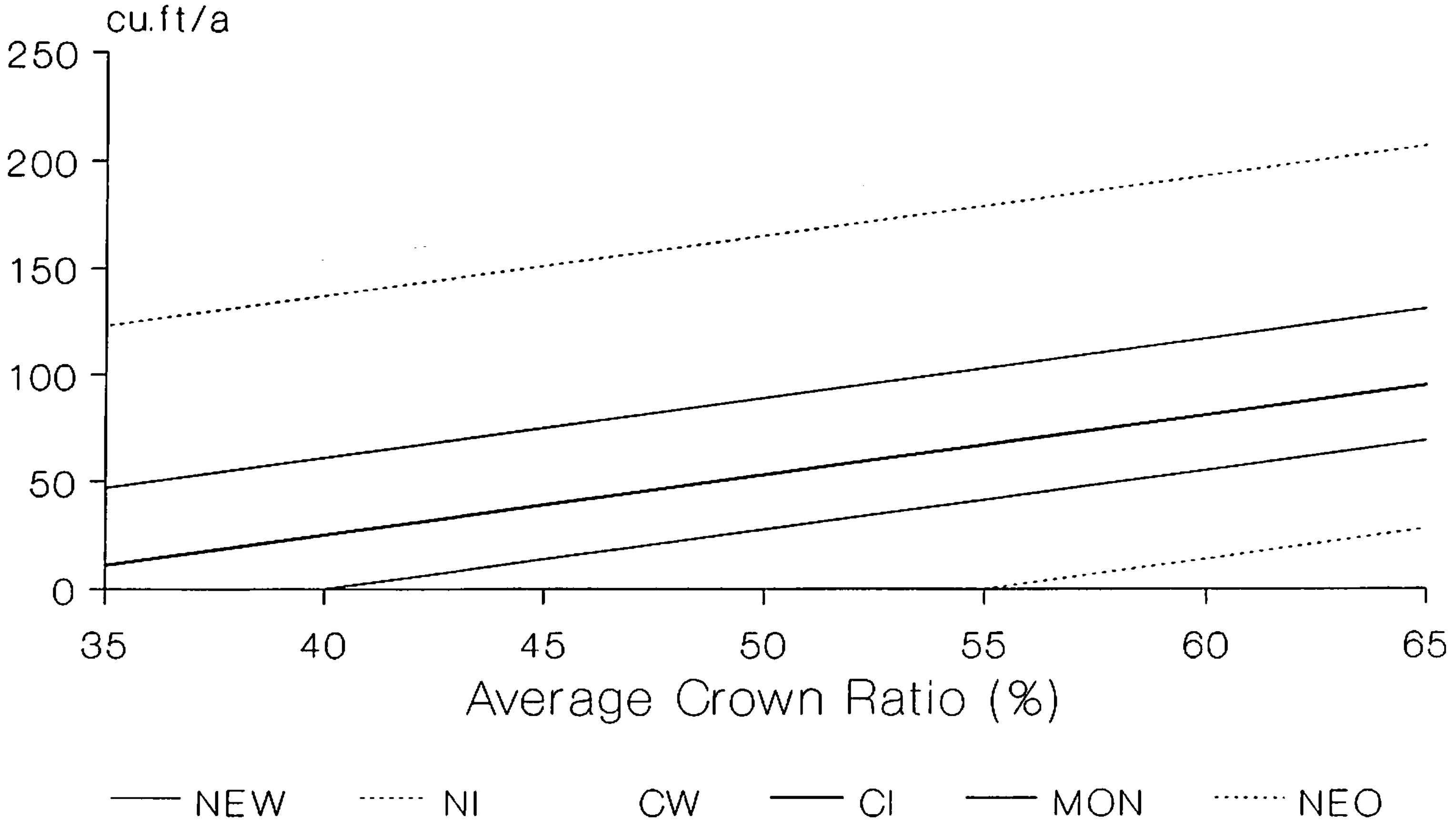
In models 5 and 6 soil mineralizable nitrogen is added. The relationship simply confirms that sites with adequate prior supplies of nitrogen will not

Prediction Models

- Site and Stand Conditions
  Model 1 R-SQ = 0.2066 CV = 83.02%
  Model 2 R-SQ = 0.3406 CV = 76.10%
  -Region
  -Treatment
  -Vegetation series
  -Average crown ratio
  -Initial volume
  -Gross volume pai on control
  -% basal area in grand fir

Gross Volume Response

By Region



V=3500, VI=175, %GF=0, DF series, 200# N

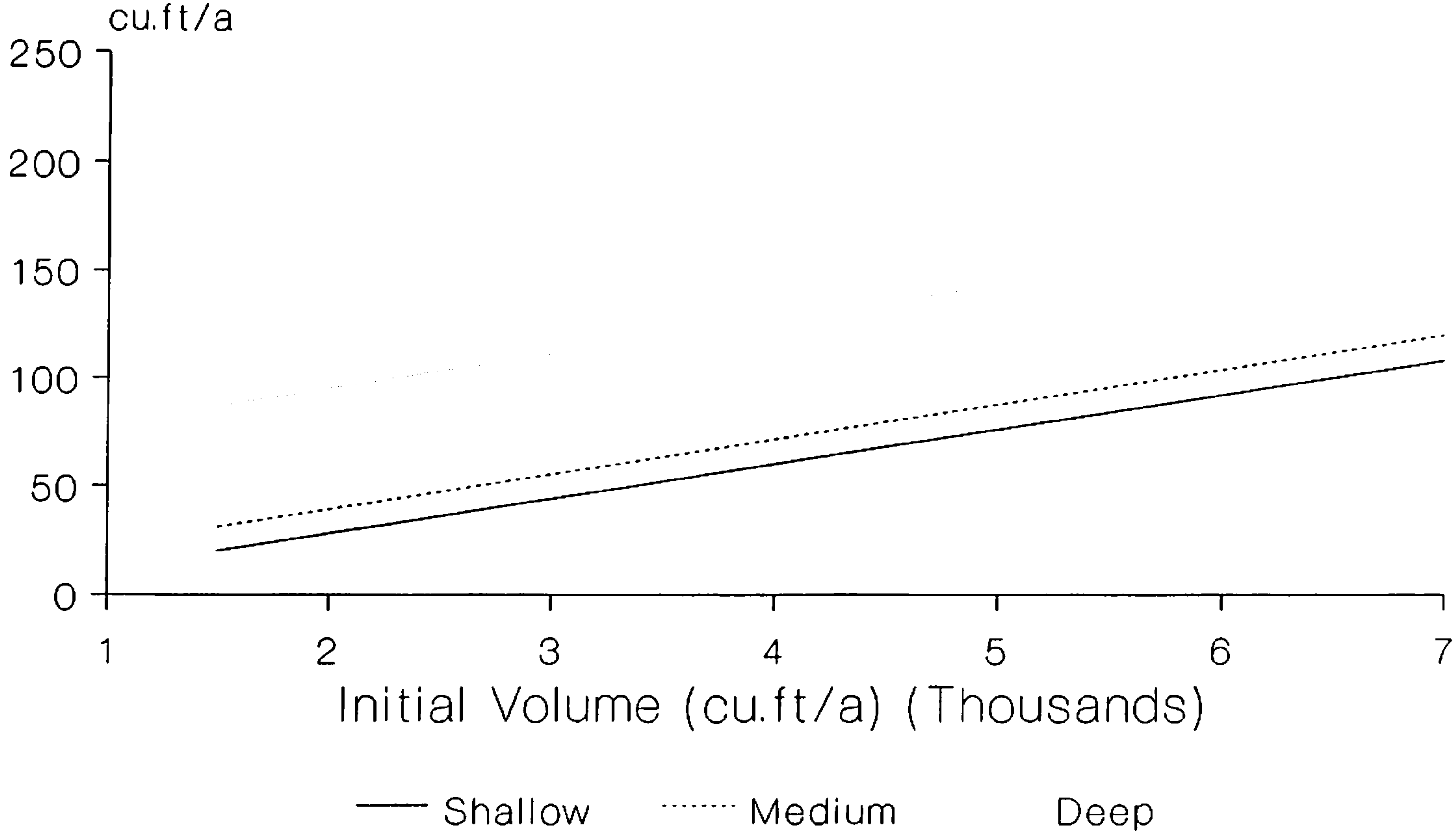
Prediction Models

- Site and Stand Conditions
  Model 1 R-SQ = 0.2066 CV = 83.02%
  Model 2 R-SQ = 0.3406 CV = 76.10%

- Soil Classification
  <u>Model 3</u> R-SQ = 0.2814 CV = 79.89%
  -Treatment
  -Elevation
  -Parent material
  -Soil depth
  -Average crown ratio
  -Initial volume
  -Gross volume pai on control
  -% basal area in grand fir

Gross Volume Response

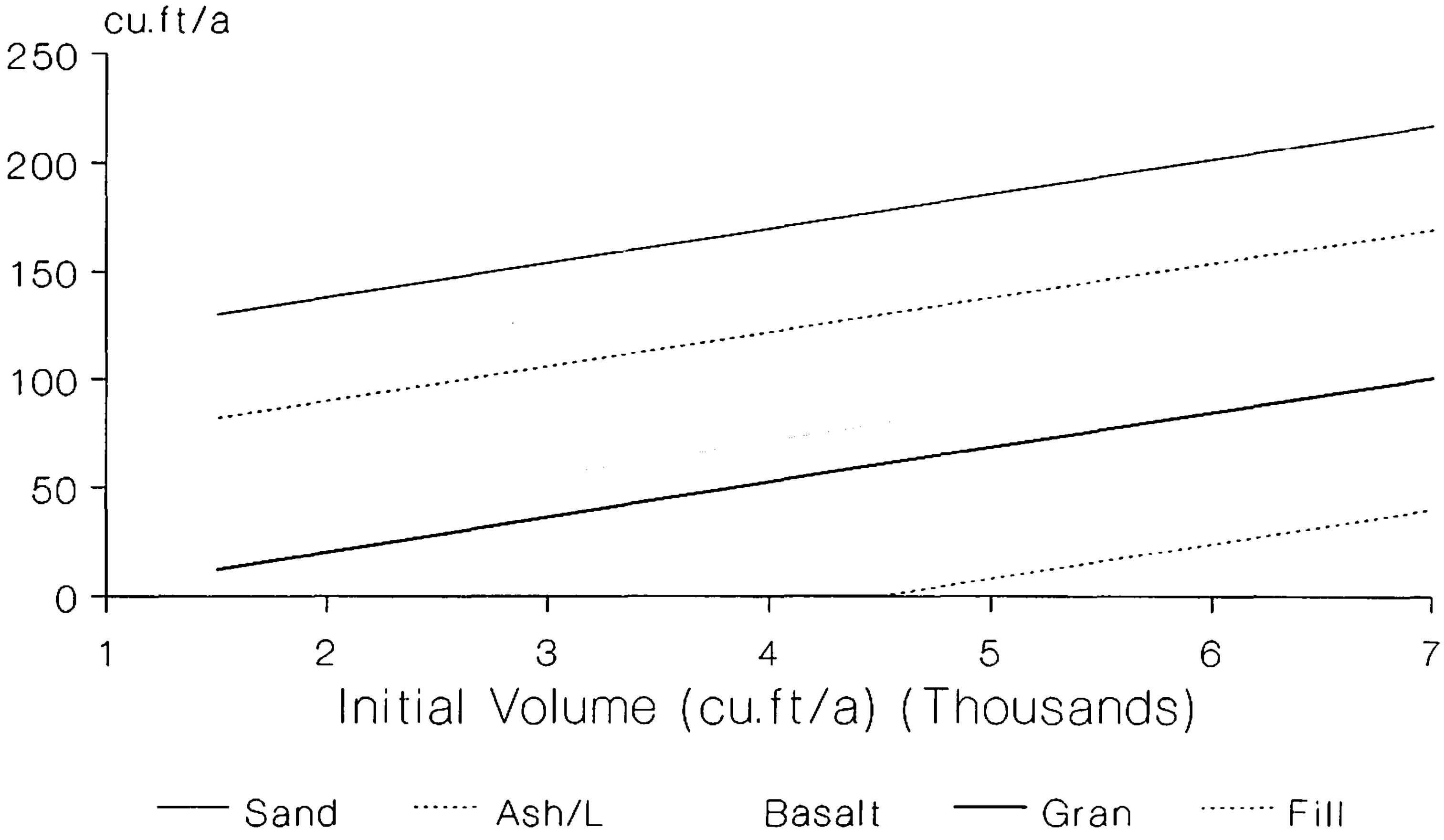
By Soil Depth



E=3500,CR=45,VI=175,%GF=0,Basalt,200# N

Gross Volume Response

By Parent Material



E=3500,CR=45,VI=175,%GF=0,Medium,200# N

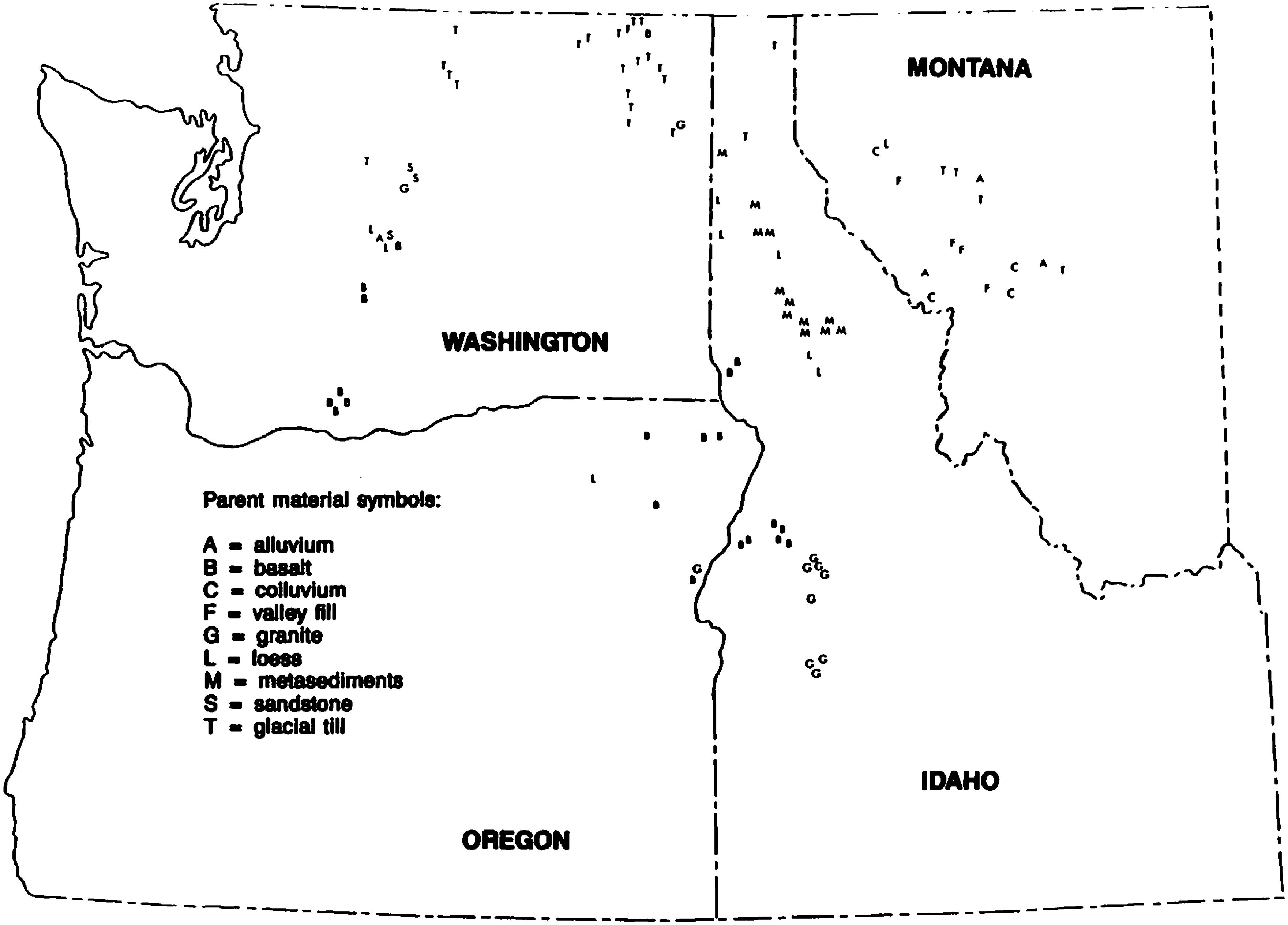
Prediction Models

- Site and Stand Conditions

  Model 1 R-SQ = 0.2066 CV = 83.02%
  Model 2 R-SQ = 0.3406 CV = 76.10%

- Soil Classification

  Model 3 R-SQ = 0.2814 CV = 79.89%
  <u>Model 4</u> R-SQ = 0.3553 CV = 75.46%
  -Region
  -Treatment
  -Vegetation series
  -Soil depth
  -Average crown ratio
  -Initial volume
  -Gross volume pai on control
  -% basal area in grand fir



Soil parent material for the 94 Douglas-fir installations of the Intermountain Forest Tree Nutrition Cooperative

Prediction Models

- Soil Classification

  Model 3 R-SQ = 0.2814 CV = 79.89%

  Model 4 R-SQ = 0.3553 CV = 75.46%

- Soil Physical and Chemical Characteristics

  Model 5 R-SQ = 0.3313 CV = 76.70%

  -Treatment

  -Parent material

  -Soil depth

  -Average crown ratio

  -Initial volume

  -Gross volume pai on control

  -% basal area in grand fir

  -Mineralizable nitrogen

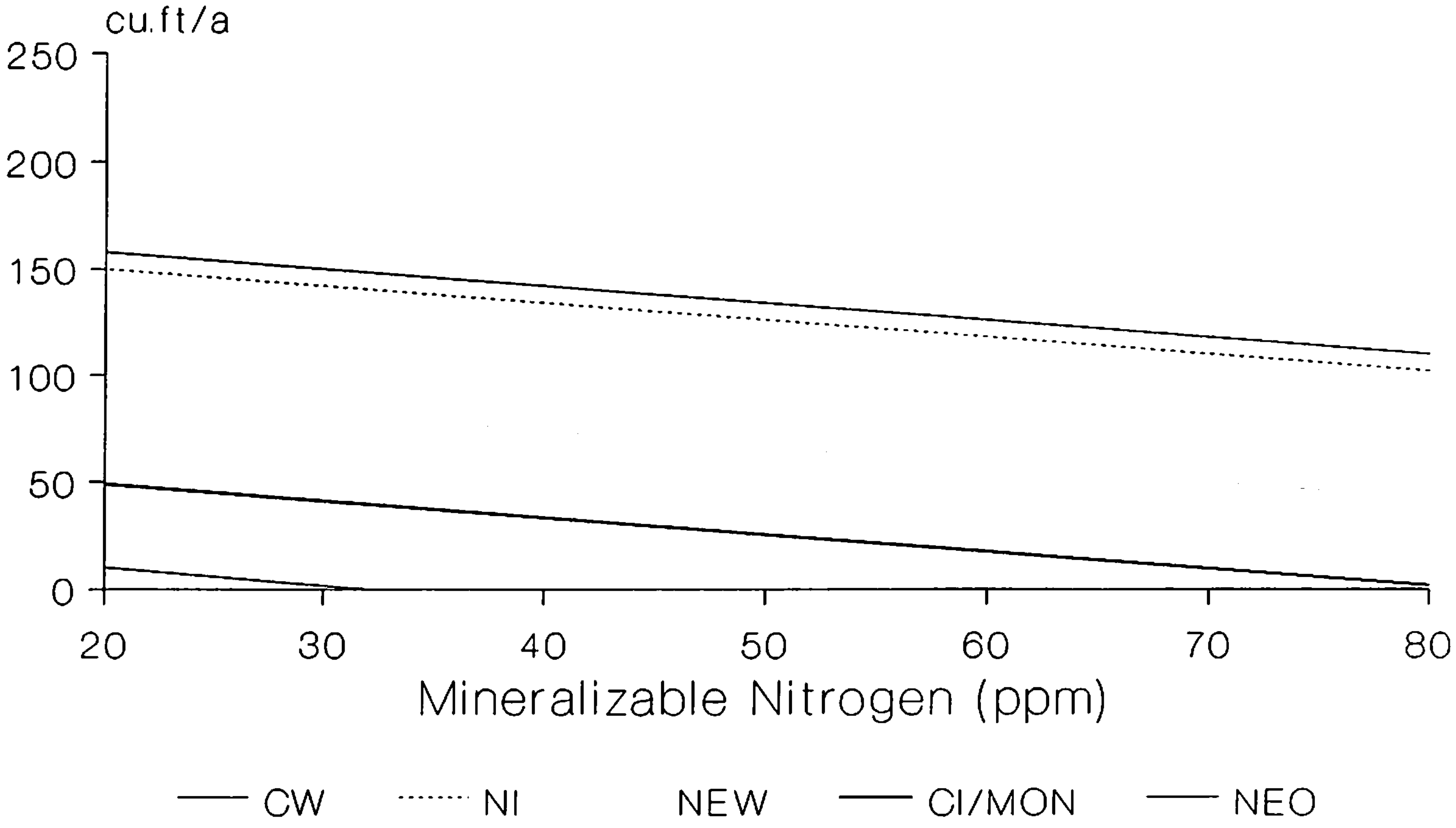
Prediction Models

- Soil Classification
  Model 3 R-SQ = 0.2814 CV = 79.89%
  Model 4 R-SQ = 0.3553 CV = 75.46%

- Soil Physical and Chemical Characteristics
  Model 5 R-SQ = 0.3313 CV = 76.70%
  Model 6 R-SQ = 0.3610 CV = 74.86%
  -Region
  -Treatment
  -Vegetation series
  -Soil depth
  -Average crown ratio
  -Initial volume
  -Gross volume pai on control
  -% basal area in grand fir
  -Mineralizable nitrogen

Gross Volume Response

By Region



CR=45,V=3500,VI=175,%GF=0,DF,200# N

respond to nitrogen fertilizer. Note that the differences among regions have changed from those shown in model 4, reflecting the adjustment for levels of mineralizable nitrogen. Thus the large response in central Washington is partly attributable to low initial levels of nitrogen.

