NINTH ANNUAL REPORT

Intermountain Forest Tree Nutrition Cooperative

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College of Forestry, Wildlife
and Range Sciences
University of Idaho
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INTERMOUNTAIN FOREST TREE NUTRITION COOPERATIVE

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TABLE OF CONTENTS

SUMMARY

Results based on analysis of six-year basal area, volume growth, average stand diameter, and mortality for all Douglas-fir installations indicate the following:

(A) There continues to be significant differences in response to the nitrogen treatments between geographic regions.

(B) Northern Idaho and central Washington produced statistically significant differences in gross basal area and volume response between treatments of 200 and 400 lbs. per acre of nitrogen, the other regions did not.

(C) Gross basal area and volume growth response for both nitrogen treatments remained significantly greater than the controls for all geographic regions after six years. However, for net basal area and volume response, Montana, central Idaho, and northeast Oregon did not show a significant response to either nitrogen treatment.

(D) Both nitrogen treatments resulted in significant increases in average stand diameter after six years for all geographic regions except northeast Oregon. The 400 lb. nitrogen treatment produced a significant

increase in average stand diameter over the 200 lb. treatment for northern Idaho, central Washington, and northeast Washington.

(E) Mortality rates were significantly influenced by nitrogen treatments. The most common cause of mortality differed by region. Wind or snow damage and root rots were the most common treatment related mortality agents.

(F) Installations with good pre-treatment foliar potassium status continue to produce significant response after the first two-year time period after treatment; those with poor potassium status do not. The six-year results support the same conclusions as the four-year results relative to the influence of potassium on response to nitrogen treatments.

Introduction

This year's report includes estimates of six-year basal area and volume growth response to nitrogen fertilization treatments as well as mortality estimates for all Douglas-fir installations of the IFTNC. Basal area growth response estimates are also provided for each two-year period (i.e., years 1 and 2, years 3 and 4, years 5 and 6). Probabilities for obtaining a specified six-year growth response to nitrogen fertilization by region are also reported. New data, showing the effect of nitrogen and nitrogen plus potassium fertilization on foliar nutrients after treatment for one-half of the Douglas-fir installations and six western Montana ponderosa pine sites will be provided later as an addendum to this report. Foliage samples for the remaining Douglas-fir installations will be collected in the fall of 1989.

Six-year Growth Response of all Douglas-fir Test Sites: General Description

Ninety four installations were established in managed Douglas-fir stands (45 in both 1981 and 1982, and 4 in 1980). One installation was partially destroyed by logging operations in 1987. 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, four, and six growing seasons.

Total height was measured for all sample trees at the start of the experiment and for a subsample of trees after the sixth growing season. Mortality was recorded by cause at each measurement period. Therefore, the following analyses are based on basal area and volume growth for six years after treatment. Volume equations used are from the Prognosis model for individual tree total cubic foot volume.

A variable number of plots at each installation were retreated in the fall of 1987 and 1988. Retreatments consisted of (1) 200 pounds per acre of nitrogen only and (2) 200 pounds per acre of nitrogen and 200 pounds per acre of potassium. Urea and murate of potash were the sources for nitrogen and potassium respectively. Two-year growth responses from the retreatments will be available after remeasurements in the fall of 1989 and 1990.

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 6 years (or 2 years in the case of the periodic analysis);

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).

The model form was identical for all responses considered, including gross and net basal area increment (ft^2/A), and gross and net volume increment (ft^3/A).

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 pages 2 through 12 of the Technical Documentation Report.

Basal Area Growth Response:

Average basal area increment and response to the nitrogen treatments (adjusted to a common initial basal area of 150 ft^2/A) for both gross and net basal area increments are given in Table 1. The six-year gross basal area per acre increments for both the 200 and 400 lb nitrogen treatments were statistically

Table 1. Average six-year net and gross basal area growth response by region and treatment.[1]

Region	Treatment	Net Basal Area Increment			Gross Basal Area Increment		
		Total ft^2/acre	Increase over control ft^2/acre	Increase over control percent	Total ft^2/acre	Increase over control ft^2/acre	Increase over control percent
Northern Idaho	Control	32.3			33.6		
	200 # N	35.7	3.3	10.3	40.1	6.5	19.4
	400 # N	39.3	7.0	21.7	43.6	10.0	29.8
Montana	Control	16.4			18.6		
	200 # N	16.7	0.4 NS	2.3	21.5	2.9	15.6
	400 # N	16.4	-0.0 NS	-0.1	21.6	3.0	16.3
Central Idaho	Control	24.3			25.4		
	200 # N	26.3	2.1 NS	8.5	28.7	3.3	13.0
	400 # N	26.3	2.1 NS	8.5	29.3	3.9	15.3
Northeast Oregon	Control	16.0			20.2		
	200 # N	14.7	-1.3 NS	-8.1	22.9	2.7	13.3
	400 # N	16.9	0.9 NS	5.5	23.9	3.6	18.0
Central Washington	Control	23.0			24.3		
	200 # N	27.9	4.9	21.2	30.5	6.2	25.5
	400 # N	31.2	8.2	35.8	34.2	9.9	40.5
Northeast Washington	Control	21.9			26.6		
	200 # N	25.4	3.5	15.8	30.3	3.7	13.9
	400 # N	20.5	-1.4 NS	-6.4	30.8	4.2	15.7
Overall	Control	23.1			25.4		
	200 # N	25.6	2.5	10.9	29.9	4.5	17.6
	400 # N	26.3	3.2	13.9	31.6	6.2	24.5

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

NS = Not Significant ($\alpha = .1$)

different from the controls across all geographic regions. Only in northern Idaho and central Washington were the gross increments for the 400 lb treatment significantly greater than the 200 lb treatment. The response patterns in these two regions resulted in a significant difference between the two nitrogen treatments for all regions combined. These results are the same as for the two-year basal area response (1984 IFTNC Annual Report). However, the difference between the two nitrogen treatments in northern Idaho was not statistically significant based on four-year response estimates.