Model 7, the final model, adds information on foliar nutrient levels to the variables present in model 5. While this is the best model in terms of predictive power, some of the variables are totally impractical for any applied use. But a number of interesting relationships are revealed. Note that a complementary model including geographic region has not been presented; variability formerly accounted for by region is now better explained by soil parent material in combination with the foliar nutrient data.

Phosphorus Concentration Since phosphorus concentrations are generally above known critical levels, this relationship likely restates that sites with adequate nutrient supplies prior to treatment will not respond to nutrient amendments.

Change in Nitrogen Concentration The more nitrogen we were able to get into the trees, the better those trees responded. Sites where such changes were higher also had generally lower nitrogen levels prior to treatment. This variable has also accounted for variation in response due to differences in rate of nitrogen application.

Critical Potassium Concentrations Sites where potassium levels dropped far below critical did not respond well, indicating a possible pre-existing or treatment-induced potassium deficiency.

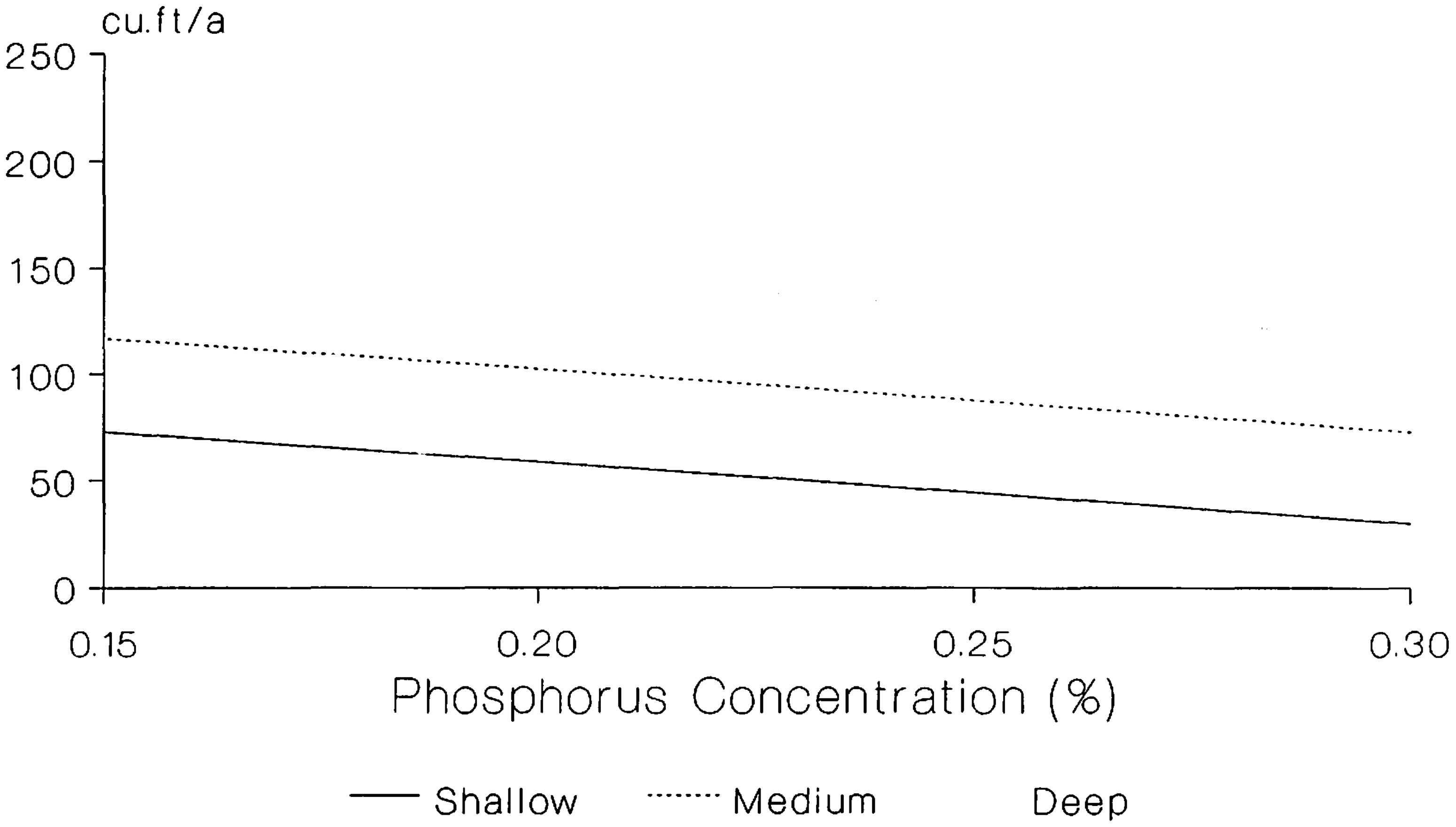
Prediction Models

- Soil Physical and Chemical Characteristics
  Model 5 R-SQ = 0.3313 CV = 76.70%
  Model 6 R-SQ = 0.3610 CV = 74.86%

- Foliar Nutrient Levels
  Model 7 R-SQ = 0.3809 CV = 73.94%
  -Parent material
  -Soil depth
  -Average crown ratio
  -Initial volume
  -Gross volume pai on control
  -% basal area in grand fir
  -Mineralizable nitrogen
  -Foliar phosphorus concentration on control
  -Change in foliar nitrogen concentration
  -Critical foliar potassium concentration

Gross Volume Response

By Soil Depth



basalt,200# N

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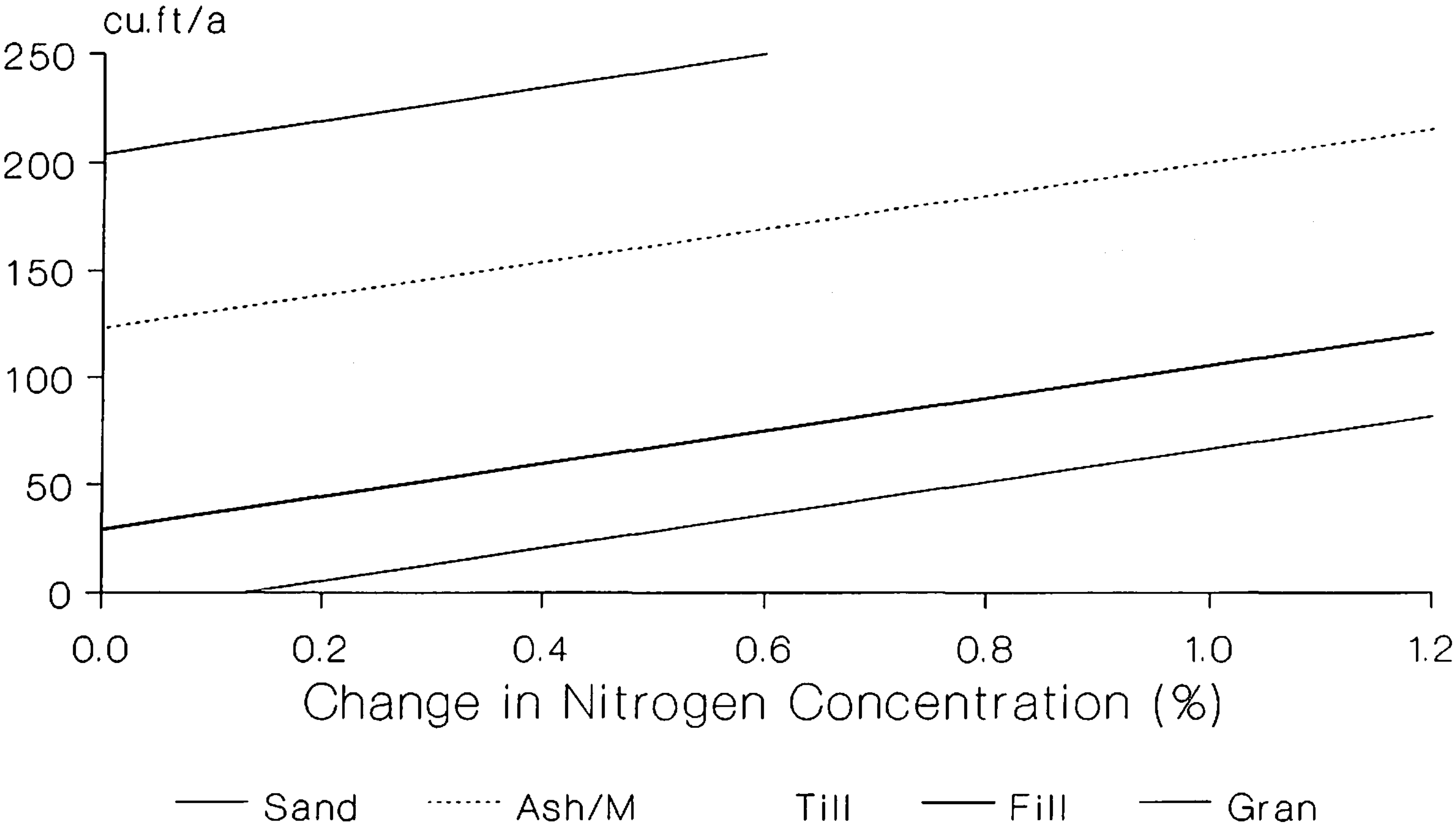
Gross Volume Response

By Parent Material

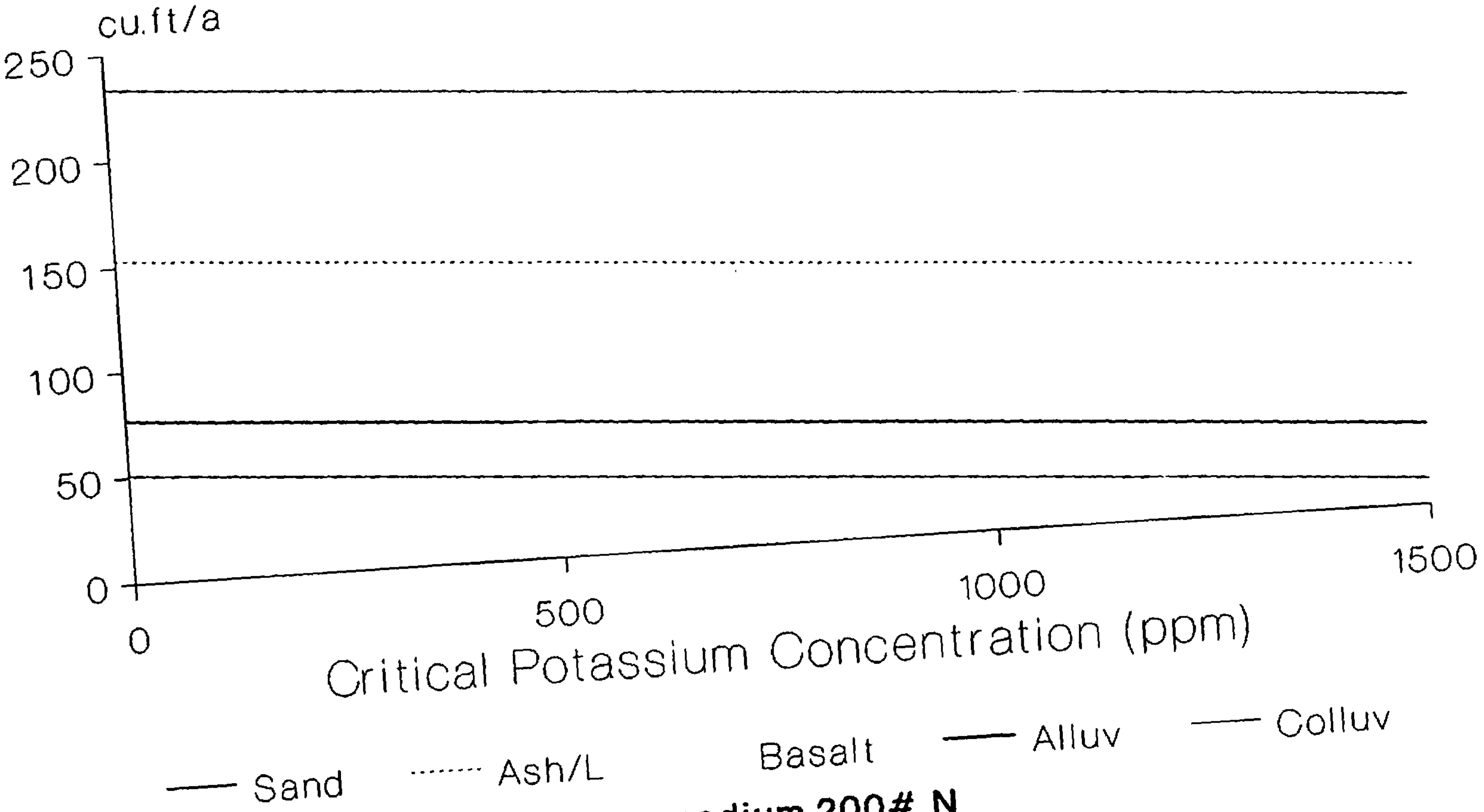


medium,200# N

CR=45,V=3500,VI=175,%GF=0,N=45,P=.2,K=0

Gross Volume Response

By Parent Material



medium,200# N

CR=45,V=3500,VI=175,%GF=0,M=45,P=.2,N=.4

Conclusions:

1. Site and stand information does improve our ability to predict response.
2. Sites with adequate available nitrogen or with low potassium levels show little response.
3. Differences in parent material and foliar nutrient levels help explain response differences among regions.
4. The amount of nitrogen in the tree, not on the ground, controls response.

Distribution of Fertilizer Response Across Tree Size Classes

IFTNC Fertilization Workshop
April 1988

Presented to: IFTNC
Fertilization Workshop
April 12, 1988

DISTRIBUTION OF FERTILIZER RESPONSE ACROSS TREE SIZE CLASSES

Jim Moore and Peter Mica presented a generally positive biological response trend for nitrogen applications in managed Douglas-fir stands considered to be typical of the Inland Empire region. As has been demonstrated by similar experiments throughout the region, a lack of nitrogen seems to generally limit growth of Douglas-fir forests. What does this tell us about the potential value of response, however. An important piece of the puzzle not yet addressed is - How are these observed increases in volume/acre distributed across the tree sizes? Do the larger, more valuable trees respond proportionally more than small trees? This type of information will be important in our evaluation of economic response and to our ability to develop models that can predict response in advance of treatment.

We all know that we derive financial return from our silvicultural investments when we sell or process the wood generated by treatment. We don't process cubic volume per acre, we process trees and logs. The distribution of response, and growth for that matter, within a stand impacts log size, product quantity and value. In our region, stumpage value is essentially determined simply by species and general product category, like sawlogs. Nitrogen response, however, affects individual tree dimensions. How these changes in size are distributed within the stand affects the amount of recoverable, merchantable volume and, in turn, value.

When all is said and done, it seems we actually would like to be able to identify stand types that are most responsive to nitrogen in terms of increased merchantable log dimension .... These may or may not be the same stands that yield the highest total cubic volume response per acre. Understanding more about the distribution of growth and response provides a stronger basis for estimating economic returns from treatment.

To obtain this type of information we must look more closely at how nitrogen response is distributed within the stand. In this regard, two basic questions present themselves.

First, is within tree increment distribution. Simply put, does the nitrogen treatment affect the distribution of growth increment along the bole of the individual tree? If so, is it significant?

Changes in stand structure brought about naturally or through stocking control activities can obviously influence the distribution of volume growth increment along the tree bole by changing crown dimensions, primarily crown length. For example, the more open grown the tree the longer the crown and the more does fertilizer fit in? Studies conducted on Douglas-fir in the PNW tend to indicate that nitrogen alone probably has little impact, from an economic standpoint, on within tree volume increment distribution. Changes in tree form have been noted however. If nitrogen induces significant mortality, structural changes in the stand can alter tree to tree competition and have greater impact on within tree increment distribution because of its affect on individual tree crown characteristics.

An important question then, from a treatment value standpoint, centers on the distribution of response or volume increment across tree sizes present in the stand. In other words, do specific size classes respond differently in relation to others after fertilization? Might this vary by stand structure or condition? What types of stands lend themselves to higher relative increases in value as opposed to total volume? Answers to these questions will assist us in predicting and valuing response to nitrogen.

Does everyone have a feeling for for what is meant by "distribution of increment within the stand"? A schematic picture might help with clarification. First, let's consider a 35 year old Douglas-fir stand, well stocked with a typical distribution of tree sizes.

Graphically, these lines represent examples of how 4-year cubic volume increment might be distributed across a hypothetical diameter range?

Intuitively, we probably would expect larger trees to contribute larger amounts of volume. Bigger trees tend to put on more wood than smaller trees as shown by Lines 1 or 2. The exact shape or slope of the distribution, however, is dependent on specific stand conditions like age, range or diameters present, and so on.

In this example, Line #1 implies that the contribution of volume increases with tree size at a decreasing rate and then begins to plateau. The largest trees are actually growing at a rate equal to the smaller trees within the plateau area, in terms of volume.

Line #2 simply shows volume increment increasing at a constant rate with respect to DBH - the bigger the tree the more wood produced. This may be typical of fairly vigorous stands.

Line #3 indicates that all sizes contribute nearly equal amounts of wood. A stand with a narrow DBH range that has been thinned might be representative of this situation.

Let's take this concept one step further by converting cubic volume increment to a <u>relative</u> scale simply by dividing volume increment for a given tree by total volume increment for all trees. And let's do the same for initial tree size using basal area instead of diameter. The curves look similar here but now represent relative values that can be more easily compared across stands with different initial diameter distributions - like between IFTNC installations for example.

How would you expect relative volume growth, not response, to be distributed in the fertilization trials the cooperative is represent "managed" stand conditions implying that stocking control had been carried out or was not required.

Results are consistent with most everything we study in forestry - they are variable!! The relative volume growth distributions vary between sites. Both linear, like Line #1 and #3, and curved distributions for the IFTNC installations.

(Slide 1) For example, the distribution of relative volume increment is linear for Installation #204. The larger trees are contributing greater amounts of volume to the total.

(Slide 2) Installation #261 is an example of a curved distribution.

In fact, of the 90 installations in total, 37 have linear distributions and 53 are curved. Bahman Shafii found similar variability in the distribution of relative volume increment during his study of several other grand fir/Douglas-fir sites. He reported on this work last year and concluded that stand structure at time of treatment affected the distribution of both growth and response in the stand.

Results show that relative volume increment is distributed differently among installations. These differences are evident in spite of our efforts to select "similar" managed stand conditions. Stand structure, age, vigor, and so on, obviously influence the pattern of relative volume increment within the stands under study. Holding total volume increment constant, one could surmise that these differences in distributions might influence value since the distribution of growth within the stand will determine changes in tree and log sizes and, in turn, the amount of merchantable board-feet of wood. It follows then that the value of response to fertilization might also, in part, be dependent on basic increment distribution patterns that exist prior to treatment.

What about changes in the distribution of relative volume increment within a stand following a nitrogen treatment. How might nitrogen affect stand dynamics and in turn stand development patterns?

There are different hypotheses regarding the effect of fertilizer on stand dynamics and growth that are worth mentioning briefly.

One is what you might call a "time-warp" concept that states fertilizer merely accelerates the stand in time. The normal development of the stand is really not altered, it's simply speeded up. Trees become bigger faster thereby providing more merchantable volumes in a shorter period of time. However, the basic or normal stand development pattern is not fundamentally changed.

Another takes this same concept a bit farther. IFTNC results show that nitrogen can affect stand structure through increased mortality in addition to accelerating growth. Several IFTNC installations experienced significant mortality in treated plots, due to a combination of severe damage (e.g., wind or snow) and competition. Is the stand structure altered enough to change the normal pattern of development? This question has yet to be addressed, but it seems possible in certain conditions.

These are interesting possibilities but we still do not completely understand what is actually taking place. Maybe both concepts have merit and stand condition and structure at time of treatment predisposes a stand to one of these or other scenarios. If we can gain a better understanding of how stand structure and dynamics influence treatment response and visa-versa, we might be able to improve our ability to predict treatment response and economic returns, and thereby do a better job at estimating the best timing and selecting the best stand condition to fertilize in effort to maximize returns.

Would we expect <u>shifts</u> in the relative volume increment distribution to occur following treatment of the IFTNC installations? Does nitrogen change the proportion of volume contributed by specific size classes? Let's first consider how the relative volume increment distributions might be altered by a nitrogen treatment. As you recall, I categorized the coop installations into two basic volume increment types, linear and curved. What would shifts in these distributions imply about the distribution of fertilizer response in the stand?

Line T1 indicates an almost parallel shift upwards. This would imply that each tree is contributing more volume in relation to the total after treatment. This situation might be possible if some size classes are no longer contributing to the total growth. An example might be a stand where significant mortality occurred in the small diameter stems after treatment. The second line, T2, shows a change in the relative contribution of volume increment, larger trees now contribute a larger proportion of the volume after treatment. Accelerated stand differentiation might cause this this to happen.

(Slide 3) With this in mind, a summary of all IFTNC installations provides some interesting food for thought. Of the 90 installations, 4 distinct relative volume increment distribution classes could be identified--(explain slide).

Installations were fairly evenly distributed among these classes, except for the Type III category where only 7 installations were identified.

Type I	30 installations
Type II	23 installations
Type III	7 installations
Type IV	30 installations

Note that Type I & II classes do not show a treatment effect, meaning nitrogen didn't appear to influence the proportion of volume contributed by each tree size. Interestingly, both <u>responding</u> & <u>non-responding</u> installations were classified in these categories (based on total cu.ft./acre estimates). Of a total of 53 Type I or Type II installations, 41 had a 4-year gross cubic volume response of more than 10%, yet no apparent shift in the relative volume increment distributions was noted. Nitrogen did not appear to affect the normal growth pattern in these stands, at least over the 4-year post treatment period we

(Slide 4) Installation #230 for example is classified as a Type I, responding site. Four year gross cubic volume response is estimated to be 322 cu.ft.(59.9%).

Type III and IV installations did show a significant treatment effect in that the relative volume increment distribution curves appear to shift following treatment. All installations classified as Type III were responders on a cubic volume per acre basis thus a shift might be expected.

(Slide 5) Installation #202 is an example of the Type III responding site. (50 cu.ft./ac or 14.9%)

Interestingly, of the 30 installations in the Type IV category, nine were actually non-responders based on per acre response estimates (gross volume response < 10% response after 4 years). If there is no significant per acre response, why the apparent shift in the relative volume increment distribution?

(Slide 6 & 7) Installations #203 and #236 are examples of Type IV <u>non</u>-responders (response - #236 = -5%, 61% & #203 - 10%, -1%).

<u>Mortality was not a factor in the Type IV non-responding installations</u> implying the shift in relative volume did not result from the loss of specific size classes. One explanation might be that even though no significant gross volume per acre response is evident, nitrogen still affected basic stand dynamics causing a shift in increment from smaller to larger trees or in some cases from larger to smaller trees, without actually changing total volume increment. Response may in fact be measurable on an individual tree basis even though per acre analysis indicated otherwise. Clearly, further investigation is needed to better understand what is going on. More importantly, a better understanding is required before good response models can be developed. We have really only scratched the surface of this topic.

Obviously, the bottom line regarding the distribution of response relates to the amount of additional merchantable wood that can be realized. Last year I made an attempt to estimate merchantable volume response, as compared to total cubic volume response, by merchandizing individual trees in control and treated plots for Inst. #204 (Region NI, IDL) and #230 (Region CW, BC).

A short-coming of last year's comparisons, however, was that I had to compare treated and untreated stand tables before treatment and after 4 years - which is subject to error caused by small differences in initial tree size distributions, even though the installations were established in uniform stands. This year I again compared gross cubic and merchantable response for 6 responding IFTNC installations but this time each treated plot in effect serves as it's own control. Stand tables at the end of the 4-year period were projected for both 200 lb. and 400 lb. treatments as well as for the control using the initial control plot stand table data and each respective installations volume increment distribution pattern. This approach eliminates potential differences in initial stand structure. Projected stand tables representing conditions 4 years after treatment, for 200 lb., 400 lb. and control, were simply merchandized and compared to provide estimates of merchantable response by treatment.

(Slide 8) This table summarizes results of my comparisons for 6 installations including the two done last year. Both 4-year gross total cubic and board foot response is shown for each installation. Note that percent response is the increase or decrease in total standing volume, not the increase in 4-year increment. Note that board foot response for 5 of the 6 installations exceeds 1800 for the 200 lb. treatment. The 400 lb. treatment of Inst. #261 resulted in an increase of over 4200 board feet in 4 years. That is alot of wood! These estimates of board foot response reflect the actual distribution of fertilizer response observed for each installation. How the response is distributed across tree size classes influences the magnitude of merchantable response.

Store some of these response figures away. Later this afternoon we'll be addressing the "does fertilizer pay" question.

Conclusions

1. It is evident that the distribution of relative volume increment varies within the population of "managed" stands being monitored by IFTNC.

2. Fertilization appears to affect the distribution of relative volume increment in different ways. Certain changes may have greater influence on the economic value response than others.

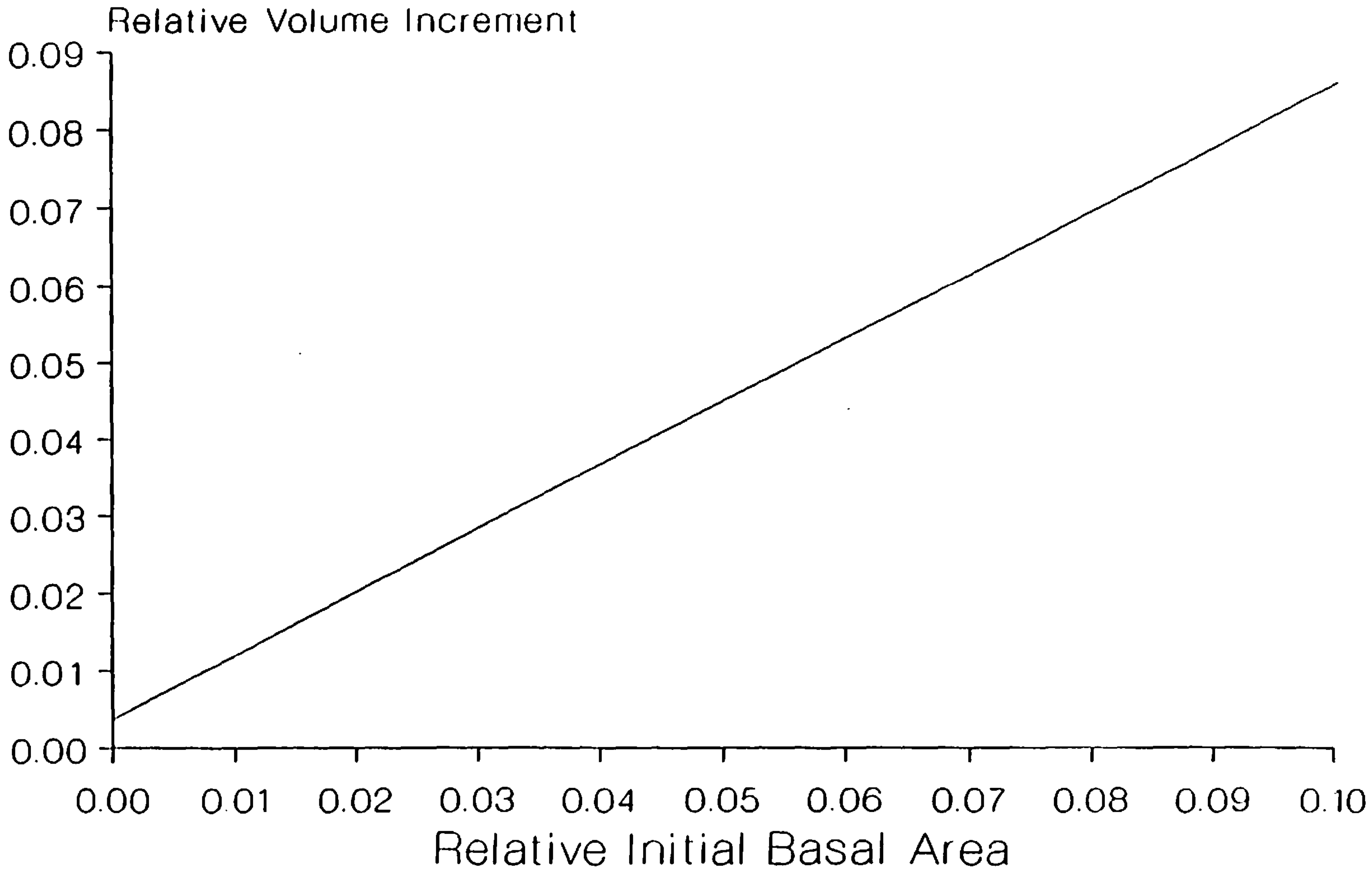
3. Both growth acceleration and major structural changes are possible with nitrogen fertilizer treatment. Stand condition at time of treatment may be an important factor in determining the magnitude of either.

4. Both responding and non-responding installations, based on per acre response estimates, indicated changes in the distribution of relative volume increment due to treatment.

5. Further investigation is warranted and a better understanding is required to assess whether or not stand condition or structure could be used to help predict and select responding sites prior to treatment.