The results are different for net basal area increment (Figure 1). There is no statistical difference in net basal area increment between either nitrogen treatment and the controls for the Montana, central Idaho, and northeast Oregon regions. In northeast Washington, the 200 lb treatments were significantly greater than the controls, but the 400 lb treatments were not. Both nitrogen treatments produced a significant net basal area growth response in northern Idaho and central Washington, and the 400 lb nitrogen treatment was also significantly greater than the 200 lb treatment for these two regions. Central Washington continues to show the largest net growth response to both nitrogen treatments, and the 400 lb treatment remains significantly greater than the 200 lb treatment. Also notice the large decrease from gross to net basal area response for the 400 lb treatment in all other geographic regions, particularly northeast Washington. These patterns are essentially the same as they were after four years (1987 IFTNC Annual Report). The

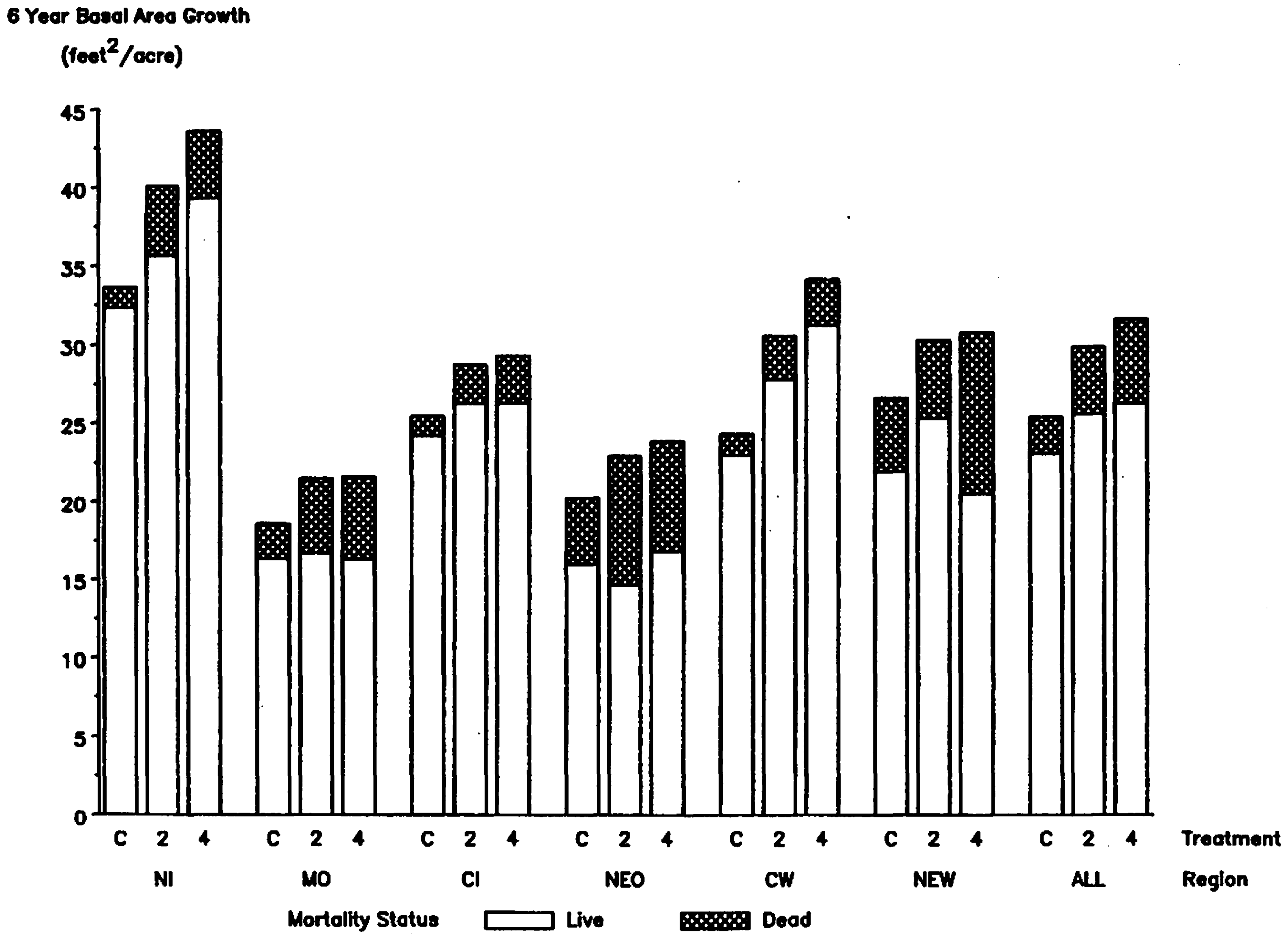

Figure 1. Six-year Basal Area Increment by Region and Treatment Partitioned into live (net) and dead Components.

reason for the different results for gross and net basal area growth response is fertilized plots had significantly higher mortality rates during years 3 through 6 than the control plots. Mortality will be discussed in detail in a later section of this report. Over a short time period, the loss of a few trees on fertilized plots can erase per acre response due to fertilization. However, over a longer time horizon, mortality may not be "bad" depending on which size class within a stand is most affected. This point is addressed in the next section.

Average Stand Diameter Response

Our data suggests that nitrogen fertilization produces two different types of treatment-related mortality. The first type, which can be called "nutrient-related" mortality, will be discussed in a later section. The second mortality type can be called "competition-related". Larger trees within a stand respond more to fertilization than small trees. Over time this would accelerate crown differentiation within a stand with resulting increased mortality rates for smaller trees in subordinate crown positions, in effect a thinning from below. The combination of greater fertilization response for larger trees and a fertilization thinning-effect produced the treatment related differences in average stand diameter provided in Table 2 and illustrated in Figure 2.

The increase in average stand diameter resulting from both nitrogen treatments was significantly different from the controls for all geographic regions except northeast Oregon. The 400 # N

Table 2. Six-year response in average stand diameter by region and treatment.