Distribution of Volume Growth

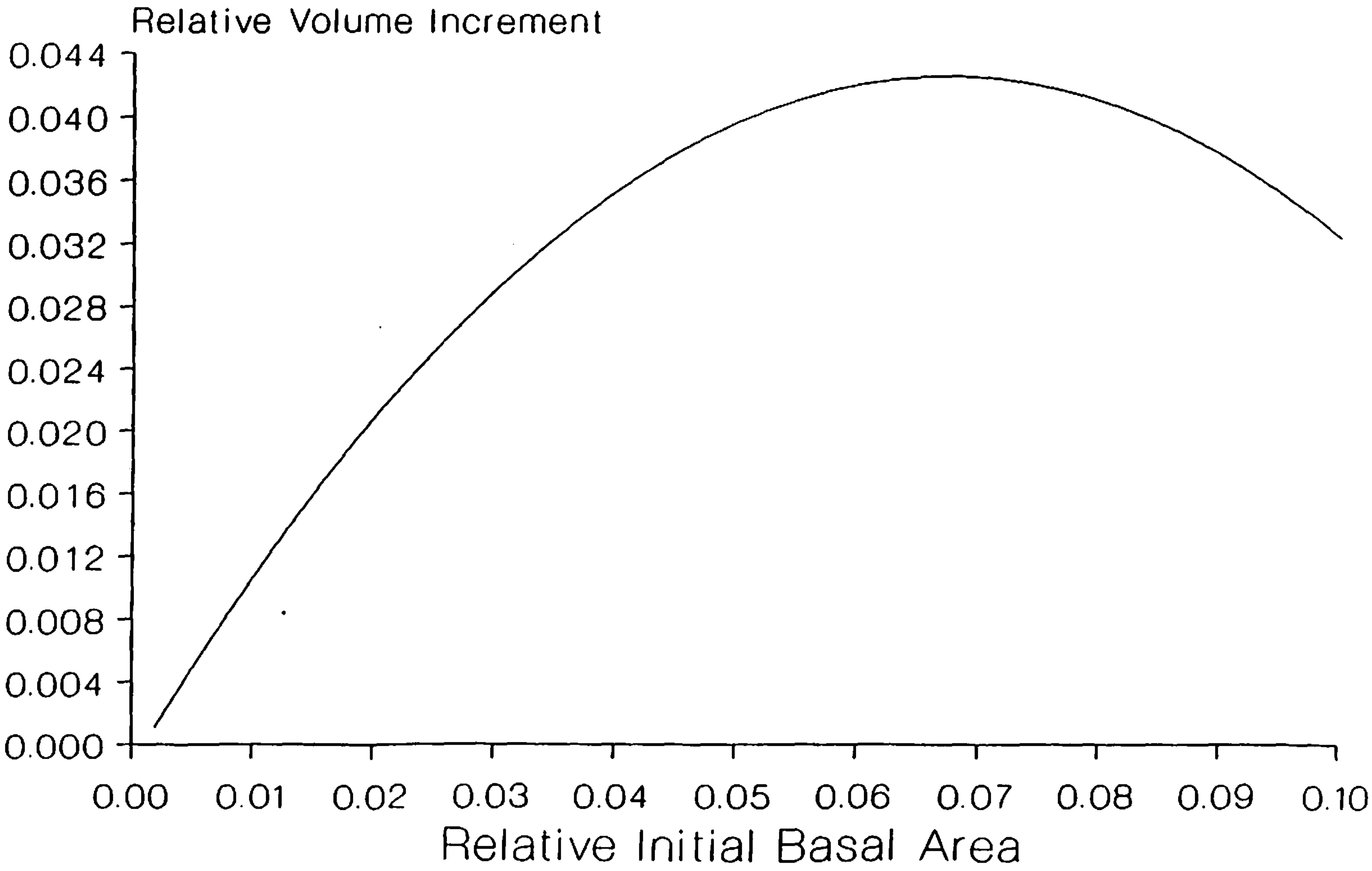
INSTALLATION 204



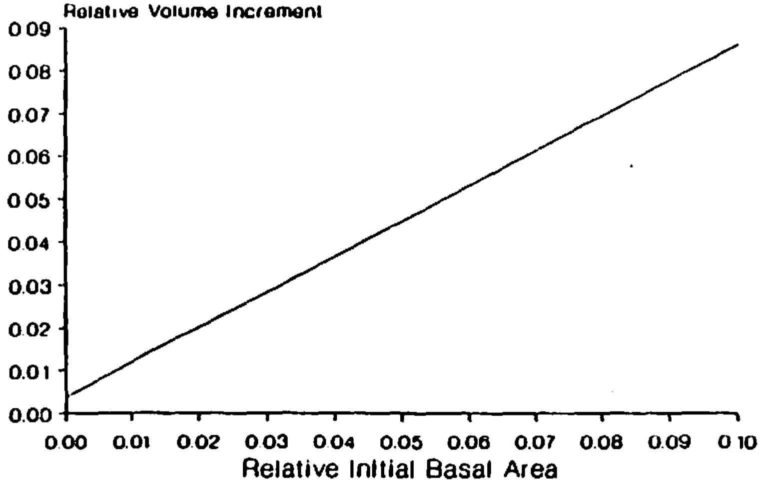
#1

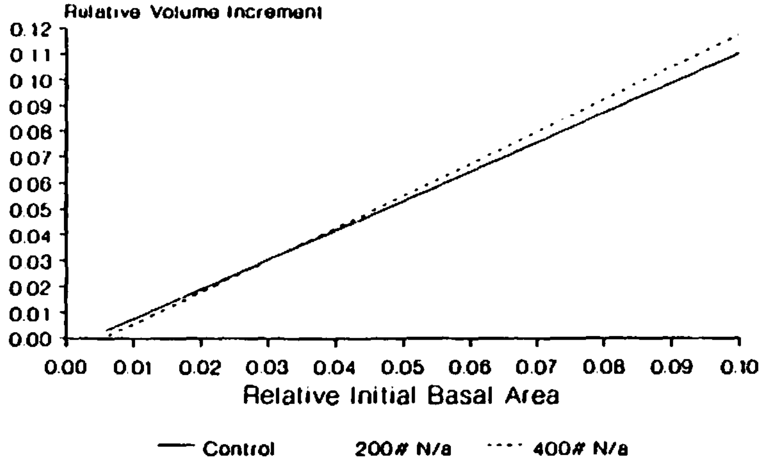
Distribution of Volume Growth

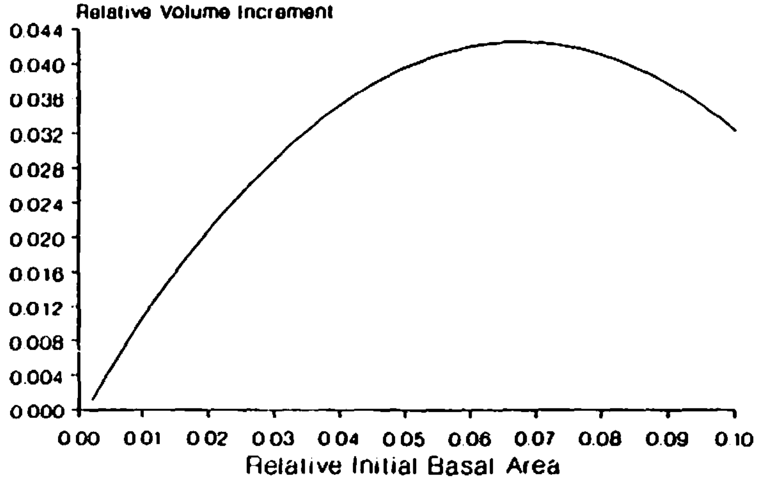
INSTALLATION 261

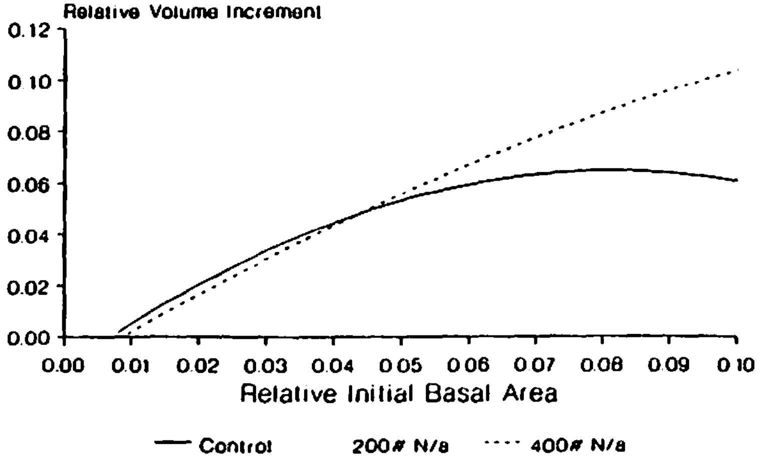


#7


Distribution of Volume Growth
INSTALLATION 204


Distribution of Volume Growth
INSTALLATION 202

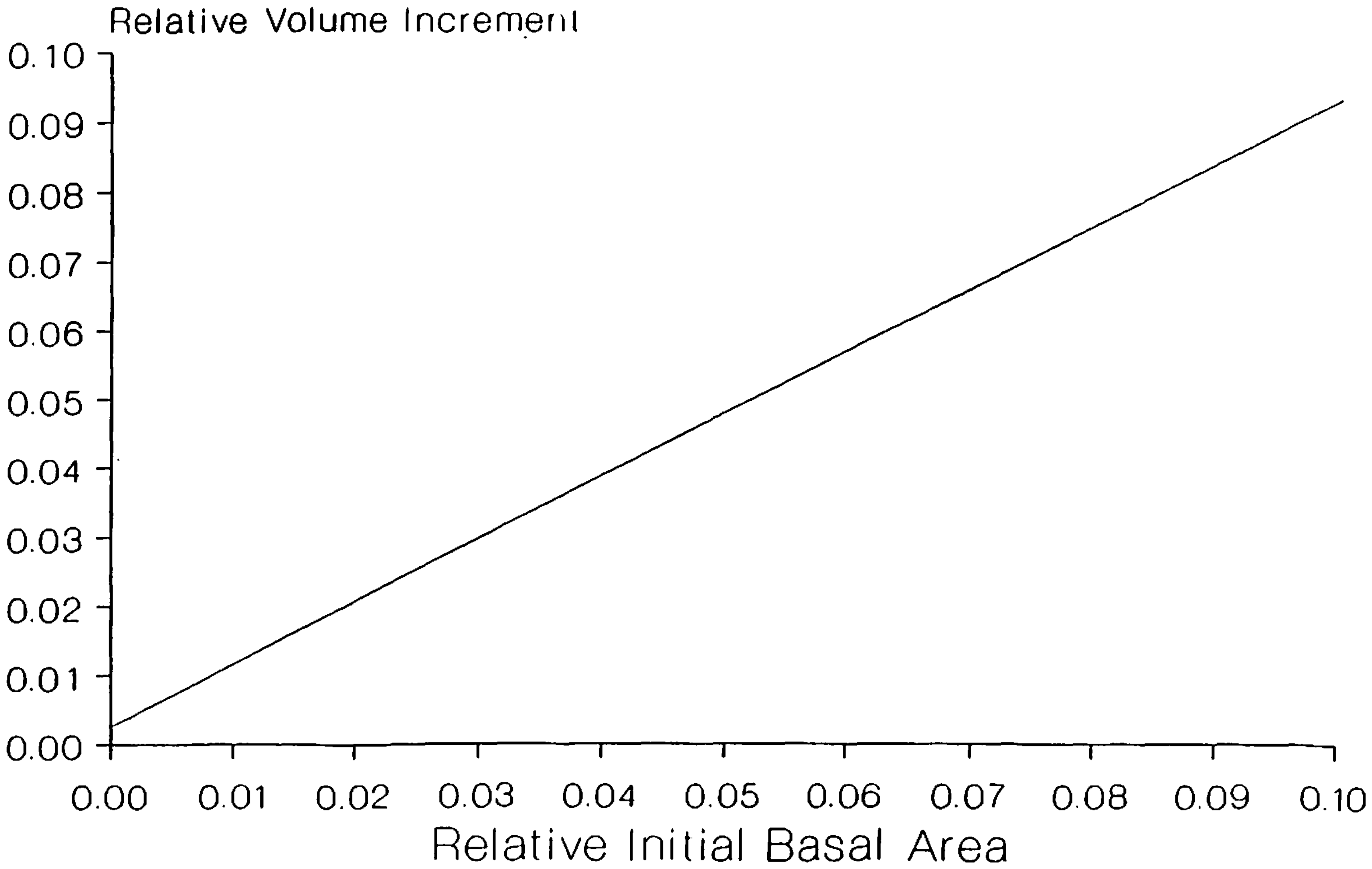

Distribution of Volume Growth
INSTALLATION 261


Distribution of Volume Growth
INSTALLATION 203

#3

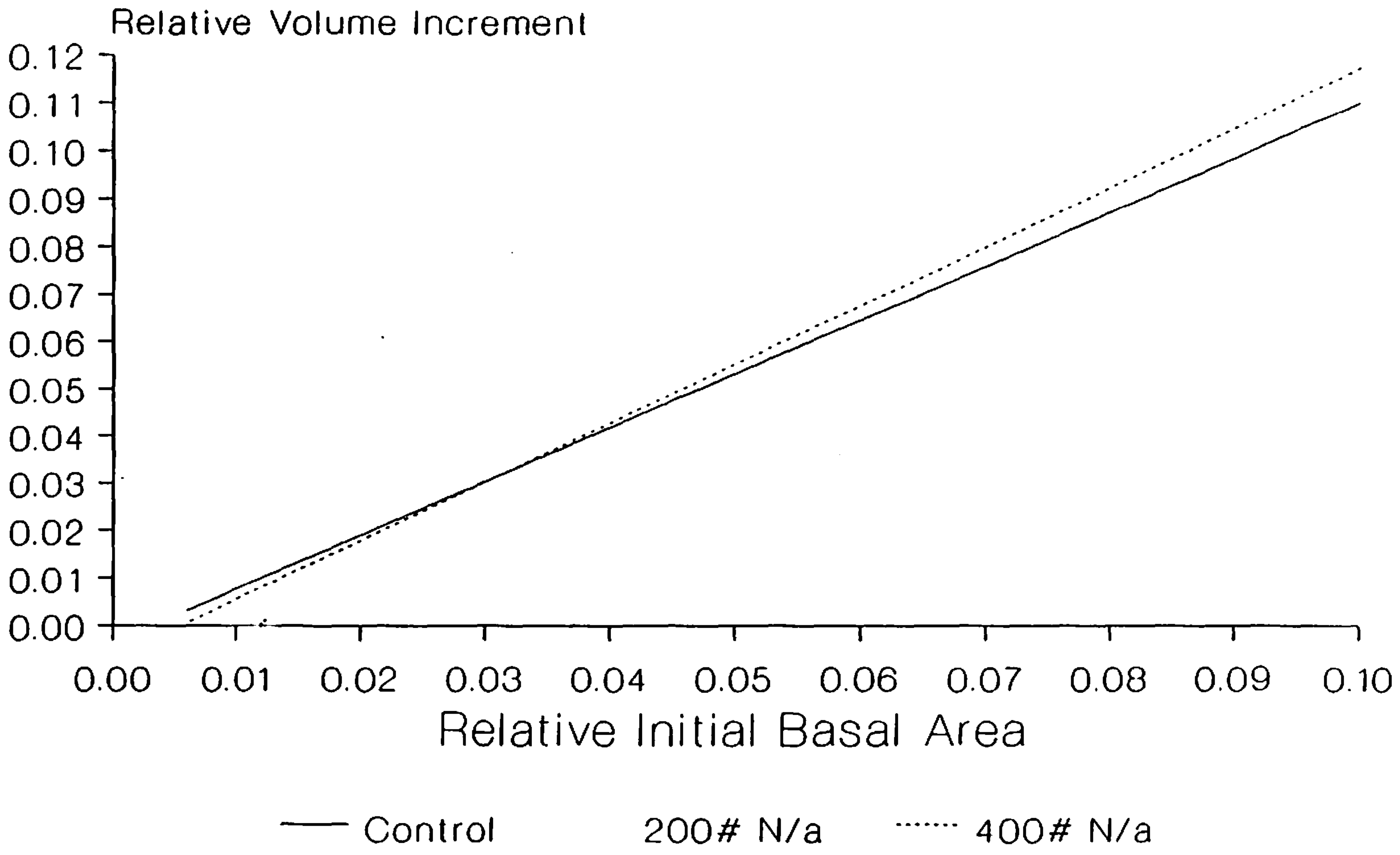
Distribution of Volume Growth

INSTALLATION 230



Distribution of Volume Growth

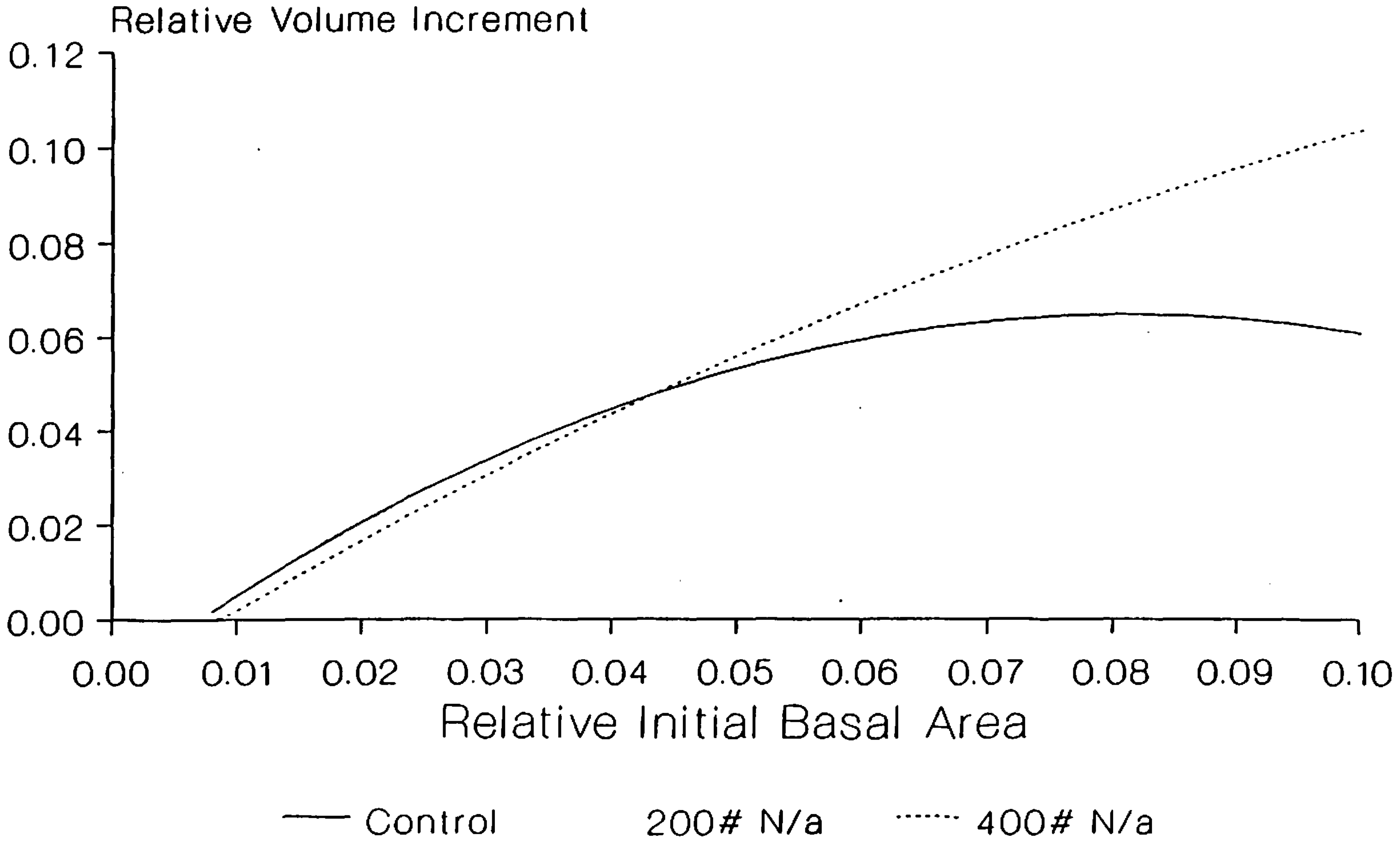
INSTALLATION 202



#5

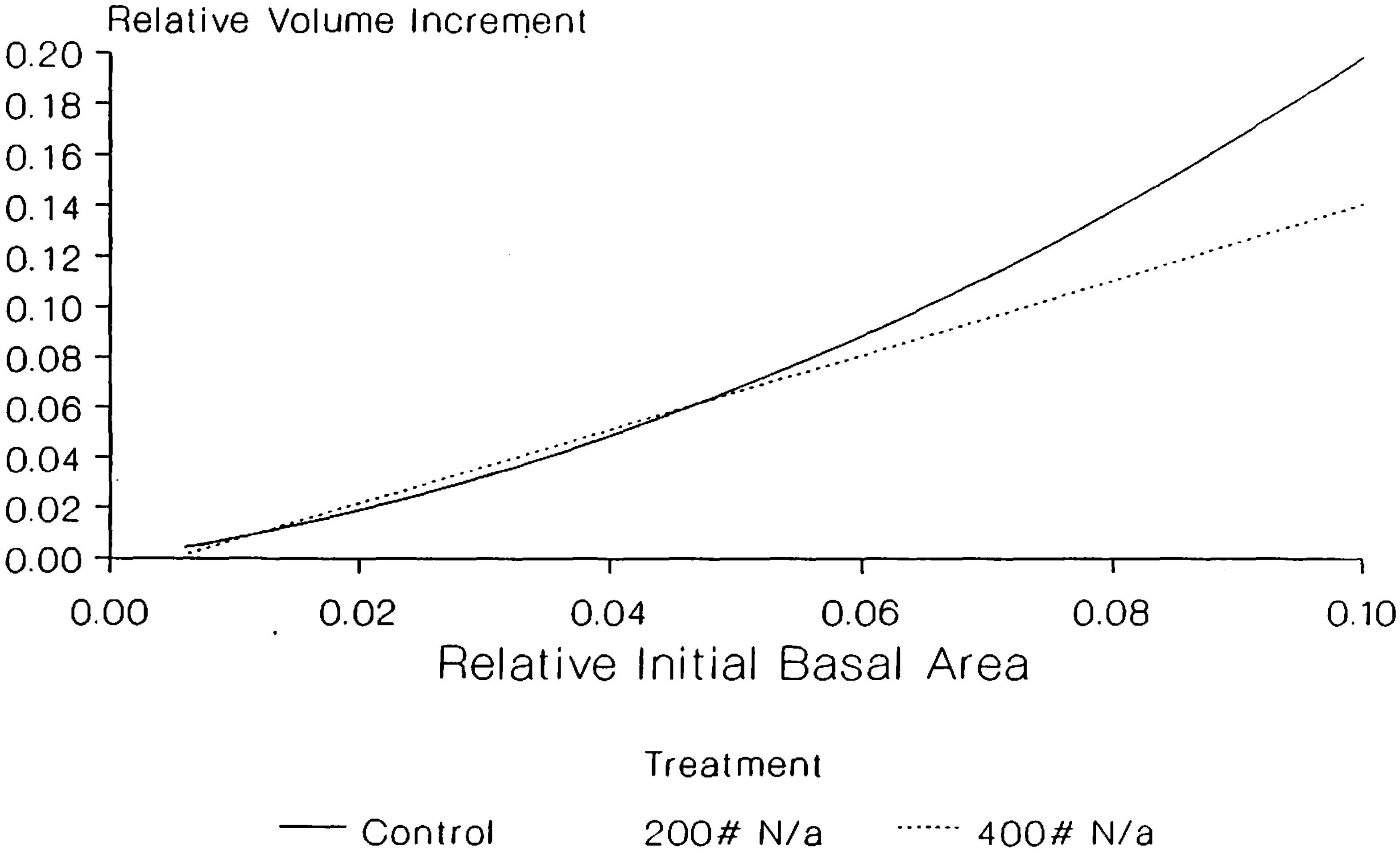
Distribution of Volume Growth

INSTALLATION 203



Distribution of Volume Growth

INSTALLATION 236



THE NUTRITION OF DOUGLAS-FIR IN THE INTERMOUNTAIN REGION

BY

JOHN SHUMWAY

Douglas-fir is a major commercial species in the intermountain west. Its successful management requires an understanding of the ecosystems and ecosystem factors where it grows. Nutrition, particularly in the intermountain region, is one ecosystem factor which has not been studied extensively until quite recently. However, as you have seen earlier today, nitrogen is an important factor in most Douglas-fir stands. Nitrogen is not the only nutrient which limits growth in the intermountain region. Potassium also appears to be deficient or marginal on many sites and may have important management implications.

There are several methods for evaluating the nutrient status of plants. The first is to examine nutrient concentrations in the foliage and compare concentrations with known standards or critical levels. Another method is to look at ratios of nutrients in question and compare them to standard ratios which index nutritional balance. Although critical levels and ratios have not be derived for Douglas-fir, empirical estimates are available and can be used to do a general evaluation of nutrient status.

The critical concentration of potassium in Douglas-fir foliage has been estimated at about 6000 ppm. When the concentration of potassium is below this level, deficiencies are likely. Slightly over 40% of the intermountain Douglas-fir stands in this study have potassium levels at or below the critical levels (figure 1). Urea fertilizer appears to increase the percentage of stands below the critical level. This is in sharp contrast to the condition for calcium, magnesium, and phosphorus which appear to be adequate in all stands both before and after nitrogen fertilization.

Trees, like people, must have a balanced diet. Too much of one food and not enough of another can cause poor health in trees as well as humans. With respect to potassium nutrition, the potassium-nitrogen ratio is often used as a guide to good nutrition. A K/N ratio, expressed as a percent, between 50-100 is considered best for healthy Douglas-fir. In intermountain fir, 19% of the study stands had potassium nitrogen less than 50 prior to fertilization (figure 2). This indicates that potassium is low with respect to nitrogen in these stands. The number of stands with low K/N increased dramatically when nitrogen fertilizer was applied.

The balance between nitrogen and other nutrients did not follow the same pattern as potassium. Prior to fertilization there were no imbalances in calcium or magnesium and only about 1% of the stands exhibited phosphorus-nitrogen imbalances. Nitrogen fertilizer increased the number of stands exhibiting imbalances only slightly.

Low potassium levels and low levels of potassium also effect tree response to nitrogen fertilizer in the intermountain region. Stands which had foliage potassium levels below 6000 ppm and K/N ratios of less than 50 responded less to nitrogen fertilizer than stands having foliage potassium levels greater than 6000 ppm and K/N above 65 (figure 3). Stands with foliage values which did not meet either of the above conditions gave intermediate response. In addition, 400 lbs/ac. of nitrogen did not increase growth above that obtained with 200 lbs./ac. N when K was low but did, on average, when K level was intermediate or high.

Potassium plays a key role in several plant enzyme systems. It has been found to be important in regulating plant water balance and is important in the structural development of cell walls. Low potassium has been associated with increased severity of disease, and the addition of potassium fertilizer has reduced the severity of several root diseases in many agricultural crops. These factors may translate into poor seedling survival and growth, increased wind breakage, and greater severity of disease on potassium deficient sites. If these problems are associated with low or marginal potassium levels in forest crops, it will be important to avoid creating or aggravating potassium deficiency. Silvicultural activities which: promotes compaction, accelerates removal of top soil or prevents litter fall can reduce levels of soil potassium or its availability.

The evidence from the University of Idaho forest nutrition plots throughout the intermountain region indicate potassium may be deficient or marginal on many sites. Foliar potassium levels are below critical concentration in a large portion of the study stands and stands low in K do not respond to nitrogen fertilizer as well as stands high in K. More importantly, low potassium may have broad silvicultural implication relating to harvesting methods, seedling survival, and incidence and control of disease. These aspects of forest nutrition in the intermountain region appear to be fruitful avenues for additional investigation.

PERCENT OF STANDS BELOW THE CRITICAL NUTRIENT CONCENTRATION

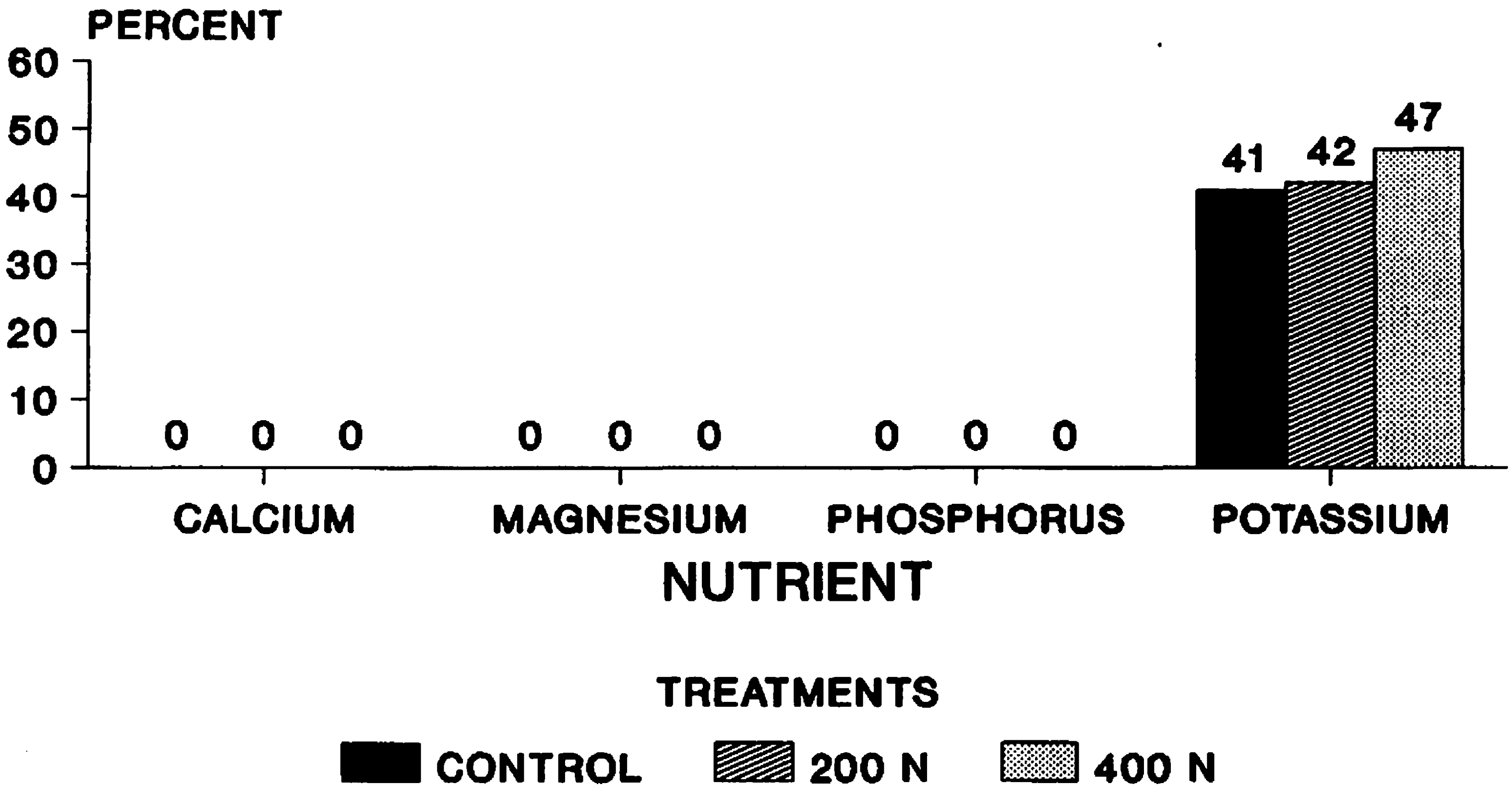
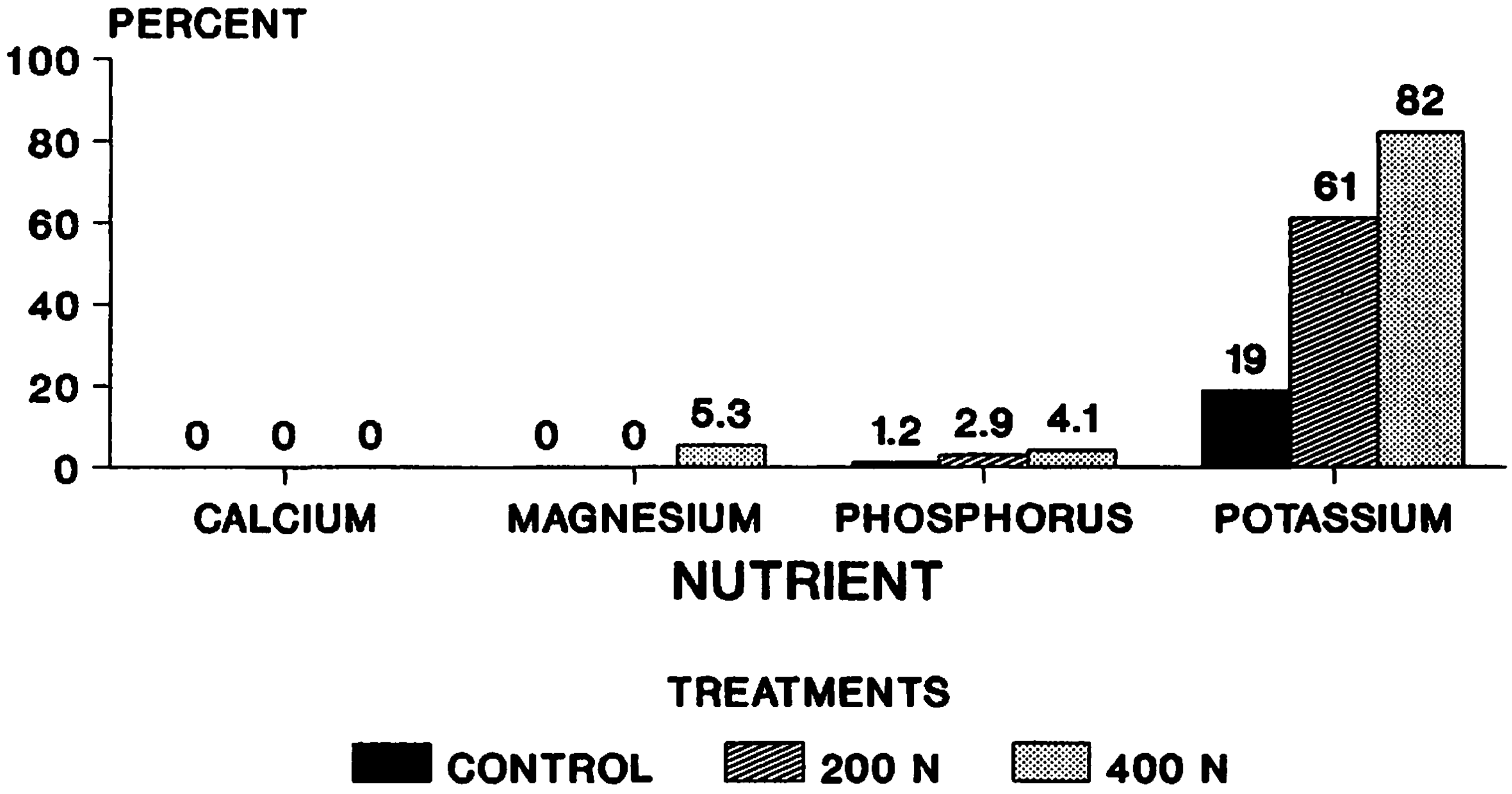


FIGURE 1



PERCENTAGE OF STANDS BELOW
THE CRITICAL NUTRIENT RATIO

FIGURE 2.