		Change in Average Stand Diameter		
Region	Treatment	Growth (inches)	Response (inches)	percent
Northern Idaho	Control	1.10		
	200 # N	1.29	0.19	17.3
	400 # N	1.42	0.32	29.5
Montana	Control	0.60		
	200 # N	0.68	0.08	14.5
	400 # N	0.75	0.15	26.2
Central Idaho	Control	0.86		
	200 # N	0.99	0.13	15.4
	400 # N	0.95	0.10	11.4
Northeast Oregon	Control	0.96		
	200 # N	0.94	-0.02 NS	-2.0
	400 # N	0.99	0.03 NS	2.9
Central Washington	Control	0.93		
	200 # N	1.14	0.21	22.6
	400 # N	1.25	0.32	34.3
Northeast Washington	Control	0.91		
	200 # N	1.06	0.15	16.2
	400 # N	1.16	0.25	27.1
Overall	Control	0.90		
	200 # N	1.04	0.14	15.6
	400 # N	1.12	0.22	24.4

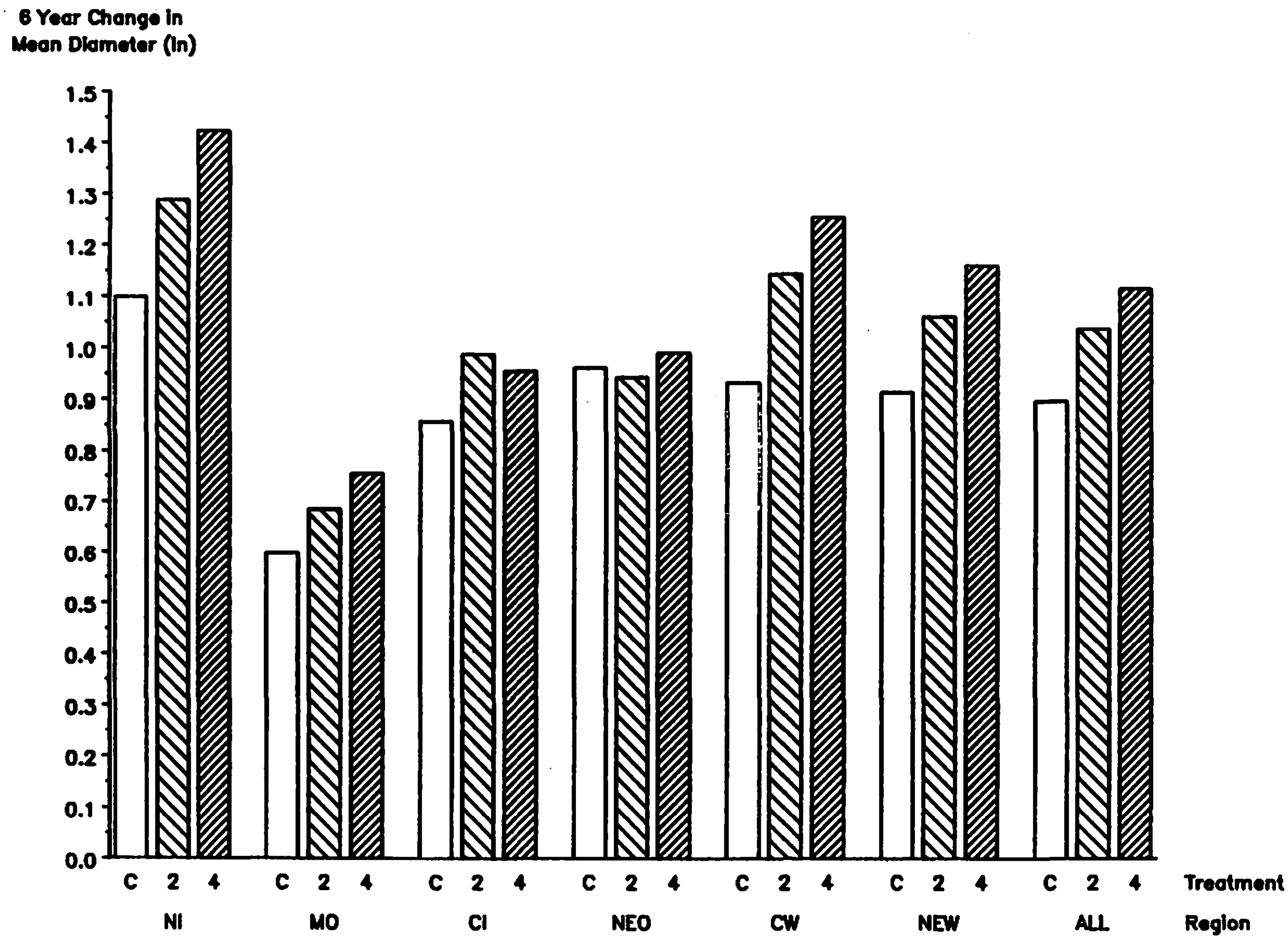

Figure 2. Six-year Change in Average Stand Diameter by Region and Treatment.

treatment was also significantly greater than the 200 # N treatment for northern Idaho, central Washington, and northeast Washington. The effects of the two treatments are consistent across geographic areas (with the exception of northeast Oregon), and these results suggest that even in those regions where net per acre response is not significant, the nitrogen treatments are having significant effects within stands.

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 3 and shown in Figure 3. 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.

As with four-year results, there is no statistical difference in net volume increment for the 400 lb nitrogen treatments and the controls in northeast Washington, and no difference between either fertilizer treatment and the controls in Montana, central Idaho, and northeast Oregon. Central Washington showed the greatest net volume growth response to both nitrogen treatments (200 lb N = 201 ft^3, 21.8%; 400 lb N = 319 ft^3, 34.5%). The net volume growth for the 400 lb treatment is significantly greater than the 200 lb treatment in northern Idaho and central Washington.