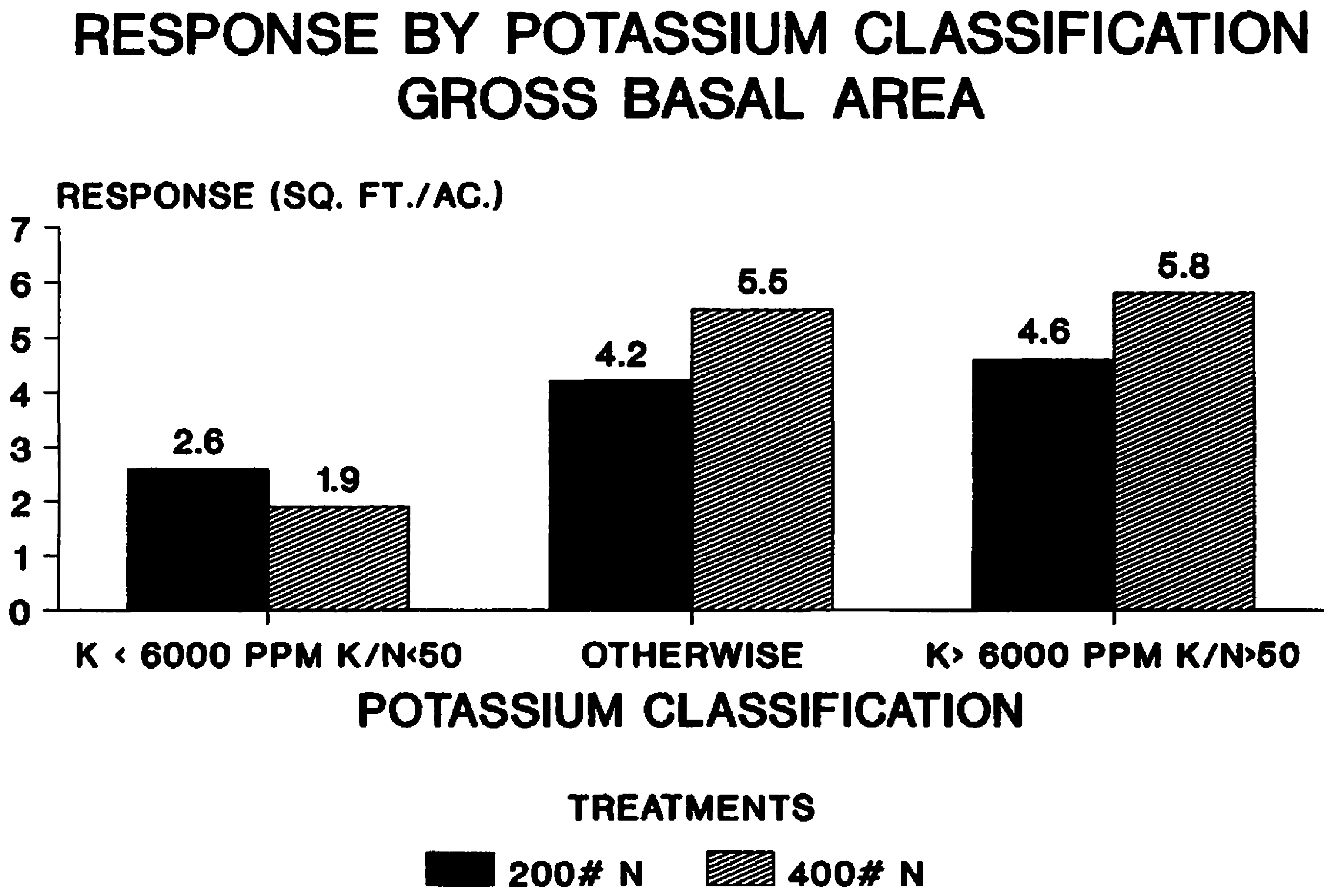

RESPONSE BY POTASSIUM CLASSIFICATION
GROSS BASAL AREA
RESPONSE (SQ. FT./AC.)
7
6
5
4
3
2
1
0
2.6
1.9
4.2
5.5
4.6
5.8
K < 6000 PPM K/N<50
OTHERWISE
K> 6000 PPM K/N>50
POTASSIUM CLASSIFICATION
TREATMENTS
200# N
400# N

FIGURE 3.

1988 WORKSHOP
INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

THEME: FOREST FERTILIZATION AND NUTRIENT MANAGEMENT IN THE INTERMOUNTAIN WEST

EXTRAPOLATING THE RESULTS TO MANAGEMENT PRACTICES: NUTRIENT MANAGEMENT/SILVICULTURAL IMPLICATIONS

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CHAMPION INTERNATIONAL CORPORATION

OUTLINE

1. INTRODUCTION
2. NUTRIENT MANAGEMENT
3. NUTRIENT CYCLES
4. WATER AND NUTRIENTS
5. TYPICAL MANAGEMENT IMPACTS ON FOREST NUTRITION
6. LOCAL STUDIES
7. REVIEW OF SILVICULTURAL CONSEQUENCES OF FOREST NUTRITION

Expanded Outline - Introduction

- Review of Outline

- 2 Industrial Timber Beast Silviculturists on Program
  - The "bottom-line," "wood is good" boys
  - My approach may surprise you - forest management is complex

- A typical attitude when we began the co-op was "just put in the plots and give our staff the data for analysis." Then the staffs went away.

- Other research co-ops were models for this co-op. We have similar plot and installation designs organized by physiographic zones into a large regional experimental design.

- West Coast results then, and to date are:
  - An approximately 25% volume growth response lasting 4-6 years.
  - A 3 out of 4 chance of getting a response on a specific site.
  - Nitrogen is the only element to be considered worth working with.

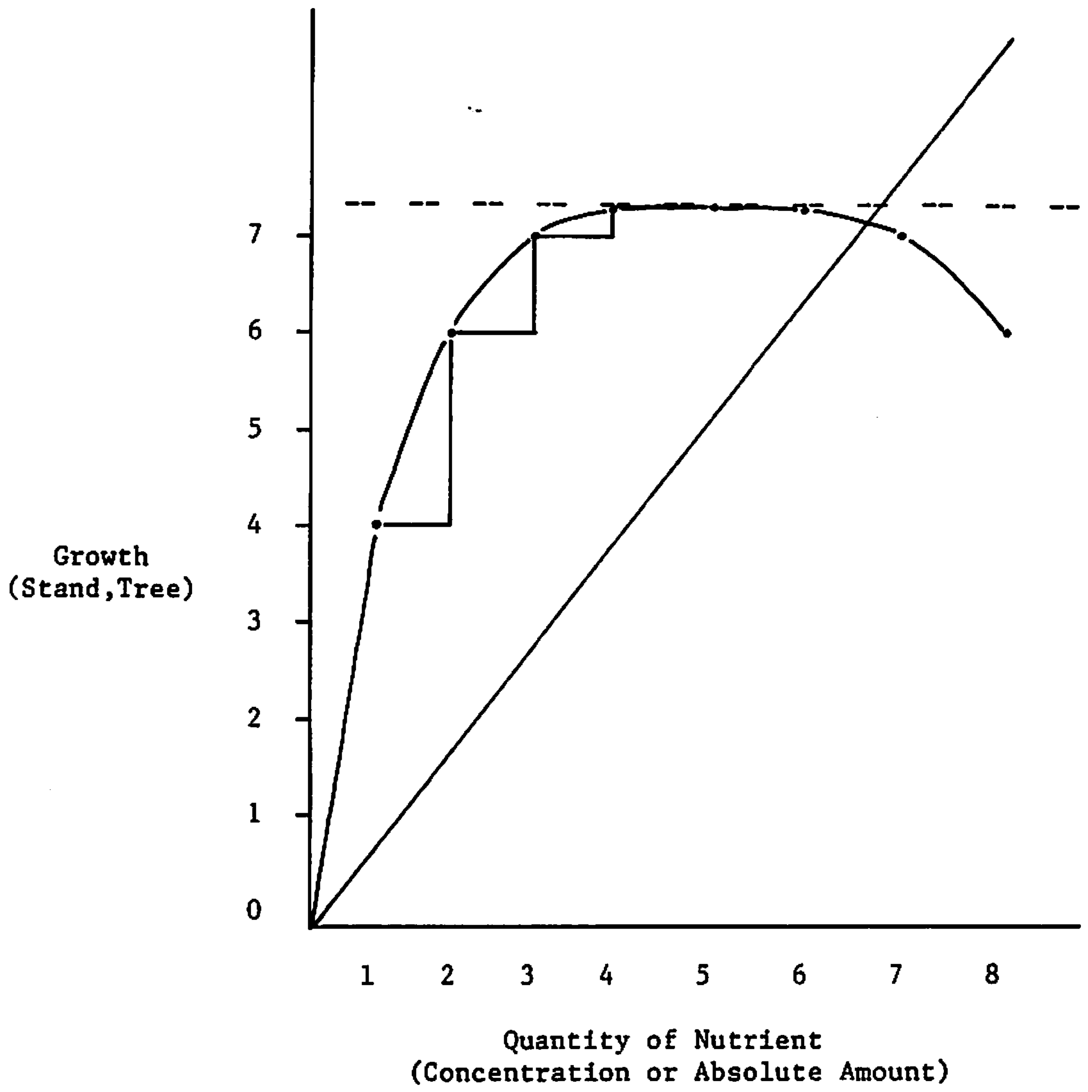
- Our approach was somewhat different.
  - Did not want to get into a position where we could not explain why response does or does not occur (to an acceptable degree) on specific sites.
  - Recognized that "negative information" is valuable.
  - We believed that based on previous work that nitrogen was very important in the region, but had a strong suspicion that other elements could be important in the region.
  - We could not afford the multi-element trials and complete site assessment work we would have preferred.
  - We installed a nitrogen trial and followed up as we could afford it with what we hoped were the most promising foliar and soil tests and developed a scheme for correlating broad soil materials.

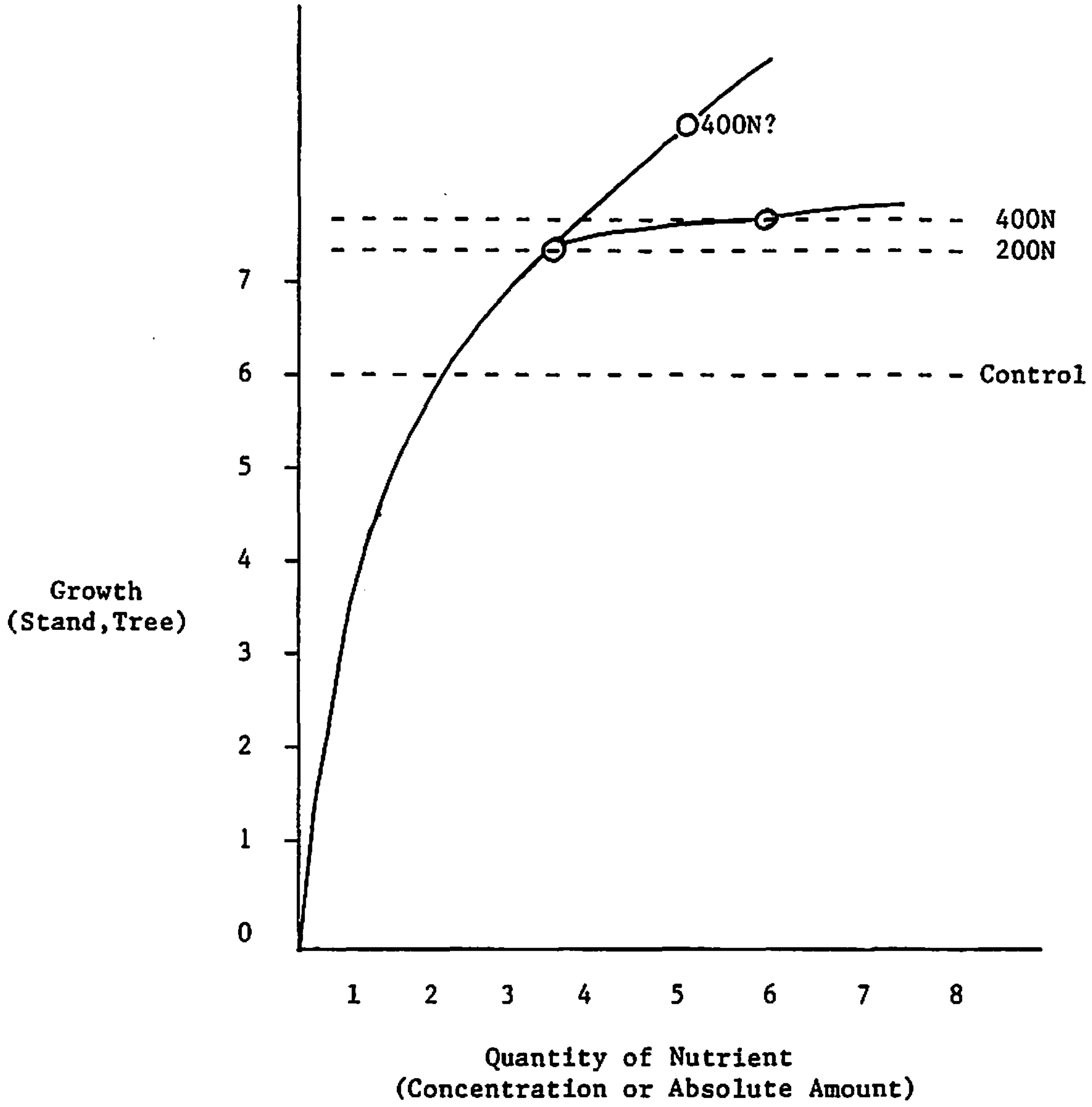
- In summary, our approach was somewhat parallel in that we installed a classic fertilizer trial, but followed up with supplementary forest nutrition assessment work.

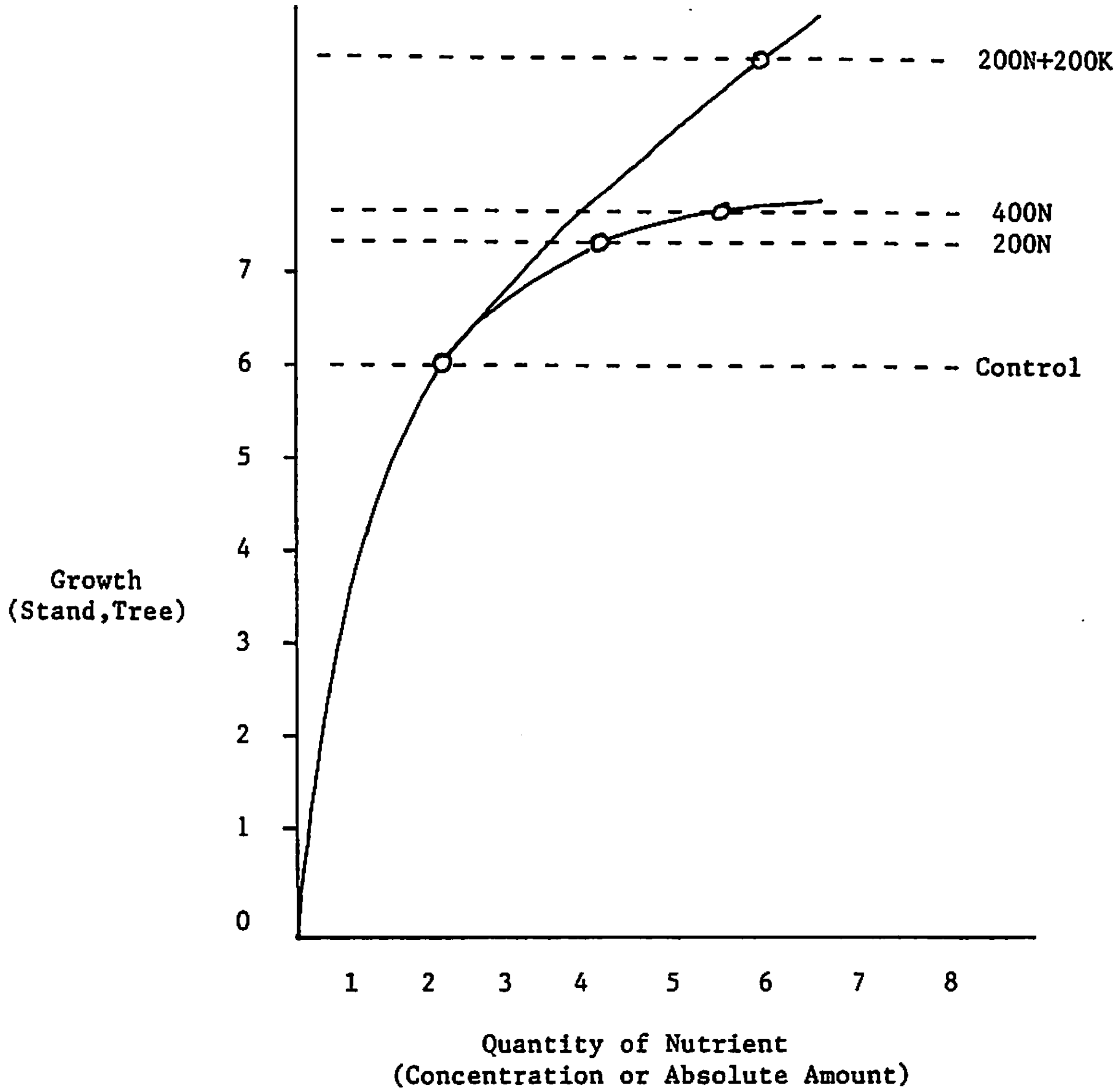
Expanded Outline - Nutrient Management

- Analysis of the Mitzerlich Growth Factor Diagram.
  - Upside and downside reactions to changes in growth factors.

- Fertilizer Trial Interpretations
  - Determination of nutrients limiting stand production.
  - List of critical and adequate foliar nutrient concentrations.
  - Importance of ratios of element content in plants
  - Examples of fertilizer trial interpretations.


0
1
2
3
4
5
6
7
Growth
(Stand,Tree)
1
2
3
4
5
6
7
8
Quantity of Nutrient
(Concentration or Absolute Amount)


400N?
400N
200N
Control
Growth
(Stand,Tree)
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
Quantity of Nutrient
(Concentration or Absolute Amount)


200N+200K
400N
200N
Control
7
6
5
4
3
2
1
0
Growth
(Stand,Tree)
1
2
3
4
5
6
7
8
Quantity of Nutrient
(Concentration or Absolute Amount)

Critical and Adequate Foliar Nutrient Values for Douglas-fir

Element	----Concentration Range-----		Reference
	Adequate	Critical Range	
Nitrogen	1.8	1.4 - 1.6%	Webster & Dobkowski 1983
Phosphorus	0.2	0.13 - 0.15%	Webster & Dobkowski 1983
Potassium	1.0	0.6 - 0.8%	Webster & Dobkowski 1983
Calcium	0.5	0.15 - 0.25%	Webster & Dobkowski 1983
Magnesium	0.2	0.08 - 0.12%	Webster & Dobkowski 1983
Sulfur		50 - 100 ppm (for low sites)	Turner 1979
	0.2	All - 0.14%	Webster & Dobkowski 1983
Iron	150	25 - 60 ppm	Webster & Dobkowski 1983
Zinc	30	10 - 15 ppm	Webster & Dobkowski 1983
Copper	8	2 - 4 ppm	Webster & Dobkowski 1983
Boron	25	10 - 15 ppm	Webster & Dobkowski 1983
Manganese	August	452 - 503 ppm	Stone 1967 "Intermediate" concentrations from upper crown
	Oct - Feb	687 - 758 ppm	
	Nov - Dec	390 - 1294 ppm	
	Plantations	111 - 416 ppm	Weetman (1987) "Adequate" values from various literature
	Young Stands	50 - 1956 ppm	
	Mature Stands	150 - 2700 ppm	
	Pot Trials	36 - 400 ppm	
	100	15 - 25 ppm	Webster & Dobkowski 1983

Expanded Outline - Nutrient Cycles

- Nutrient Cycling Diagram for Potassium

- Compartmentalizations and Transfers
  - 13 essential elements cycling (in somewhat different ways)
  - Quantities, rates and pathways vary by the particular essential element.
  - Distribution and content (concentration) varies within the above-ground parts of the trees.
  - Understory (variable proportion of total cycling). (May be competitive.)
  - Litter layer.
  - Soil and roots, soil organisms.
  - Concept of nutrient availability.