Table 3. Average six-year net and gross cubic foot volume growth response by region and treatment.[1]

		Net Volume Increment			Gross Volume Increment		
Region	Treatment	Total ft^3/acre	Increase over control ft^3/acre	Increase over control percent	Total ft^3/acre	Increase over control ft^3/acre	Increase over control percent
Northern Idaho	Control	1304			1310		
	200 # N	1423	119	9.1	1517	207	15.8
	400 # N	1529	225	17.3	1608	298	22.7
Montana	Control	625			689		
	200 # N	668	43 NS	6.8	793	104	15.1
	400 # N	658	32 NS	5.2	792	103	15.0
Central Idaho	Control	889			924		
	200 # N	982	94 NS	10.5	1048	124	13.4
	400 # N	970	81 NS	9.1	1058	134	14.5
Northeast Oregon	Control	705			802		
	200 # N	648	-57 NS	-8.1	883	81	10.1
	400 # N	664	-41 NS	-5.8	887	85	10.5
Central Washington	Control	923			962		
	200 # N	1124	201	21.8	1201	239	24.9
	400 # N	1242	319	34.5	1333	371	38.6
Northeast Washington	Control	905			1027		
	200 # N	1036	131	14.5	1154	127	12.5
	400 # N	893	-12 NS	-1.3	1156	129	12.6
Overall	Control	920			977		
	200 # N	1024	104	11.3	1134	157	16.1
	400 # N	1041	121	13.2	1181	204	20.9

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

NS = Not Significant (α = .1)

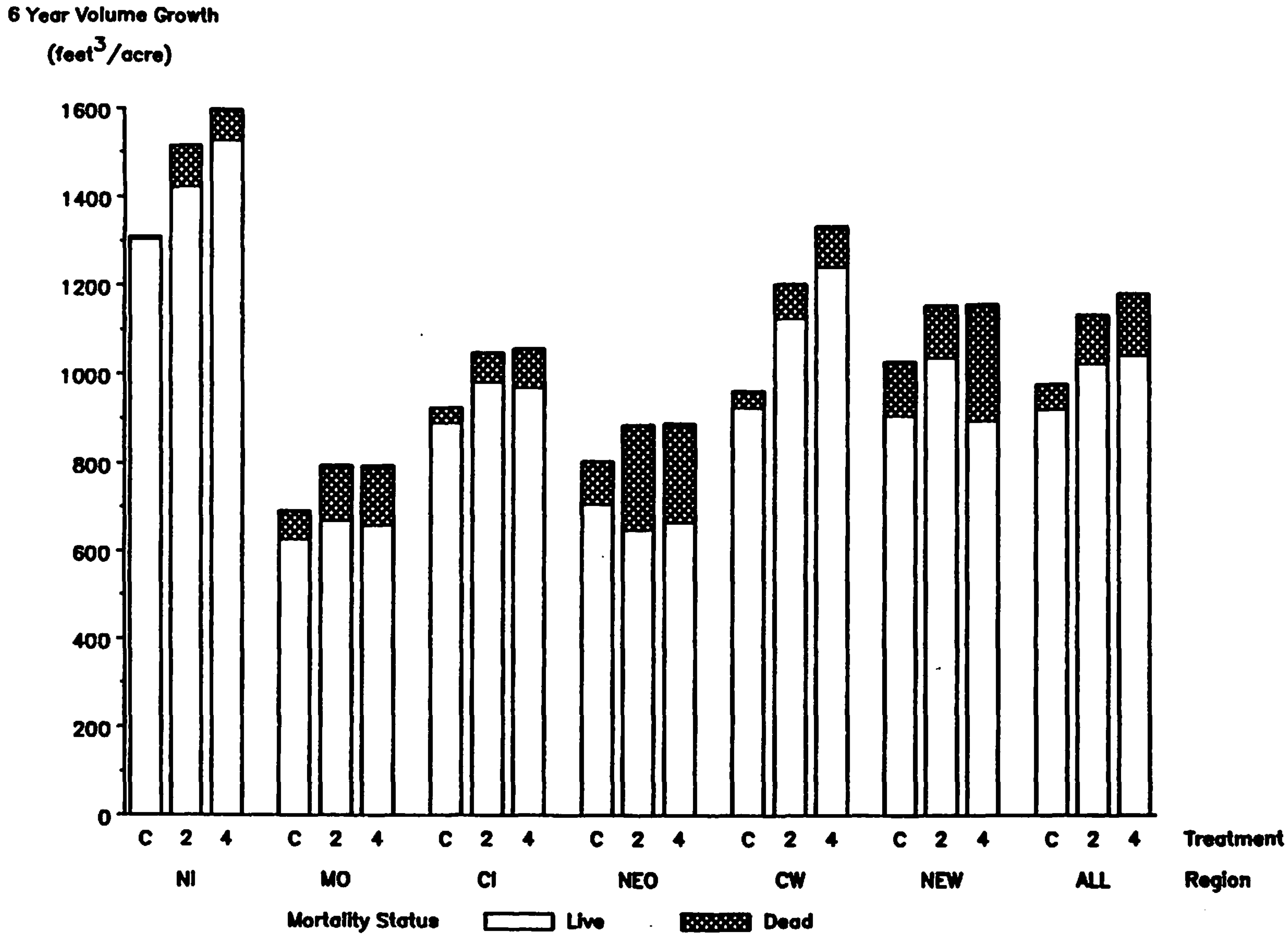

Figure 3. Six-year Volume Increment by Region and Treatment Partitioned into live (net) and dead Components.

<u>Differences in Mortality Rates by Treatment</u>:

Mortality rates differed significantly by nitrogen treatment. Volume per acre mortality rate estimates by treatment and geographic region are given in Table 4. Most of the mortality occurred during the second and third two-year periods and was significantly higher for the nitrogen treatments. For most regions, the middle period (i.e., years 3 and 4) had the highest mortality rate. The mortality rates were higher for the 400 lb treatment than for the 200 lb, particularly in northeast Washington. Northeast Oregon has incurred substantial treatment related mortality for both nitrogen levels. Central Idaho showed the lowest mortality levels. The distribution of mortality by cause and geographic region are provided in Table 5. A more detailed breakdown of mortality by region, treatment, time period, and cause is included in the Technical Documentation Report. The most common causes of mortality differed by region. In northern Idaho and northeast Washington the most common cause was wind/snow. Although control plots sustained significant wind damage, the amount of wind-caused mortality on the fertilized plots was substantially higher for the 400 lb treatment. Wind-caused mortality was localized at several installations in both of these regions. Root rot-caused mortality was higher for both nitrogen treatments in northeast Oregon and for the 400 lb. N treatment in northeast Washington. In Montana and northeast Oregon, there were mortality factors apparently unrelated to treatment such as mountain pine beetle in ponderosa pine and spruce budworm. These (and other) external factors that cause

Table 4. Average six-year volume mortality rates by region and treatment.