- Sources of Nutrients
  - Soil parent material (quartz sand) (weathering, mineral alterations).
  - Atmospheric inputs (rain, dust, gases, pollen and other organics).
  - "Fixation" of nitrogen on site from N_2 gas (algaes, fungi, lichens, legumes, alders and other N - fixing plants).

- Losses of Nutrients (System fairly tight with intact vegetation and soil flora) (leaching) (Natural material export - erosion, pollen, grazers).

- Effect of Site (soil) Development (from raw parent material)
  - Development of soil layers (horizons).
  - Accumulation of organic matter & nitrogen reserves (N-fixers).
  - Weathering, alteration of soil minerals.

- Effect of Stand Development (on nutrient demand)
  - Mature stand
  - Decadent stand
  - Recently deforested site
  - Effects of complete devegetation
  - Regeneration phase (small trees) (dominance of other plants) (nutrient deficiency)
  - Time of canopy closure

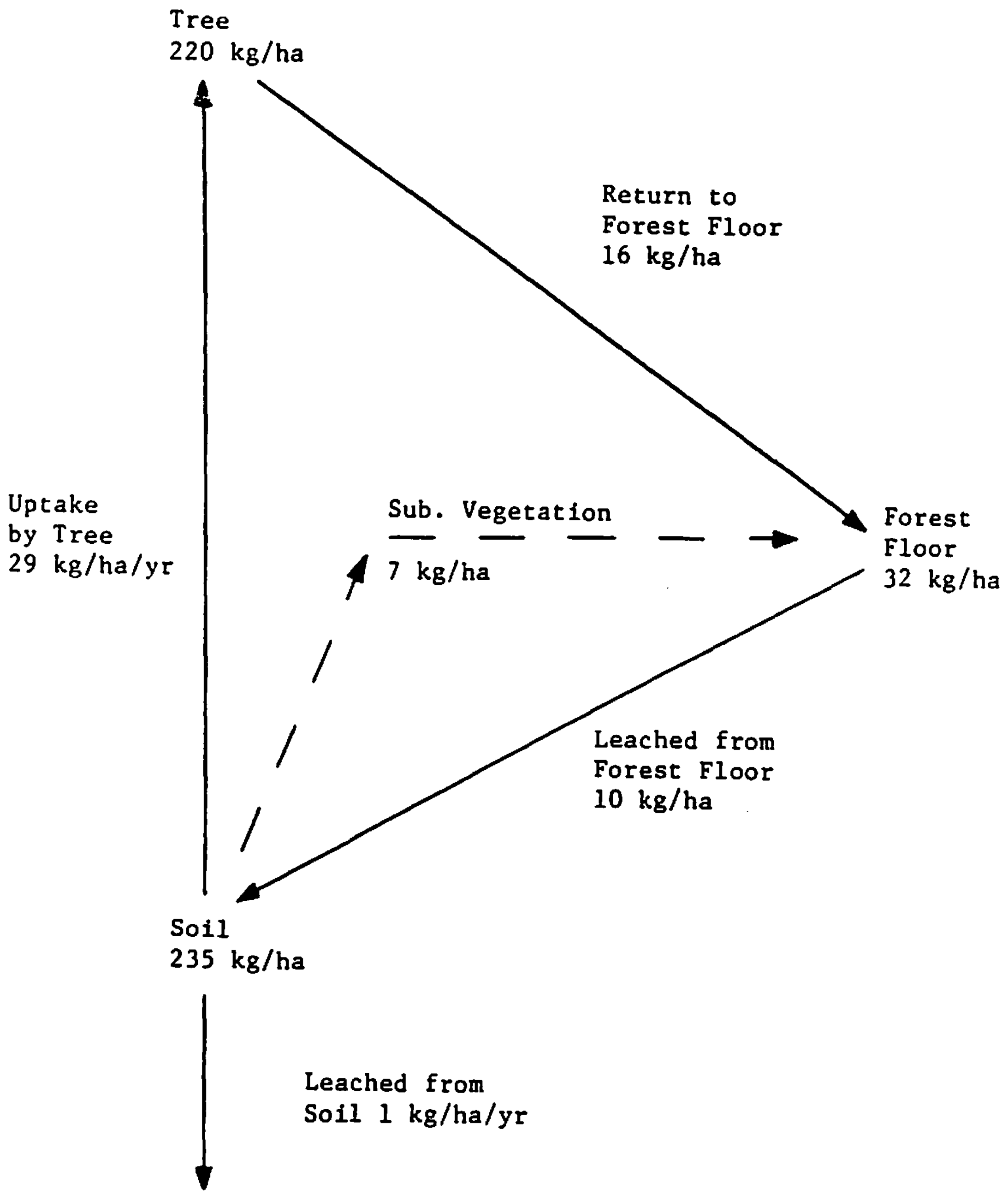


FIG. 1. Distribution and cycling of potassium in a second-growth Douglas fir ecosystem (Cole et al 1967)

Expanded Outline - Water and Nutrients

- Tisdale et al 1985 - "Water stress has often been a convenient scapegoat on which to blame any poorly growing crop, even though nutrient deficiency, pests and other factors were full-fledged accomplices."

- Concept of water use efficiency - all evidence indicates that water use efficiency, or dry matter produced per unit of water used, can be greatly increased if fertilizer increases yield.

- Plants vary widely in water use efficiency and the capacity to control loss of water through transpiration and control water stress.
  - Conifers - use 200-300 liters of water/Kg of dry matter produced.
    - herbaceous plants use 2-3 times the above amount.
    - senescing grasses lose all stomatal control.

- How improved nutrition improves water use efficiency.
  - Improvement in stomatal control - K critical in functioning of stomates.
    - CO_2 uptake requires stomatal opening.
  - Photosynthate production - the proper quantities of elements are required for formation of chlorophyll, enzymes, cell membranes, and other elements of biochemical machinery.

- Weed and Feed Treatments - herbicide release effects.
  - grazing.
  - fertilization and vegetation management.

Expanded Outline - Typical Management Impacts on Forest Nutrition

Do Nothing
- Range of natural productivity and nutrient status exists.
- Nitrogen status typically poor in the Northwest.
- Vegetation on northwest sites is rarely supplied with sufficient nutrients for maximum growth.

Do Something
- Wide range of effects - some favorable, some not so favorable. (Important to know whether effects are significant environmentally or financially.)
- Analysis key is the impact on nutrient cycles.
- Effects on - stand, understory, structure (i.e., above ground biomass).
  - litter layers.
  - soil layers - soil displacement.
    - soil compaction.
  - "bottom-line" effects
- Thinning or crop tree release treatments.
  - Effects normally are to favorably redistribute available water, nutrients, and light to fewer stems. But, large benefits can go to the understory rather than the crop tree.
  - PCT - No mechanical removal of nutrients from a site.
  - CT - Mechanical removal of nutrients.

- Harvesting
  - Range of residual stands left.
  - Range of material and nutrient extraction.
  - Log extraction vs. whole-tree extraction. Remember high concentrations of nutrients exist in fine branches and leaves.

- Site Preparation
  - Mechanical - Range of treatments.
    - Redistribution effects common on the site.
  - Fire - Broadcast vs. pile or windrow.
    - Necessity of fire hazard reduction.
    - Nutrient redistribution effects.
    - Loss of nitrogen in combustion.

- Forest Fertilization - Wide Range of Results

  No Effect
  - No deficiency or incorrect fertilization treatment.
  - Negative or even toxic effects.
  - Good effects.
  - Outstanding effects.
  - Importance of right nutrient combination and rates.

- Olson Presentation

Expanded Outline - Local Studies

- Intermountain Literature Review
  (Brockley & Fahlman 1981) (Stark & Others)

- VanderPloeg - Analysis of K status of IFTNC plots relative to slash disposal history.

- Olson - Seedling growth and nutrient content vs. site treatment.

- Lubrecht - Timber harvesting/thinning demo plots.
  - Typical stand treatments
  - Unreplicated plots
  - Species differences (PP, DF) in foliar nutrient content, low nitrogen content
  - Other interpretations (judgements) not warranted

Assessment of Foliar Nutrient Status of Trees in the Lubrecht Harvesting Demonstration Area

Adequate	Critical Zone		
25	10 - 15 ppm	B	- Douglas-for values generally above critical zone for Douglas-fir. Many ponderosa pine in "Douglas-fir critical zone", rest are slightly higher.
0.5	.15 - .25%	Ca	- marginal to adequate for Douglas-fir. Ponderosa pine values in or below Douglas-fir critical values.
8	2 - 4 ppm	Cu	- generally above the critical zone to adequate for Douglas-fir and ponderosa pine. A few values are low; wide range of values.
150	25 - 60 ppm	Fe	- generally in or somewhat above the critical zone for Douglas-fir. Ponderosa pine values are lower, typically within the Douglas-fir critical zone.
0.2	.08 - .12%	Mg	- generally in the upper end of the critical zone for Douglas-fir, ponderosa pine values are somewhat lower.
(50-100 ppm SO_4-S) (for low sites) 0.2	.11 - .14%	S	- No data; probably adequate based on other experiences in the area.
100	15 - 25 ppm	Mn	- fairly good values for the region; not sure of critical levels.
0.2	.12 - .15%	P	- generally in or above the critical zone for Douglas-fir. Ponderosa pine values generally are in high end of Douglas-for critical zone.
30	10 - 15 ppm	Zn	- all values well above Douglas-fir critical zone.
1.0	0.6 - 0.8%	K	- wide range of values. - generally at high end of critical zone to adequate for Douglas-fir. - ponderosa pine - most values in "Douglas-fir critical zone."
1.8	1.4 - 1.6%	N	- All values deficient, typically well below the Douglas-fir critical zone. - Much higher values for Douglas-fir and ponderosa pine sampled near windrows.

Review of Silvicultural Consequences of Forest Nutrition

Macro
- Silviculture - Art & science of establishing, tending and renewal of the products of the forest.
- Human race has no choice but to protect the forests of the earth - it's a survival issue.
- Understanding of the mineral nutrition of forest ecosystems is part of the forest management science along with genetics, stand dynamics, regeneration, entomology, etc.

Upside
- Potential exists, given a sufficient information base to profitably increase forest production using fertilization or other nutrient management techniques.

Downside
- Potential exists to inadvertently decrease forest production due to the lack of understanding of the effects of forest management practices on forest nutrition (i.e. - The next relation(s) could be less productive than the current).
  - Soil Compaction Analogy

Defensive
- If its plays to the interests of any party that forest management as currently practiced is imperiling forests under professional management, little useful information is currently available to responsibly defend against or substantiate such charges.

Environmental Protection
- Air pollution/acid rain (effects on min. nutrition) (fertilizer effects).
- Stress physiology (pollution, pests, weather, nutrition).
- Long term productivity (components of current productivity not quantified).
- CO_2 buildup (fertilize).

ELEMENT	WOOD	BARK	DEAD BRANCHES	CURRENT FOLIAGE	NONCURRENT FOLIAGE	CURRENT TWIGS	BRANCHES
				CONCENTRATION (%)			
N	0.06	0.27	0.22	1.09	1.00	0.78	0.37
P	0.008	0.07	0.03	0.25	0.38	0.16	0.07
K	0.04	0.28	0.06	0.71	0.61	0.47	0.26
				QUANTITY (kglha)			
N	58	45	16	23	75	4	32
	103		150				
P	8	11	2	6	29	2	6
	19		45				
K	40	46	4	15	45	2	24
	86		90				

Pang P.C., H.J. Barclay and K. McCullough. 1987. Can.J.For. Res. Vol. 17, 1987

SITE #1 - TIRED WOLF

	HEIGHT		FOLIAR NUTRIENT STATUS[1]	
TREATMENT CLASS	3-YEAR HT. INC. (cm)	STD. ERROR OF MEM. (cm)	K PPM	TOTAL N %
No Soil Disturbance No Burn	70.5	5.2	8753	1.3
Soil Piling	110.9	6.4	9355	1.4
Soil Displacement (Skid Road)	54.8	4.8	8049	1.4
No Soil Disturbance Burned	78.9	7.7	8543	1.3

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[1] Foliage collected from terminal and lateral shoots, 3rd whorl from top of tree, 2nd represents a mean of 4, 5 tree composite samples.

SITE #2 - BINGO CREEK WEST

	HEIGHT		FOLIAR NUTRIENT STATUS[1]	
TREATMENT CLASS	3-YEAR HT. INC. (cm)	STD. ERROR OF MEM. (cm)	K PPM	TOTAL N %
No Soil Disturbance No Burn	80.8	7.3	7699	1.6
Soil Piling	--	--	--	--
Soil Displacement (Skid Road)	72.1	8.0	7336	1.5
No Soil Disturbance Burned	96.5	4.8	8859	1.5
Burned Plot #1[2] (Ceonothus)			7667	1.3
			8889	1.3
			7776	1.3
Same Plot #2			8725	1.3
			7535	1.3
			7310	1.3

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[1] Foliage collected from terminal and lateral shoots, 3rd whorl from top of tree, 2nd represents a mean of 4, 5 tree composite samples.

[2] Additional foliage samples taken from seedlings in ceonothus patches adjacent to the main sample area.

The Fertilization Decision...

Using what we have learned to evaluate a Nitrogen Fertilization Program.

IFTNC Fertilization Workshop
April 1988

Presented to IFTNC
Fertilization Workshop
April 12, 1988

THE FERTILIZATION DECISION
"Using What We Have Learned to Evaluate A Nitrogen Fertilization Program"

Today, we have heard a lot about the magnitude of nitrogen response in managed Douglas-fir stands. IFTNC results show that, generally speaking, the lack of nitrogen is limiting growth on most sites in the Inland Empire region.

However, as managers and foresters the question of most importance to us is, does it pay as a silvicultural tool? If you prescribe a nitrogen treatment can you expect to earn an acceptable rate of return? The answer to this basic question is a prerequisite to and the basis for developing a nitrogen fertilization program. What I'm going to present a simple approach that might be used to address this basic question, "Does it pay?".

Obviously, an "acceptable return" can only be defined by you or your organization. Each organization has different criteria upon which this will be defined. These criteria will reflect, among other things, individual perceptions of two basic but often difficult to estimate factors, cost of capital and future wood values. As most of you know, these two factors alone will have significant impact on the economic evaluation of the nitrogen treatment. Keep in mind that those in the private sector can do three things to provide additional wood - buy land, which increases the tax base and overhead; buy timber, that might be in limited supply and therefore expensive; or buy growth! Fertilization and silviculture in general allows us the opportunity to do the latter.

I will be using what I consider to be reasonable economic assumptions in the analysis that follows - your own economic constraints might change some of the results but the basic approach presented should still apply.

To begin, the first question the forest manager or economist might ask is - "How much extra wood will I require from a nitrogen application to meet a specified minimum acceptable return on investment?" Secondly, is it reasonable to expect this level of response from treatments applied operationally to our timberlands? In response to the first question, let's first assume that I will obtain maximum return from a nitrogen application 10 years after treatment, though it's generally accepted that the duration of response is probably less than 10 years. A simple calculation provides an estimate of the amount of additional value I would need to recover in year 10 to earn a 3% and 5% return.

A $60/acre investment buys an aerial application of urea at a rate of 200 lb. N/acre, assuming urea could be obtained for approximately $150/ton. I'll assume a 400 lb. N treatment would double the cost. Treatment cost compounded at a specified discount rate (real) yields the additional value required.

This table shows the value required to earn a 3% and 5% return on both 200 lb./N and 400 lb./N treatments.

Treatment	Discount Rate (real)	10-Year
	3%	5%
	($/acre)	
200 lb.	81	98
400 lb.	161	195

If you could capture the same response in five years however, the additional value needed obviously declines (simple compounding). Since the response information we currently have available is based on 4-year results, this would actually be a more realistic time period to consider for this analysis unless we estimated the additional response the might occur beyond this period.

Treatment	Discount Rate (real)	5-Year
	3%	5%
	($/acre)	
200 lb.	70	77
400 lb.	139	153

Bear in mind, the increase in value could come from two sources. First, from more wood or response to nitrogen, and second, from reductions in harvest or processing costs that also might be realized. An example might be a reduction in logging cost resulting from an increase in average piece size. A stand incurring significant treatment caused mortality might have significantly fewer pieces per MBF in the future, which would lower harvest costs. I won't be accounting for this possibility in this analysis, however under certain situations cost reductions may be significant. Any cost savings would reduce the amount of treatment response required to earn a specified return and warrants further investigation.

How much more wood will be required then, assuming no reduction in harvesting or processing costs, to earn a specified rate of return? This will in large part depend on <u>your</u> own assumptions about current and future wood value. This will vary by cooperator so I'm going to use a range of Douglas-fir stumpage values, $40, $60 and $80/MBF.

In addition, to account for real (in addition to inflation) increases in wood value, I will also use a 1-1/4% per year wood appreciation rate.
Using these assumptions and the information presented in the previous table, a simple matrix can be constructed to show the board feet per acre response required from a nitrogen application to meet minimum return criteria for these different stumpage values. For the 200 lb. N treatment, these responses will be required to meet our economic requirements.

	Discount Rate (real) 200 lb.					
	3%			5%		
Time Period (Yrs.) / Stumpage Value $/MBF	40	60	80	40	60	80
	(BF/acre of response required)					
5	1,650	1,100	820	1,810	1,210	910
10	1,790	1,190	890	2,160	1,440	1,080

You can simply double the figures to arrive at the required response for the 400 lb. N treatment.

This provides an estimate of the magnitude of response that will be needed to meet a specified return. The next question will be, is it reasonable to think that a 200 lb. N/acre treatment can yield enough extra wood to be profitable? Since only 4-year response data are available, I used a 5-year investment period for the remainder of the analysis.

The IFTNC 4-year results allow us to see how growth response stacks up to these economic needs? IFTNC overall average 4-year gross cubic response is estimated to be 130 cu.ft./acre in 4 years for the 200 lb. N/acre treatment and 161 cu.ft./acre for the 400 lb. N/acre treatment.

Before proceeding, I should explain why I'm using gross response in the analysis instead of net, which excludes mortality. There are two primary reasons:

1) Mortality incurred during the 4-year period would be recoverable at year 5 and probably at year 10 - at least the large trees. It is not lost volume.

2) More importantly, any treatment caused mortality can reduce growing stock levels substantially, confounding short-term comparisons of net total cubic volume between treatments. Tree volumes removed as mortality overshadow the levels of response we are attempting to quantify. In addition, when nitrogen treatment results in mortality, there is actually a thinning effect along with growth acceleration that cannot be accurately assessed in the four year period currently available. Confusion can also arise when mortality is confined to the control plots (i.e. #204) causing Net response to sometimes exceed gross.

We have an estimate of fertilizer response, but it's in cubic feet... <u>How do I convert cubic volume response provided by IFTNC to units like board feet that have established values?</u> This may not be as critical if you're interested solely in fiber, however fiber values are considerably lower than dimension products. The most desirable way to obtain board foot response would be to simply <u>merchandise</u> the stand table data before the treatment analysis and evaluate and report board foot response. This might be a reasonable option in the future, at least for the larger diameter stands. This relates to my presentation earlier today. Knowing how response is distributed within a stand will improve our ability to estimate economic returns.

To make a cubic to board foot conversion for this analysis, I will be faced with having to make a few assumptions. First, the <u>average</u> stand DBH for the IFTNC trials exceeds 9", which it does for many sites. This in turn suggests that <u>most</u> of the estimated cubic foot response will be within the merchantable limits I used, 9" DBH and 6" min. top DIB.

Second, I will assume that the simple conversion rule will be: 1 cu.ft. = 5 bd.ft. This appears realistic and even a little conservative based on results of the merchandizing example I presented this morning.

Third, I think it's reasonable to assume that a percentage of the total gross cubic volume response will still be in nonmerchantable stems and therefore not recoverable. For this analysis I arbitrarily used a 10% falldown in total cubic volume response to reflect this.

Last, I think we would also incur treatment related operational operational falldown? Would you expect to get the same response to nitrogen had we applied the treatment by helicopter over a large and more variable stand area? Probably not, and to account for this I will assume an additional 10% reduction in cubic volume response.

Using these assumptions, the overall IFTNC project average 4-year response of 130 cu.ft. yields 520 bd.ft. for the 200 lb. N/acre treatment and 644 bd.ft. for the 400 lb. treatment. Comparing these responses with our estimated response requirements for the 200 lb. nitrogen treatment that ranged from 820 to 2,000 bd.ft., nitrogen fertilizer alone would appear to be at best marginal from an economic standpoint. I would suggest, however, that this simple comparison might lead us to the wrong conclusion about fertilization in the Inland Empire.