Region	Treatment	Percent by Volume			
		--------Years--------			Six-year
		0-2	3-4	5-6	Total
Northern Idaho	Control	0.01	0.57	0.55	1.13
	200 # N	0.19	0.84	0.88	1.91
	400 # N	0.40	1.24	0.46	2.10
Montana	Control	0.42	0.79	0.46	1.67
	200 # N	0.98	1.69	0.20	2.87
	400 # N	0.15	1.98	0.60	2.73
Central Idaho	Control	0.15	0.37	0.19	0.71
	200 # N	0.17	0.00	0.73	0.90
	400 # N	0.07	0.17	0.61	0.85
Northeast Oregon	Control	0.75	0.97	1.19	2.91
	200 # N	0.77	1.40	2.61	4.78
	400 # N	0.96	1.69	2.55	5.20
Central Washington	Control	0.46	0.21	0.57	1.24
	200 # N	0.13	0.14	1.12	1.39
	400 # N	0.30	0.00	1.20	1.50
Northeast Washington	Control	0.22	1.71	1.02	2.95
	200 # N	0.20	1.27	0.89	2.36
	400 # N	0.20	2.98	2.20	5.38
Overall	Control	0.33	0.75	0.67	1.75
	200 # N	0.39	0.89	1.15	2.43
	400 # N	0.39	1.34	1.31	3.04

Table 5. Average six-year percent mortality by region, treatment, and cause.

Region	Treatment	Percent Cubic Foot Volume Loss by Cause					
		Competition	Bark Beetles	Root/Rot	Wind/Snow	Other	Total
Northern Idaho	Control	0.19	0.00	0.36	0.47	0.11	1.13
	200 # N	0.19	0.03	0.68	0.41	0.59	1.91
	400 # N	0.16	0.00	0.41	1.38	0.15	2.10
Montana	Control	0.01	1.54	0.00	0.08	0.03	1.67
	200 # N	0.00	2.34	0.00	0.48	0.05	2.87
	400 # N	0.04	1.28	0.00	0.79	0.63	2.73
Central Idaho	Control	0.01	0.51	0.00	0.07	0.12	0.71
	200 # N	0.00	0.29	0.45	0.17	0.00	0.90
	400 # N	0.00	0.11	0.09	0.31	0.35	0.85
Northeast Oregon	Control	0.03	0.00	1.36	1.08	0.44	2.91
	200 # N	0.00	0.10	2.23	0.31	2.14	4.78
	400 # N	0.00	1.84	1.80	0.32	1.24	5.20
Central Washington	Control	0.02	0.45	0.53	0.24	0.00	1.24
	200 # N	0.05	0.49	0.03	0.57	0.25	1.39
	400 # N	0.01	0.38	0.26	0.79	0.07	1.50
Northeast Washington	Control	0.06	0.01	0.58	2.16	0.14	2.95
	200 # N	0.21	0.29	0.54	1.14	0.18	2.36
	400 # N	0.17	0.60	1.33	3.00	0.27	5.38
Overall	Control	0.07	0.41	0.46	0.69	0.12	1.75
	200 # N	0.11	0.57	0.62	0.61	0.52	2.43
	400 # N	0.08	0.62	0.64	1.30	0.39	3.04

mortality unrelated to the experiment introduce unexplained variation in our attempts to predict net growth response to fertilization.

Duration of Response:

A subsample of trees were measured for height after six years; however, since only diameters were remeasured for all trees after the first two years and six years, the following analysis is based on periodic basal area growth, rather than volume growth. Basal area increments for the first, second, and third two-year periods are compared in Table 6. The gross and net basal area increments by treatment and region are shown in Figures 4, 5, and 6 for the first, second, and third two-year periods.

Gross basal area response has declined for each successive two-year period in all regions. The 200 lb. N treatment no longer produced a significant gross basal area response during years 5 and 6 in Montana, central Idaho, and northeast Washington. The 400 lb. N treatment continued to be significantly different from the controls in gross basal area increment across all regions. The decline in net basal area response to the fertilizer treatments is even more pronounced than for gross basal area. The only treatment in any region that produced a significant net basal area response for years 5 and 6 was the 400 lb nitrogen treatment in northern Idaho. Mortality is variable by treatment, region, and time period, and this

Table 6. Average net and gross basal area response for each two-year period by region and treatment.[1]

Basal area increment in the first two years

Region	Treatment	Net ft²/A	Net Growth Response ft²/A	Net Growth Response percent	Gross ft²/A	Gross Growth Response ft²/A	Gross Growth Response percent
Northern Idaho	Control	12.7			11.8		
	200 # N	15.0	2.3	18.5	15.3	3.5	30.3
	400 # N	15.6	2.9	23.3	16.2	4.4	37.4
Montana	Control	6.6			7.1		
	200 # N	7.2	0.6 NS	8.0	8.5	1.4	19.9
	400 # N	8.4	1.8	26.7	8.6	1.5	21.2
Central Idaho	Control	8.6			9.0		
	200 # N	10.2	1.6	18.7	10.7	1.7	19.8
	400 # N	11.1	2.5	29.2	11.2	2.2	25.5
Northeast Oregon	Control	6.1			6.8		
	200 # N	7.3	1.2 NS	20.4	8.4	1.6	22.6
	400 # N	7.5	1.4 NS	23.7	9.0	2.2	31.4
Central Washington	Control	8.6			8.9		
	200 # N	11.5	2.9	33.6	11.9	3.0	33.3
	400 # N	13.1	4.5	51.7	13.3	4.4	49.0
Northeast Washington	Control	9.4			9.8		
	200 # N	11.5	2.1	21.7	11.7	1.9	19.6
	400 # N	11.6	2.2	22.4	12.0	2.2	22.2
Overall	Control	9.0			9.2		
	200 # N	10.9	1.9	20.7	11.5	2.3	25.4
	400 # N	11.7	2.7	29.8	12.2	3.0	32.4

[1]Averages are adjusted to a common initial basal area of 150 ft2/A
NS = Not significant ($\alpha = .1$)

Table 6. (cont.)

		Basal area increment in the second two years					
			Net Growth Response			Gross Growth Response	
Region	Treatment	ft^2/A	ft^2/A	percent	ft^2/A	ft^2/A	percent
Northern Idaho	Control	9.8			10.7		
	200 # N	10.6	0.8 NS	8.2	12.9	2.2	20.7
	400 # N	11.3	1.5 NS	15.4	14.3	3.6	33.8
Montana	Control	5.0			5.9		
	200 # N	4.5	-0.5 NS	-8.8	6.9	1.0	17.2
	400 # N	3.3	-1.7 NS	-33.6	6.9	1.0	16.2
Central Idaho	Control	9.2			9.4		
	200 # N	10.7	1.5 NS	16.4	10.5	1.1	11.5
	400 # N	9.5	0.3 NS	4.2	10.5	1.1	11.5
Northeast Oregon	Control	5.2			6.9		
	200 # N	4.8	-0.4 NS	-8.8	7.7	0.8	12.6
	400 # N	5.5	0.3 NS	5.5	7.9	1.0	15.7
Central Washington	Control	8.4			8.3		
	200 # N	10.2	1.8 NS	21.3	10.4	2.1	25.5
	400 # N	11.3	2.9	35.4	11.6	3.3	40.1
Northeast Washington	Control	6.4			9.0		
	200 # N	7.8	1.4 NS	20.8	10.3	1.3	13.6
	400 # N	3.9	-2.5 NS	-38.8	10.3	1.3	13.6
Overall	Control	7.6			8.5		
	200 # N	8.4	0.8 NS	11.4	10.1	1.6	17.8
	400 # N	7.8	0.2 NS	3.3	10.6	2.1	24.2

Table 6. (cont.)

Basal area increment in the third two years

Region	Treatment	Net ft^2/A	Net Growth Response ft^2/A	Net Growth Response percent	Gross ft^2/A	Gross Growth Response ft^2/A	Gross Growth Response percent
Northern Idaho	Control	10.0			11.2		
	200 # N	10.2	0.2 NS	1.8	11.8	0.6	6.1
	400 # N	12.6	2.6	26.2	13.2	2.0	18.0
Montana	Control	4.8			5.6		
	200 # N	5.0	0.2 NS	3.9	6.0	0.4 NS	7.1
	400 # N	4.6	-0.2 NS	-2.4	6.1	0.5	9.7
Central Idaho	Control	6.4			7.0		
	200 # N	5.2	-1.2 NS	-16.7	7.4	0.4 NS	6.5
	400 # N	6.0	-0.4 NS	-6.5	7.6	0.6	10.4
Northeast Oregon	Control	3.4			5.4		
	200 # N	1.6	-1.8 NS	-54.7	6.0	0.6	10.9
	400 # N	3.0	-0.4 NS	-12.6	6.2	0.8	11.7
Central Washington	Control	6.1			7.2		
	200 # N	6.2	0.1 NS	2.6	8.4	1.2	15.5
	400 # N	7.2	1.1 NS	17.8	9.2	2.0	28.6
Northeast Washington	Control	5.6			7.4		
	200 # N	5.8	0.2 NS	3.6	8.0	0.6 NS	6.7
	400 # N	4.2	-1.4 NS	-25.0	8.1	0.7	9.1
Overall	Control	6.4			7.6		
	200 # N	6.2	-0.2 NS	-2.1	8.2	0.6	8.6
	400 # N	6.8	0.4 NS	6.3	8.8	1.2	15.8