We have additional data that should be incorporated into our analysis. By our own design, the overall average response for the project should not be expected to earn our specified acceptable return. We would have been quite lucky if it had. We intentionally selected a range of sites and stand conditions within six different geographic regions in effort to find out which ones respond and which don't. What about average response by region? Regional response trends provide the next higher level of resolution to consider.

(Slide 1) Looking only at the 200 lb. N/acre treatment, how do the individual regions stack up to my economic needs? As Jim and Peter indicated earlier, there are clear regional differences in response to nitrogen. On average, both North Idaho and Central Washington look more appealing from a biological standpoint than the other regions. However, they would still be marginal based on our economic analysis thus far. Even Central Washington's average response of 190 cu.ft. yields only 760 bd.ft. of extra wood.

Lets stop for a minute. Have we now gone far enough to answer our initial question - Does nitrogen fertilizer pay? We have looked at how much extra value and, in turn wood, we would need to generate a 3% or 5% return on fertilizer investments of $60 and $120/acre, and we compared these results with IFTNC overall and regional response estimates. On the average, neither 200 lbs. or 400 lbs. of nitrogen would appear to yield an adequate economic return, except maybe in NI and CW depending on the economic criteria used.

Based on these results, one might ask why anyone in Montana, Central Idaho or Northeast Oregon and Washington would consider nitrogen fertilizer. It doesn't appear that an acceptable return would be possible in those regions, at least for a single, 200 lb. nitrogen treatment. This is true on average but what about the installations that responded much better than the regional average. One of our objectives has been to achieve a better understanding about the stand and site conditions that lead to an economically acceptable response. Installation level responses provide the key to addressing this objective. There are strong responders in each region! For example, in Central Idaho there is Inst. #233 (287 cu.ft./ac, 1,148 bd.ft.) and in NE Washington there is Inst. #209 (217 cu.ft./ac, 868 bd.ft.)...and in Montana ....Well I'm still looking.

So far we haven't used much of what we know about the stand conditions or characteristics of these individual sites. Ignoring this type of information could result in lost treatment opportunities.

(Slide 2) Using the cumulative distribution function Jim described this morning, we can array individual installations within each region by 4-year response. This shows the distribution of installation responses across all regions. Keep in mind the break-even point for an acceptable response using my economic assumptions is near 270 cu.ft./acre. Several installations are above this level.

(Slide 3) Even in regions with low average response, like Montana, some installations show a much higher response to nitrogen than the regional average. What about these stands makes them respond? How are they different from non-responders? - <u>could it be specific site and stand conditions that we can identify.</u> Peter Mica's analysis provided some insight as to which characteristics might be important in such an evaluation but more work needs to be done in this area. Maybe the responding installations are concentrated on <u>your</u> holdings.

Because of time limitations, I'll be focusing solely on the Northern Idaho and Central Washington regions for the remainder of my analysis. Average 4-year gross cubic response to 200 lb. N/acre for the North Idaho region is 184 cu.ft. Using the board foot conversion formula presented earlier, this translates to 736 bd.ft. of response in four years. Central Washington shows an average of 760 bd.ft. of response to the same treatment. Several individual installations in each region show much higher response, however. For example, Inst.# 264 (NI) shows a 1,604 bd.ft response in four years and Inst.#260 in Central Washington posted a 1,536 bd.ft. response. Even though the average response for the region does not meet our economic requirements specific stands do. How many acres of these responding types do you manage? Having the capability to predict response and thereby rank potential investments is critical to the development of a treatment program.

(Slide 4-8) If the IFTNC installations are in fact representative of the stand and site conditions in the various regions, the cumulative frequency distributions provide a good idea of the range of returns that might be anticipated. Each region shows a different range.

To enable ranking of potential fertilizer candidates, one approach might be to generate a matrix of ROI's by specific, operationally locatable stand and site characteristics that are correlated with measured responses. This is where the installation level results really fit in. Peter has discussed correlations he found between 4-year cubic foot response and <u>site</u>, <u>soils</u>, and <u>stocking</u> factors in his presentation.

It would be convenient if only one or two factors were found to be highly correlated with nitrogen response. Clearly, this will not be the case however, as Peter discussed earlier. If it was that easy, it would have been figured it out long ago. Irregardless, we as forest managers need a tool or model that utilizes the best information available to predict response to nitrogen before we invest capital. It is also critical that such tools be operationally practical, in other words they must be driven by information we have available or could obtain at a reasonable cost.

With this in mind I asked Jim and Peter to attempt to construct a model to predict cubic volume response to nitrogen for North Idaho and Central Washington using 4-year IFTNC results. I restricted the list of possible model variables to those that most cooperators would have access to as part of a forest inventory, like site index, basal area, habitat type and so on. The list of potential variables intentionally excluded chemical analysis results, both soil and foliar. Not because these are not important, which IFTNC results indicate they might be, but because they are not readily available on most forest inventories....at least not yet.

Results of Peter's efforts provided the basis for the economic analysis that follows.

Interestingly, different variables were found to be important in predicting response for the two regions I looked at.

For North Idaho, the "best" model, meaning the highest r2 value in this case, shows 4-year gross cubic volume to be a function of site index, vegetation series, basal area, percent grand fir, average crown ratio and treatment. Only about 27% of the variation in response within North Idaho is explained by this model however. The addition of other "common" variables did not improve the prediction capability of the model.

The "best" Central Washington model includes different variables. They are vegetation series, parent material, basal area and treatment. Approximately 35% of the variation in 4-year cubic volume response is explained with this model. Not bad really when compared to the overall model Peter described this morning.

We might as well face it though, the common, easy to obtain, stand and site descriptors may not be adequate to predict volume response to nitrogen. Additional information like soil characteristics and foliar chemical analysis might be worth the investment in order to make better predictions of response. Bad decisions about the type of stands to fertilize, as well as no decision at all, will cost you money.

Though maybe not as good as we would like, I used these two models to predict 4-year cubic volume response over a range of site and stocking conditions for both North Idaho and Central Washington. The predicted responses are in turn used to estimate return on investment.

(Slide 9) Looking first at the North Idaho, within the grand fir vegetation series, over a range of fairly arbitrary site and basal area classes, we see this pattern of predicted response. Four year gross cubic response ranges from 145 to 303 cu.ft./acre. The highest response is in the mid site classes, 70-90', at both high and low basal areas.

(Slide 10) A similar matrix for the cedar/hemlock vegetation series shows a marked reduction in response, ranging from 90 to 248 cu.ft. Why are the better sites responding less you ask? ..Maybe nitrogen is not as limiting on these wetter sites. These models indicate that response is fairly strongly correlated with vegetation series in both regions as well as site index in north Idaho, indicating the need for good calls on both habitat type and site index.

(Slide 11) Using a $60/MBF stumpage value and a 1-1/4% wood appreciation rate over a 5-year period yields this range in values within the higher responding grand fir series. This is the estimated value increase per acre attributable to nitrogen. Note the range in value of $37 to $77. Remember we invested $60/acre 5 years ago and are looking for a minimum of a 3% return. Obviously, several of these potential fertilizer candidates would not be profitable given the economic criteria used in this analysis.

(Slide 12) Taking the next step, we can estimate the return on investment for each cell in the matrix. The highest return based on these predicted response values is 5%, for the site 70-80/ 200+ basal area cell. Both high and low sites indicate less response than the mid-site classes.

(Slide 13) What about Central Washington? Looking first at the Douglas-fir vegetation series over 5 major soil types and across a range of basal area classes we see a range in response of -17 to 320 cubic feet. The highest estimated response shown here would yield around a 4% return in the five year period. Few of the conditions depicted would yield an acceptable return. Approximately 270 cu.ft./acre of response is needed to earn a 3% return.

(Slide 14) The combined GF/H/C series for the same soils and basal area classes shows generally higher response. Note that the gross cubic response now ranges from 139 to 486 cubic feet. Granite parent materials are the least responsive.

(Slide 15) Converting cubic volume to board feet and estimating value, we see much higher returns as compared to North Idaho. The lower basal areas yield the highest response over all parent materials.

(Slide 16) Calculating ROI, we see a much wider range of values. Sandstone parent materials appear to be the most responsive.

The value of the approach suggested here is that it enables prediction of response by taking advantage of installation level attributes and response. It doesn't rely simply on broad regional response averages. The weak link is probably in the quality of models available at the present time. To improve the situation however, we must continue to invest in efforts to better understand the relationships between soil, environment, stand factors and growth response.

Last, bear in mind that the examples provided here are merely <u>tools</u> with which to evaluate a potential program. They do not, in themselves, identify or locate specific acres that could be treated economically. We must next attempt to match stand conditions that demonstrated an acceptable response to actual ownership acres. In order to identify the scope of a potential fertilizer program, good inventories are becoming more critical as they will provide the basis for most silviculture programs.

CONCLUSIONS

- DOES NITROGEN FERTILIZER PAY?

  Yes - For some stand/site conditions
  in several regions.

- SHOULD YOU FERTILIZE?

  Depends on the number of acres in the responding types.

- RESULTS OF THE N+K TRIALS WILL BE EXTREMELY IMPORTANT.

- MEASURING RESPONSE IS EASIER THAN UNDERSTANDING WHY IT OCCURS.

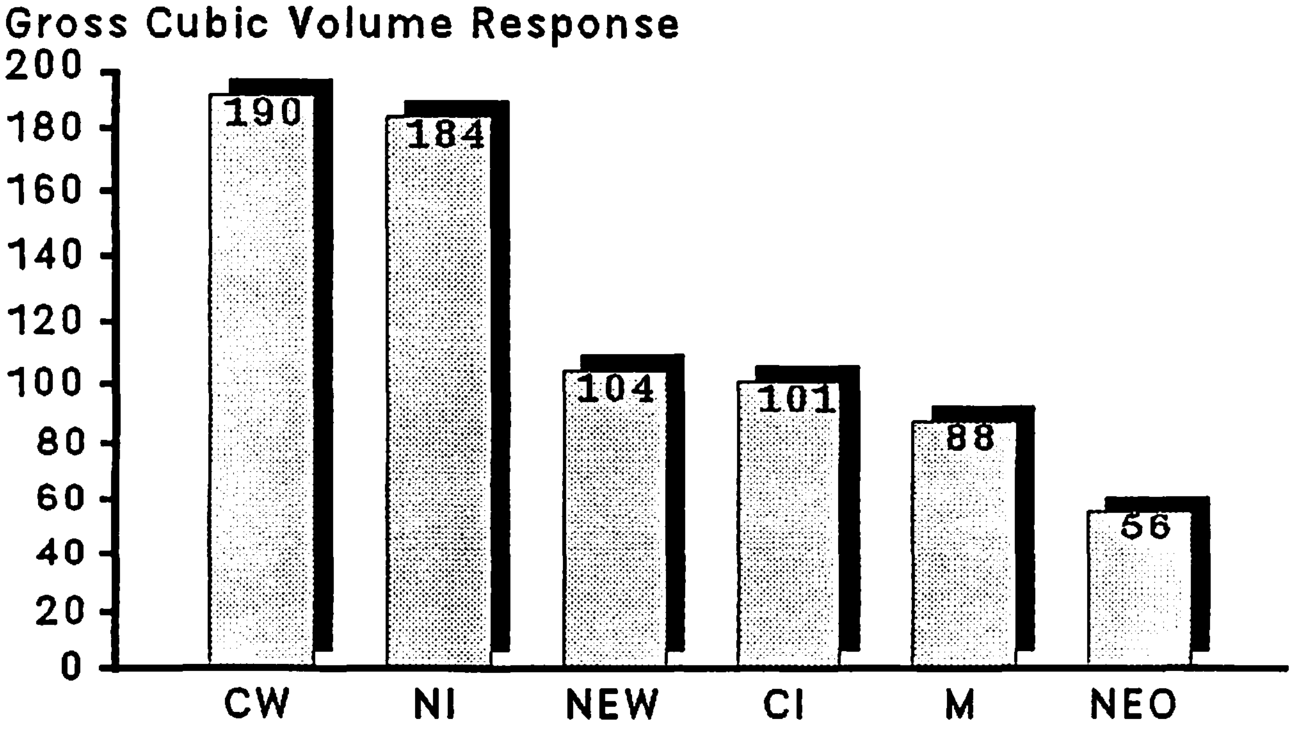
- BETTER PREDICTION OF RESPONSE REQUIRES TIME AND RESOURCES

- WOOD VALUES

  wood appreciation rates
  wood value...