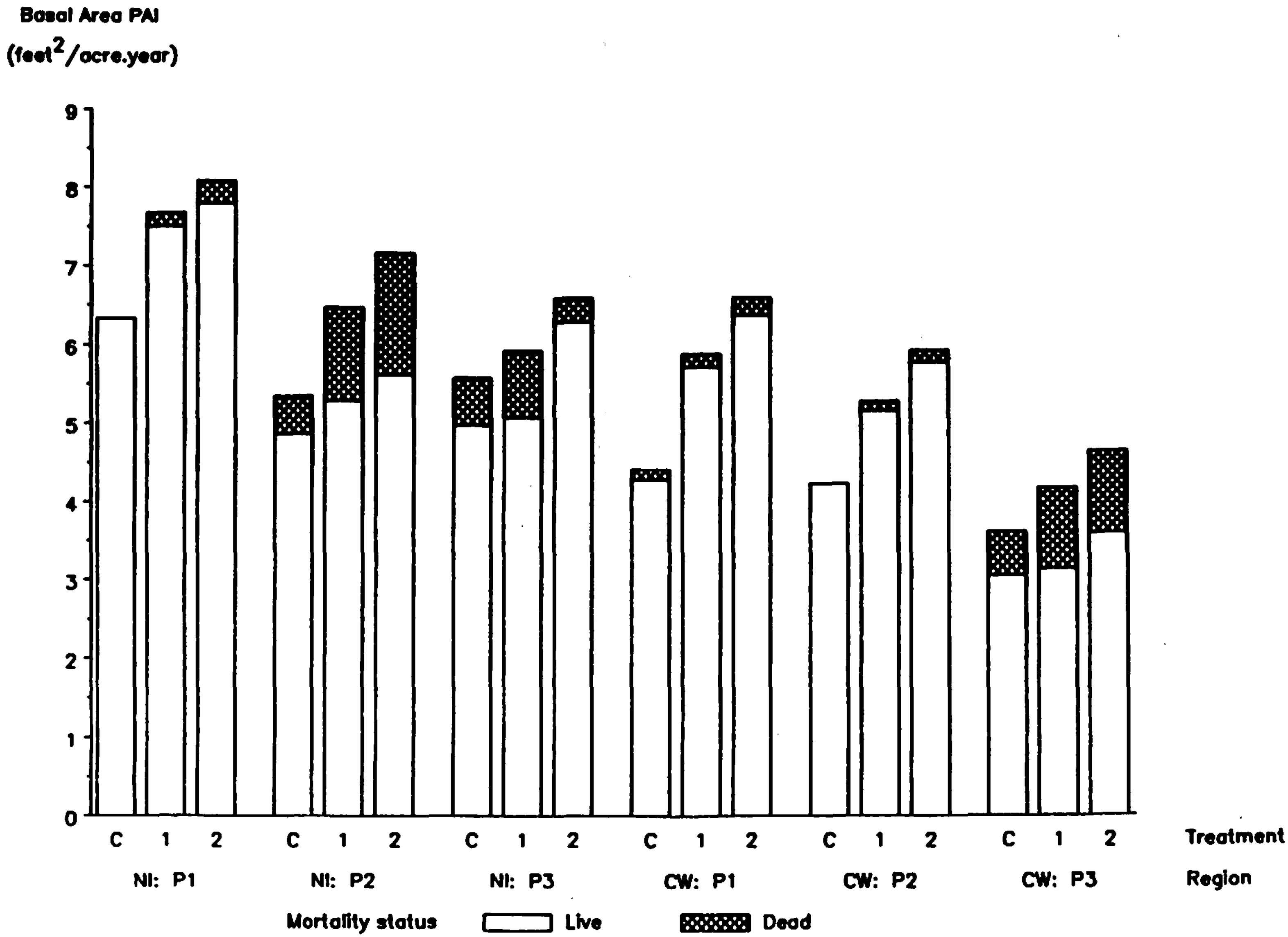

Figure 4. Periodic Basal Area Increment by Treatment for northern Idaho and central Washington.

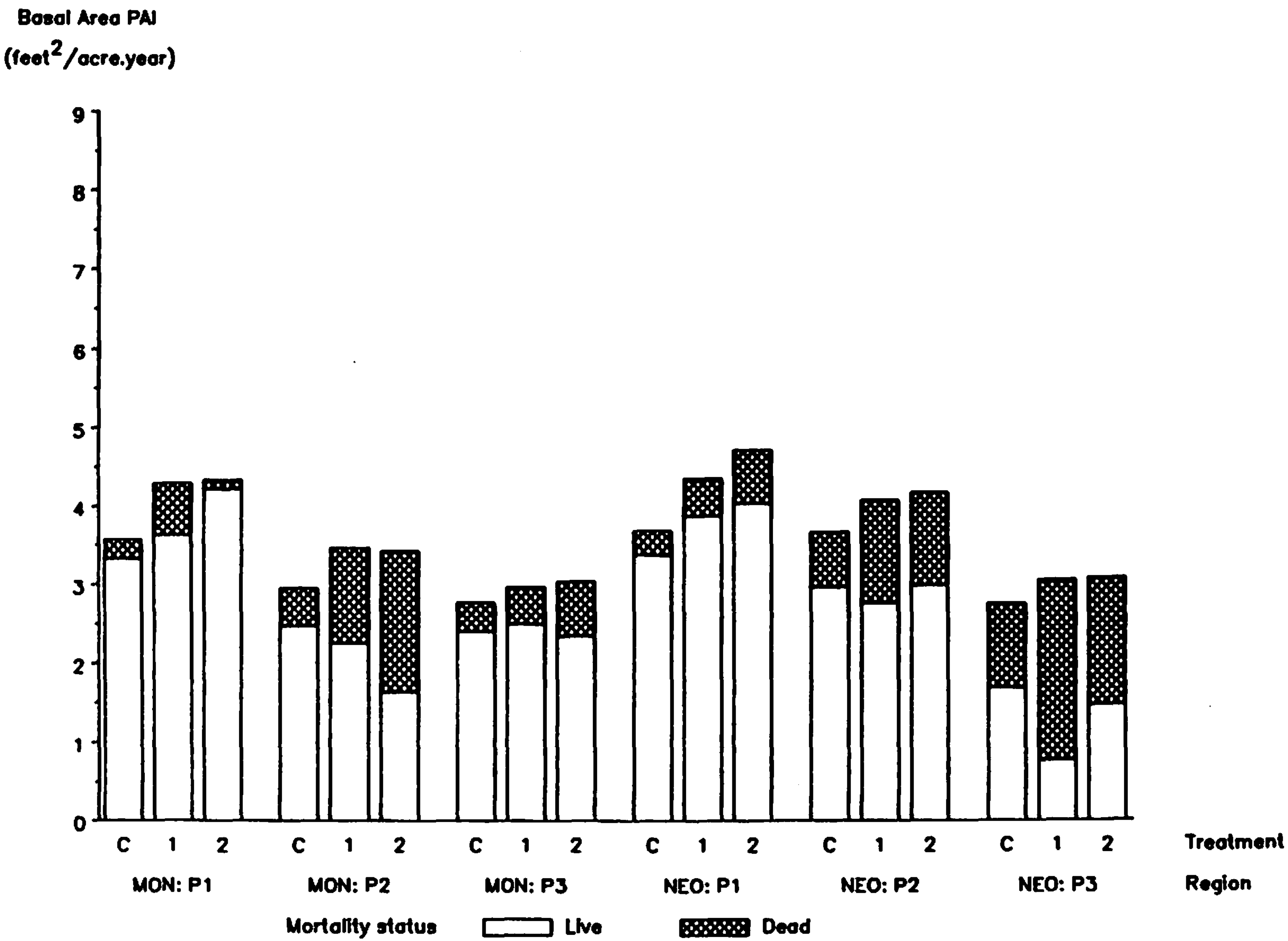

Figure 5. Periodic Basal Area Increment by Treatment for Montana and northeast Oregon.