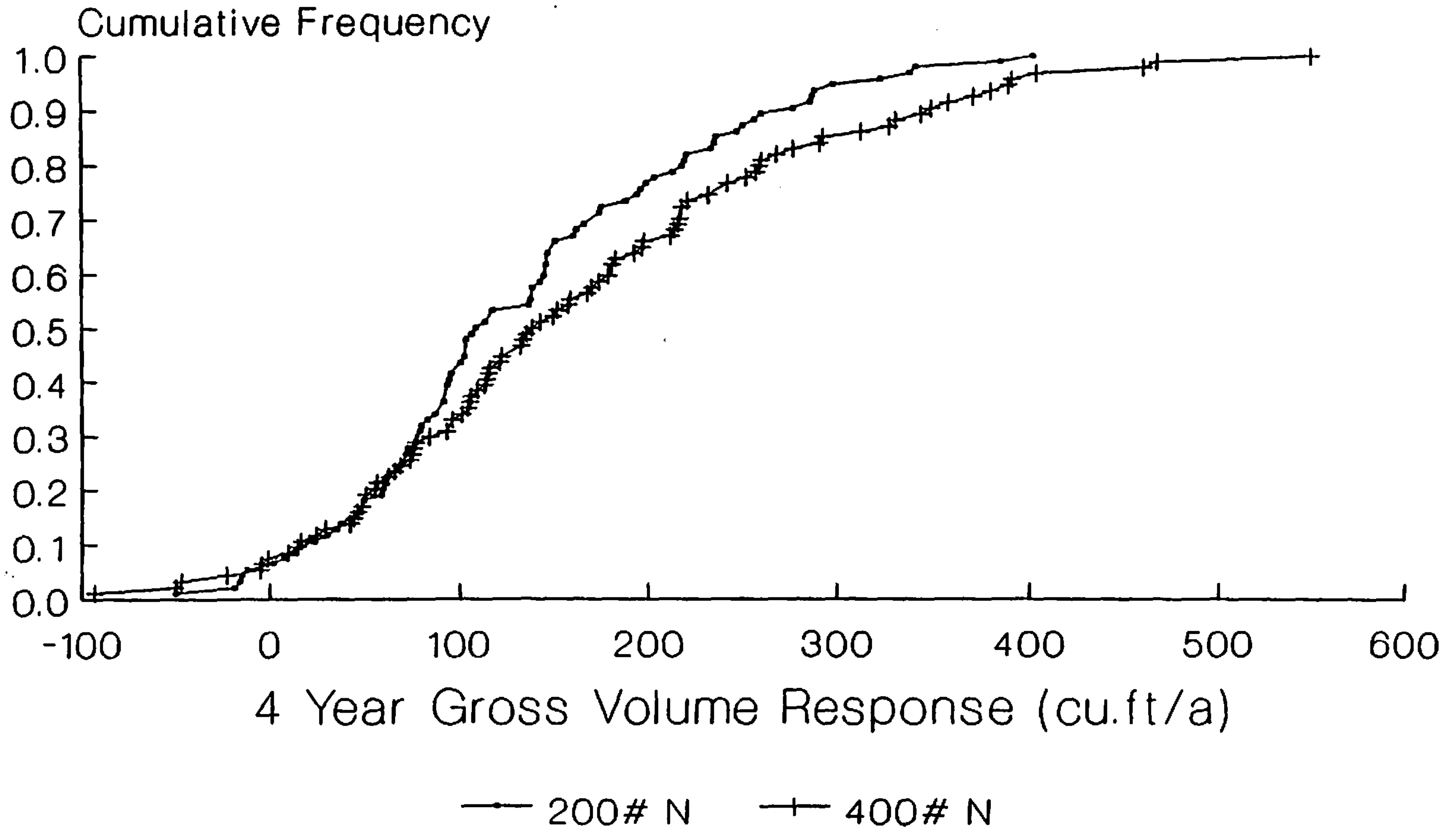
IFTNC 4-Year Gross Volume Response

Regional Average 200 lb.N



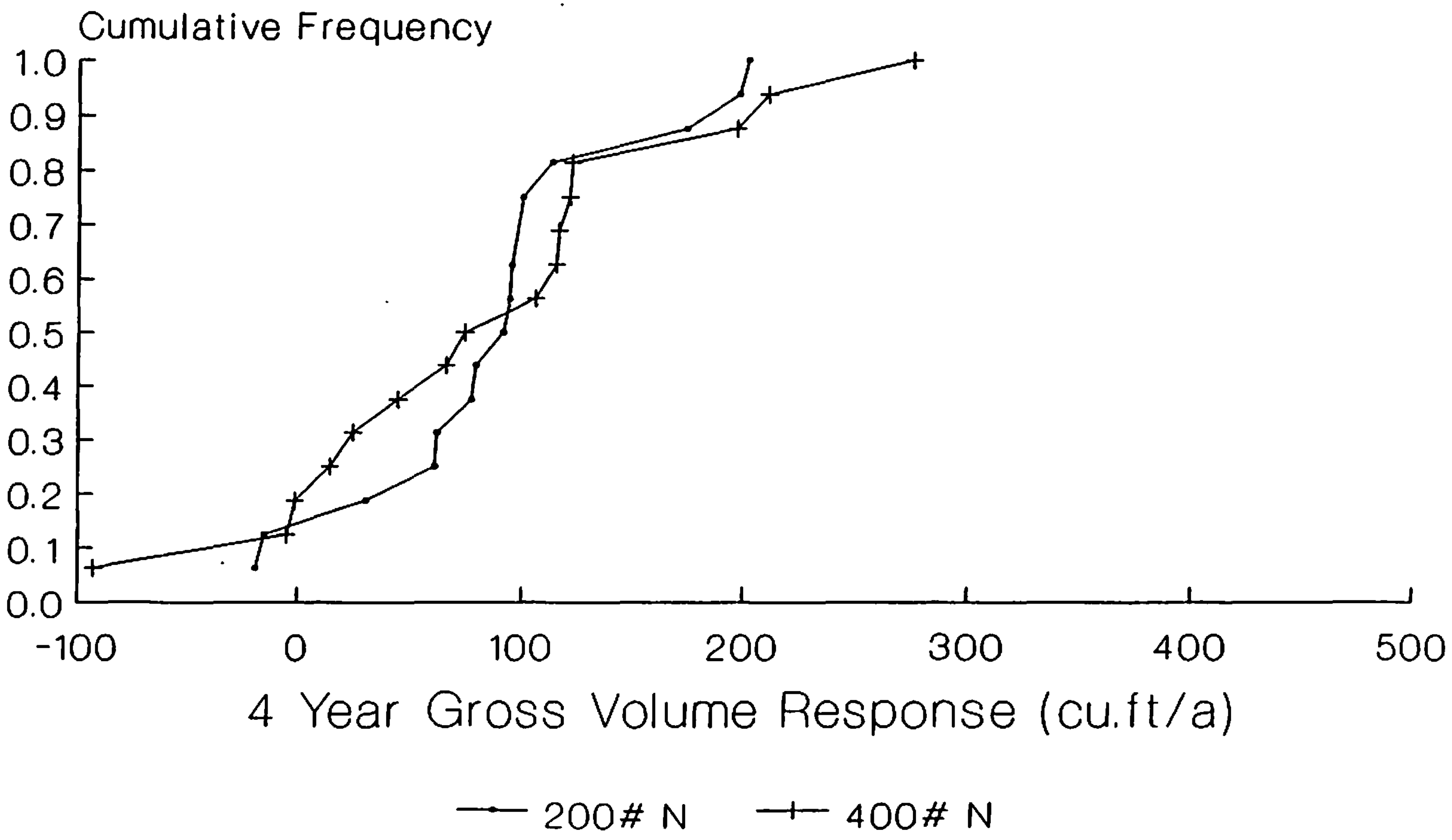
All Regions

Gross Volume Response



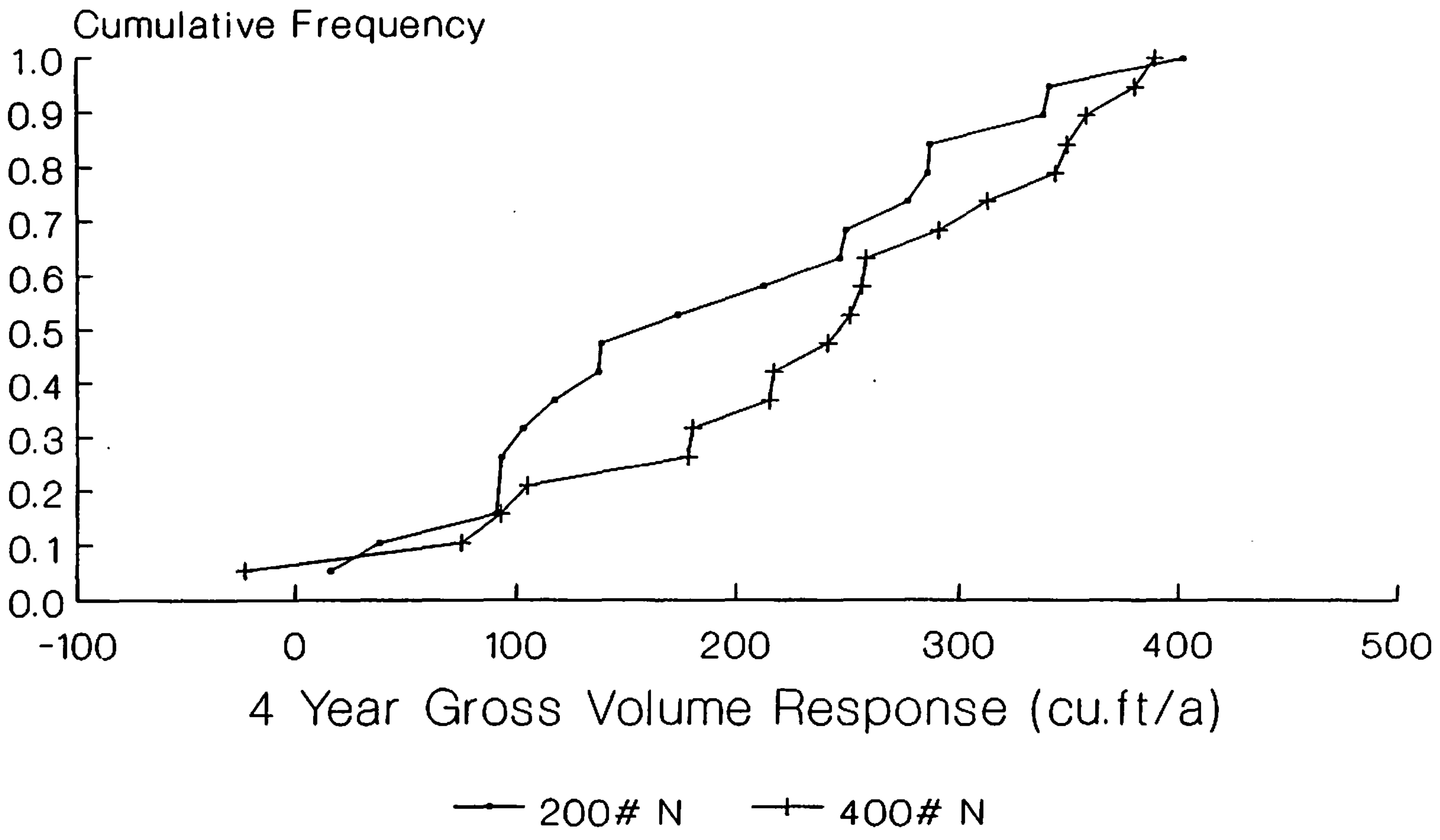
Montana

Gross Volume Response

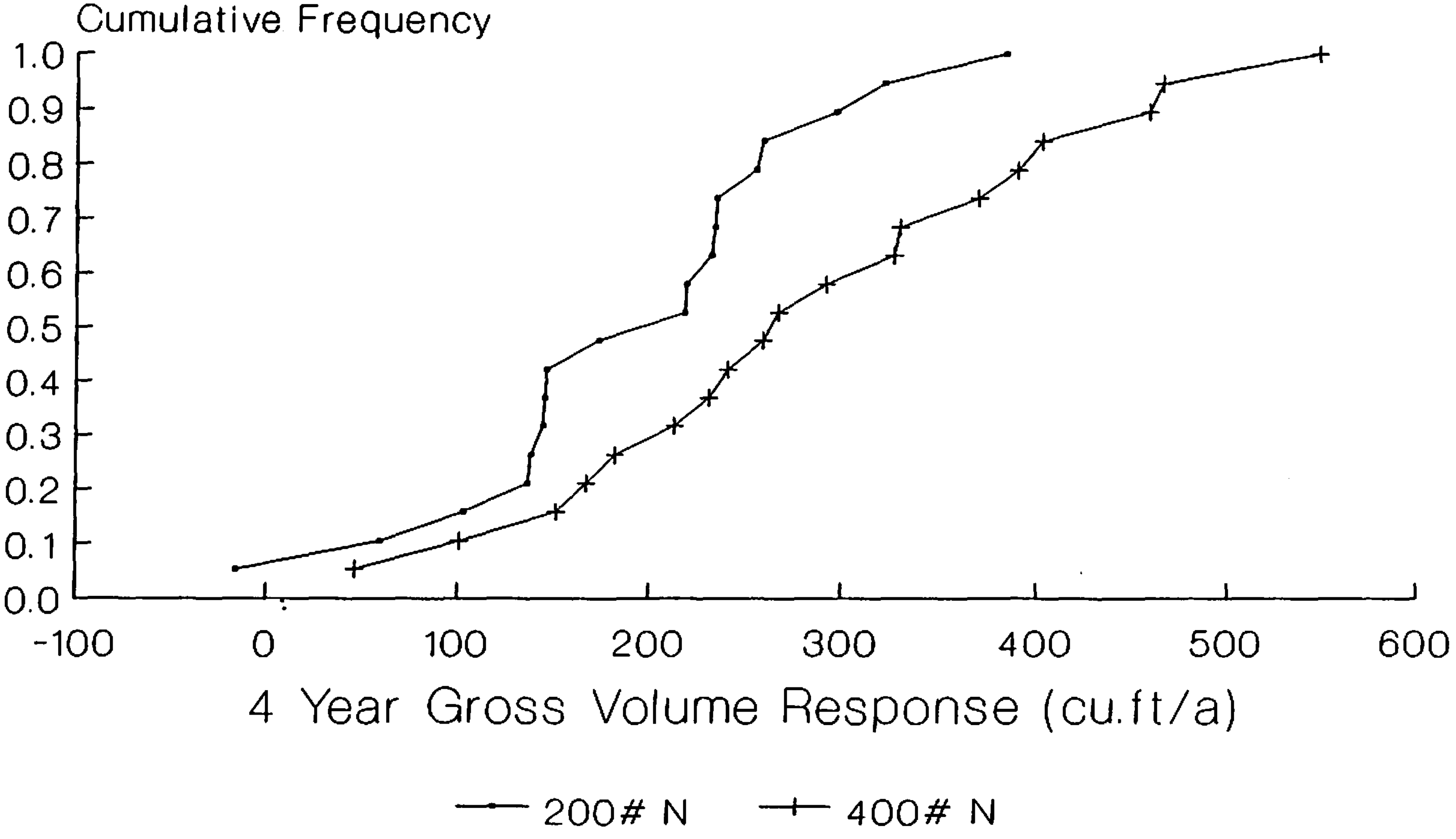


North Idaho

Gross Volume Response

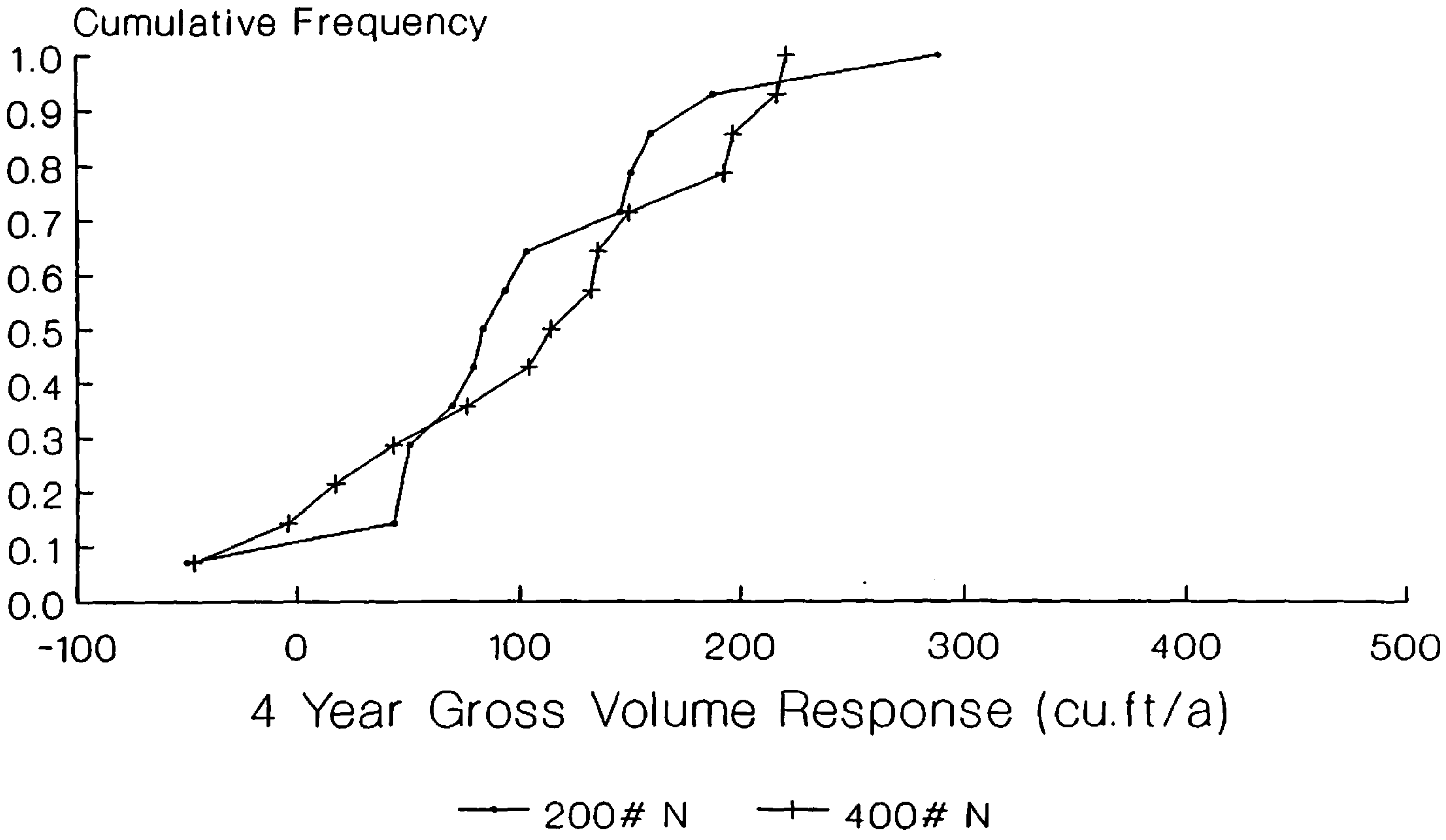


Central Washington
Gross Volume Response



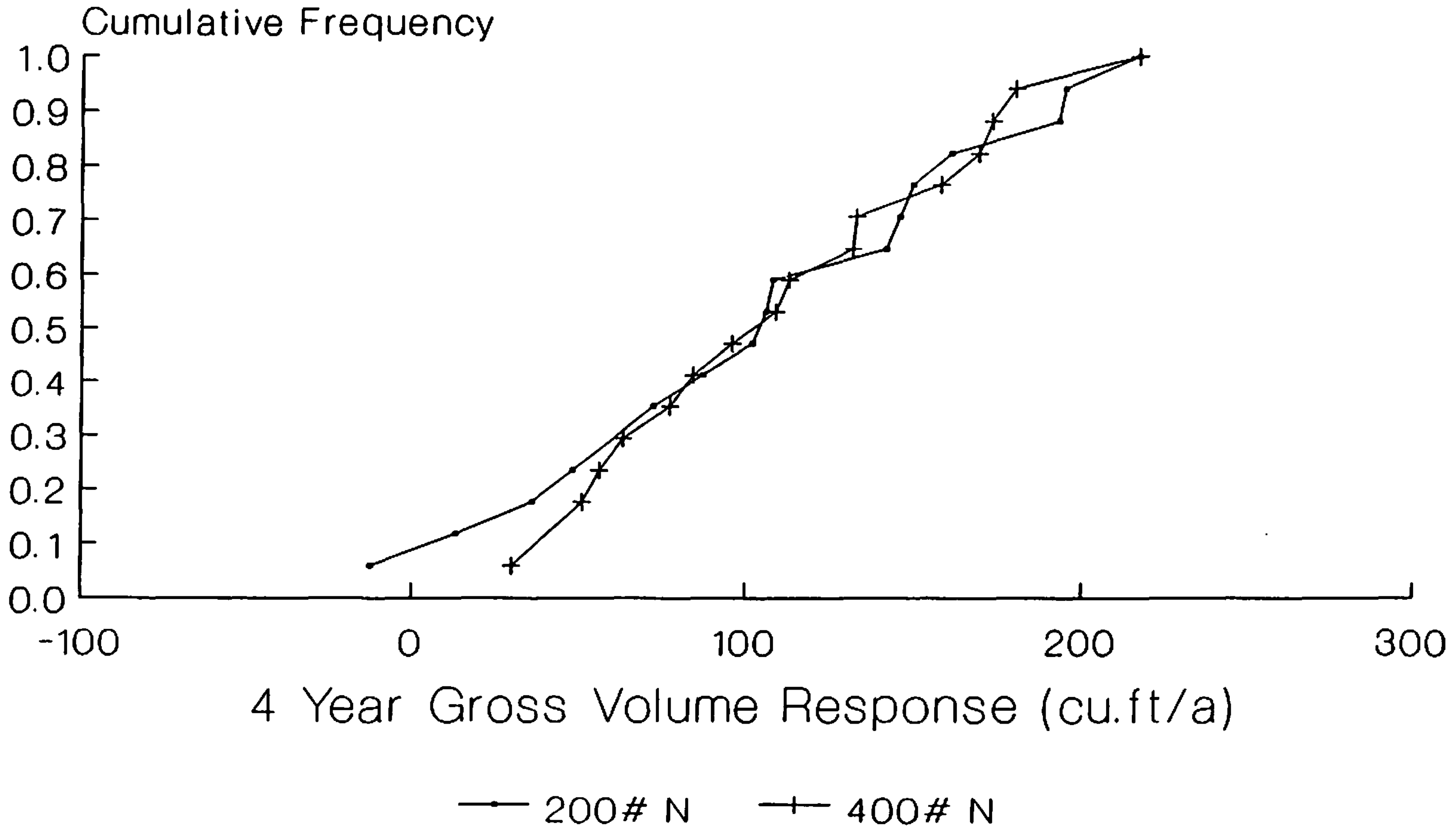
Central Idaho

Gross Volume Response



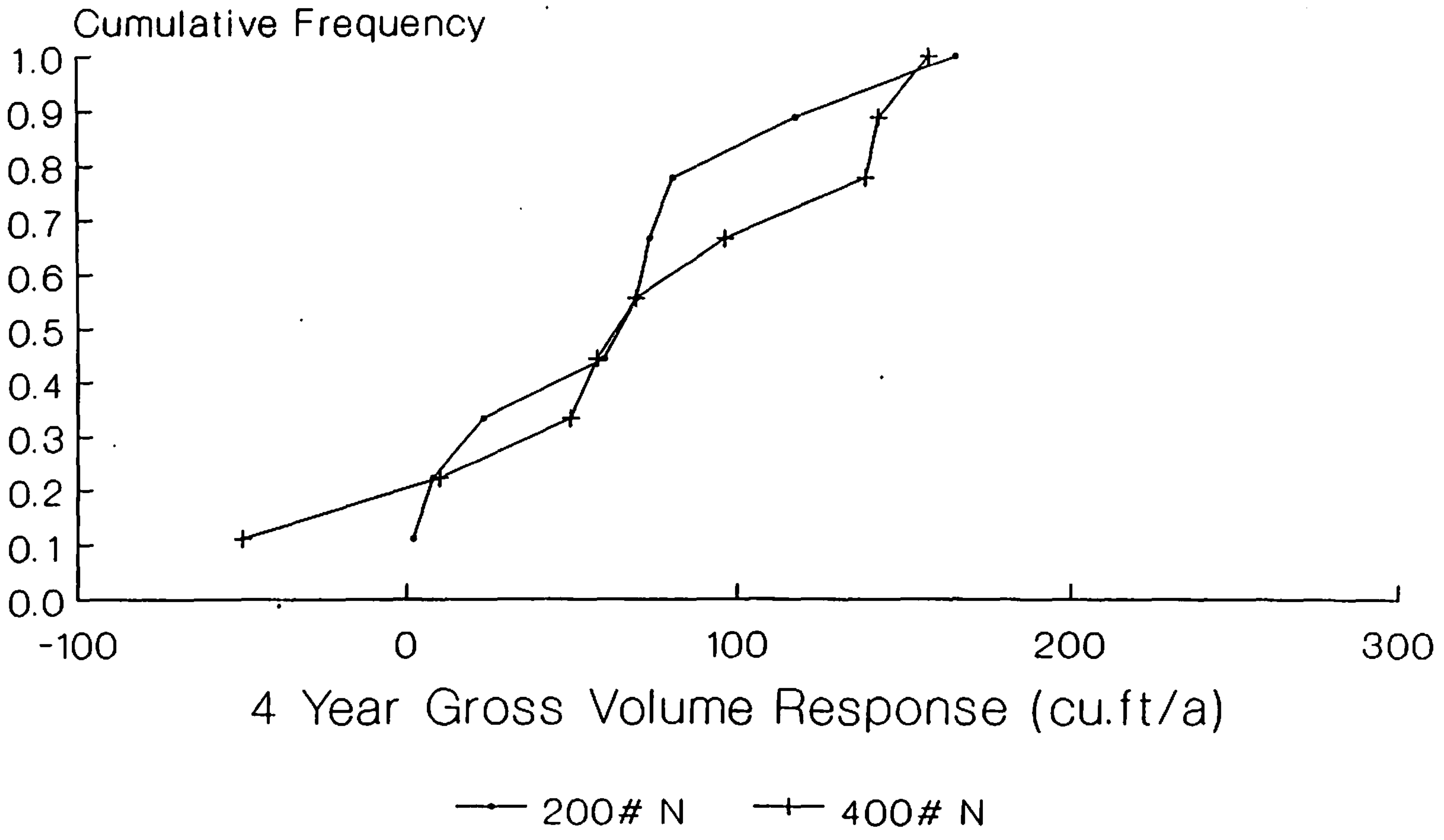
N.E. Washington

Gross Volume Response



N.E. Oregon

Gross Volume Response



North Idaho-Predicted
4-Yr Gross Cubic Foot Response (Ft.^{3})

	Site Index				
Initial Basal Area (Ft.^{2})	50-60	60-70	70-80	80-90	90-100
80-100 (61)	196	271	284	259	196
100-150 (54)	205	256	269	245	182
150-200 (42)	168	219	233	208	145
200+ (40)	238	289	303	278	215

200 lb.N

Vegetation Series -Grand-Fir
%Grand Fir-6
Average Crown Ratio-( )

North Idaho-Predicted
4-Yr Gross Cubic Foot Response (Ft.^{3})

Site Index

Initial Basal Area (Ft.^{2})	50-60	60-70	70-80	80-90	90-100
80-100 (61)	164	215	229	204	141
100-150 (54)	149	200	214	189	127
150-200 (42)	113	164	178	153	90
200+ (40)	183	234	248	223	160

200 lb.N

Vegetation Series -Cedar/Hemlock
%Grand Fir-11
Average Crown Ratio-( )

N. Idaho-Value of Response ($/Acre)
($60/MBF @ $1^{1/4}$ %-5 Year)

Site Index

Initial Basal Area (Ft.^{2})	50-60	60-70	70-80	80-90	90-100
80-100 (61)	50	69	73	66	50
100-150 (54)	52	65	69	63	46
150-200 (42)	43	56	60	53	37
200+ (40)	61	74	77	71	55

200 lb.N

Vegetation Series -Grand-Fir
%Grand Fir-6
Average Crown Ratio-( )

North Idaho-
Return on Investment (%)

Site Index

Initial Basal Area (Ft.^{2})	50-60	60-70	70-80	80-90	90-100
80-100 (61)	-4	3	4	2	-4
100-150 (54)	-3	2	3	1	-5
150-200 (42)	-7	-2	-1	-2	-9
200+ (40)	3	4	5	3	-2

200 lb.N

Vegetation Series -Grand-Fir
%Grand Fir-6
Average Crown Ratio-( )

Central Washington-Predicted 4-Yr Gross Cubic Foot Response$(Ft.^3)$

Parent Material

Initial Basal Area $(Ft.^2)$	Granite	Ash/Loess Basalt	Glacial Till	Sand Stone
70-100	188	218	291	320
100-150	70	100	174	202
150-200	-10	20	93	122
200-250	-17	14	87	115

200 lb.N

Vegetation Series-Douglas Fir

Central Washington-Predicted 4-Yr Gross Cubic Foot Response (Ft.^{3}

Parent Material

Initial Basal Area (Ft.^{2})	Granite	Ash/ Loess Basalt	Glacial Till	Sand Stone
70-100	359	390	462	491
100-150	242	272	345	373
150-200	161	192	265	293
200-250	155	185	258	286

200 lb.N

Vegetation Series GF/C/H

Central Wa.- Value of Response($/Acre)
($60/MBF @ 1 1/4 % -5Yr.)

Parent Material

Initial Basal Area (Ft.^{2})	Granite	Ash/ Loess Basalt	Glacial Till	Sand Stone
70-100	92	100	118	125
100-150	62	69	88	95
150-200	41	49	68	75
200-250	40	47	66	73

200 lb.N

Vegetation Series GF/C/H

Central Washington-
Return on Investment (%)

Parent Material

Initial Basal Area $(Ft.^2)$	Granite	Ash/ Loess Basalt	Glacial Till	Sand Stone
70-100	9	11	15	16
100-150	1	3	8	10
150-200	-7	-4	2	5
200-250	-8	-5	2	4

200 lb.N

Vegetation Series GF/C/H