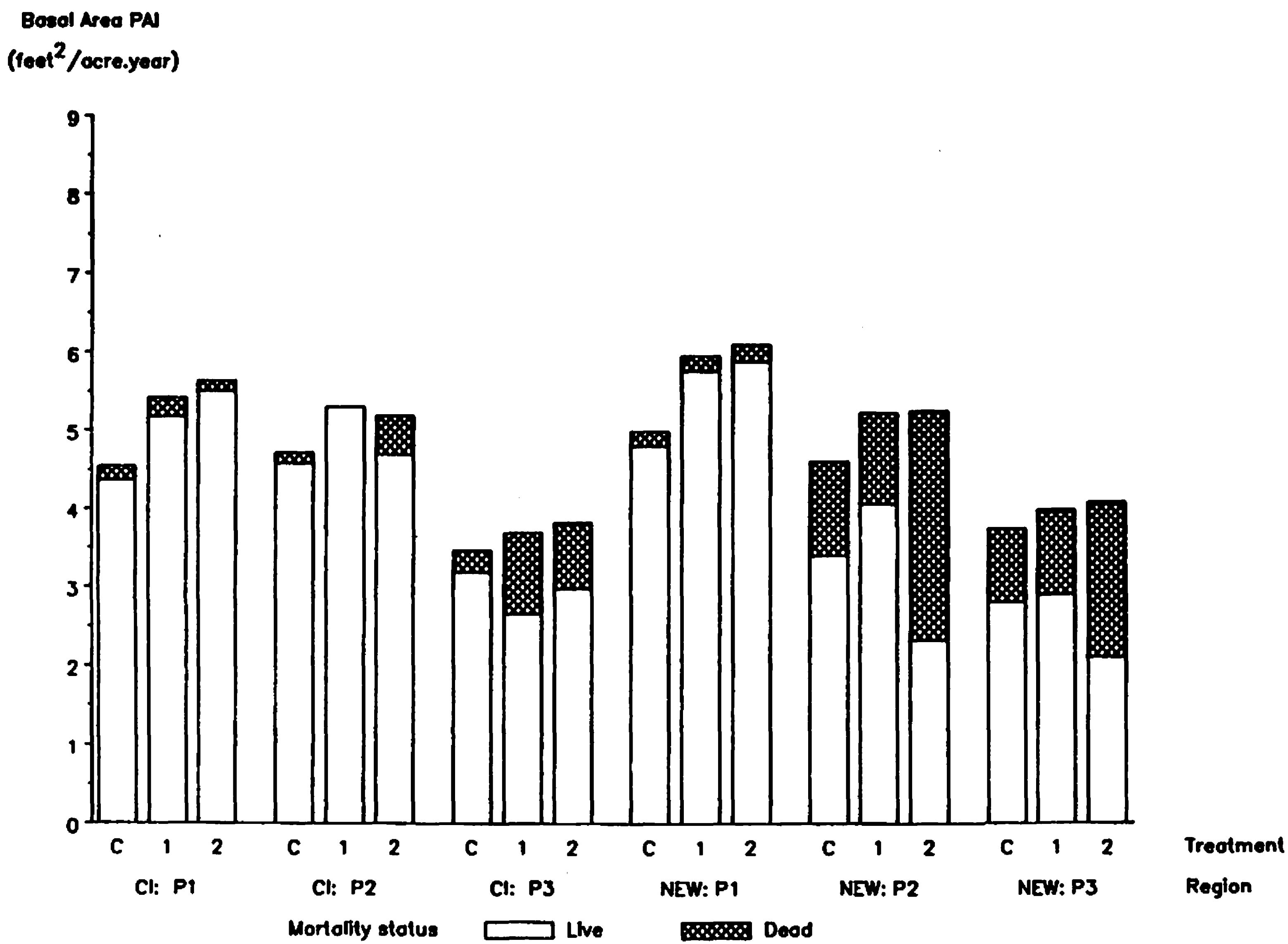

Figure 6. Periodic Basal Area Increment by Treatment for central Idaho and northeast Washington.

variation contributes to the non-significant treatment effect for net basal area.

Both net and gross basal area increments for the untreated control plots were lowest in years 5 and 6 for all geographic regions except northern Idaho. For Montana, central Washington, and northeast Washington, there have been successive declines in control plots growth for each two-year period. This decline in growth rate of the control plots is likely associated with drier than normal years, particularly the last two, and this may explain some of the reduced response to the nitrogen treatments in years 5 and 6.

Pre-Treatment Foliage Potassium Status and Duration of Response to Nitrogen Treatments

The 1987 and 1988 IFTNC Annual Reports describe the relationship between four-year response and foliar potassium status prior to treatment. Based on those results, the IFTNC Steering Committee decided to retreat the Douglas-fir installations with a nitrogen plus potassium treatment as well as nitrogen alone. These retreatments were just completed in the fall of 1988. Inadequate foliar K concentration for coastal Douglas-fir was reported to be 6000 ppm by Webster and Dobkowski (1983). Ingestad (1966) suggested that for several tree species an adequate balance or ratio of K/N should be 50 percent. Based on these values, we stratified the Douglas-fir installations into 3 classes based on pretreatment foliar K levels for control plots as follows:

POOR: K concentration < 6000 ppm and K/N < 50%

GOOD: K concentration > 6000 ppm and K/N > 65%

Intermediate (uncertain): K concentration and K/N= otherwise.

The average annual gross basal area response to the nitrogen treatments for each two-year period by potassium status class is given in Table 7 and illustrated by Figure 7. The "poor" K status was significantly lower than the other two classes for both nitrogen treatments and all three time periods. The Intermediate and Good classes were not significantly different from each other. Although not presented, the trends for net basal area were the same as for gross. Only one of the contrasts

Table 7. Periodic annual gross basal area per acre response by pre-treatment foliage potassium status, nitrogen treatment and period.

K Status		Treatment	Basal Area (Ft^2/A/yr.) Years 0-2	3-4	5-6
Poor	K<6000 ppm K/N < 50%	200 lb. N	0.78 (18.8%)	0.53 (13.07%)	0.13 (3.7%)
		400 lb. N	0.63 (15.2%)	0.31 (7.8%)	-0.06 (-1.9%)
Medium [K is otherwise]		200 lb. N	1.24 (27.7%)	0.87 (21.4%)	0.33 (8.7%)
		400 lb. N	1.59 (35.5%)	1.16 (28.7%)	0.64 (16.9%)
Good	K > 6000 ppm K/N > 65%	200 lb. N	1.40 (33.9%)	0.88 (23.2%)	0.39 (11.9%)
		400 lb. N	1.64 (39.6%)	1.27 (33.3%)	0.83 (25.3%)

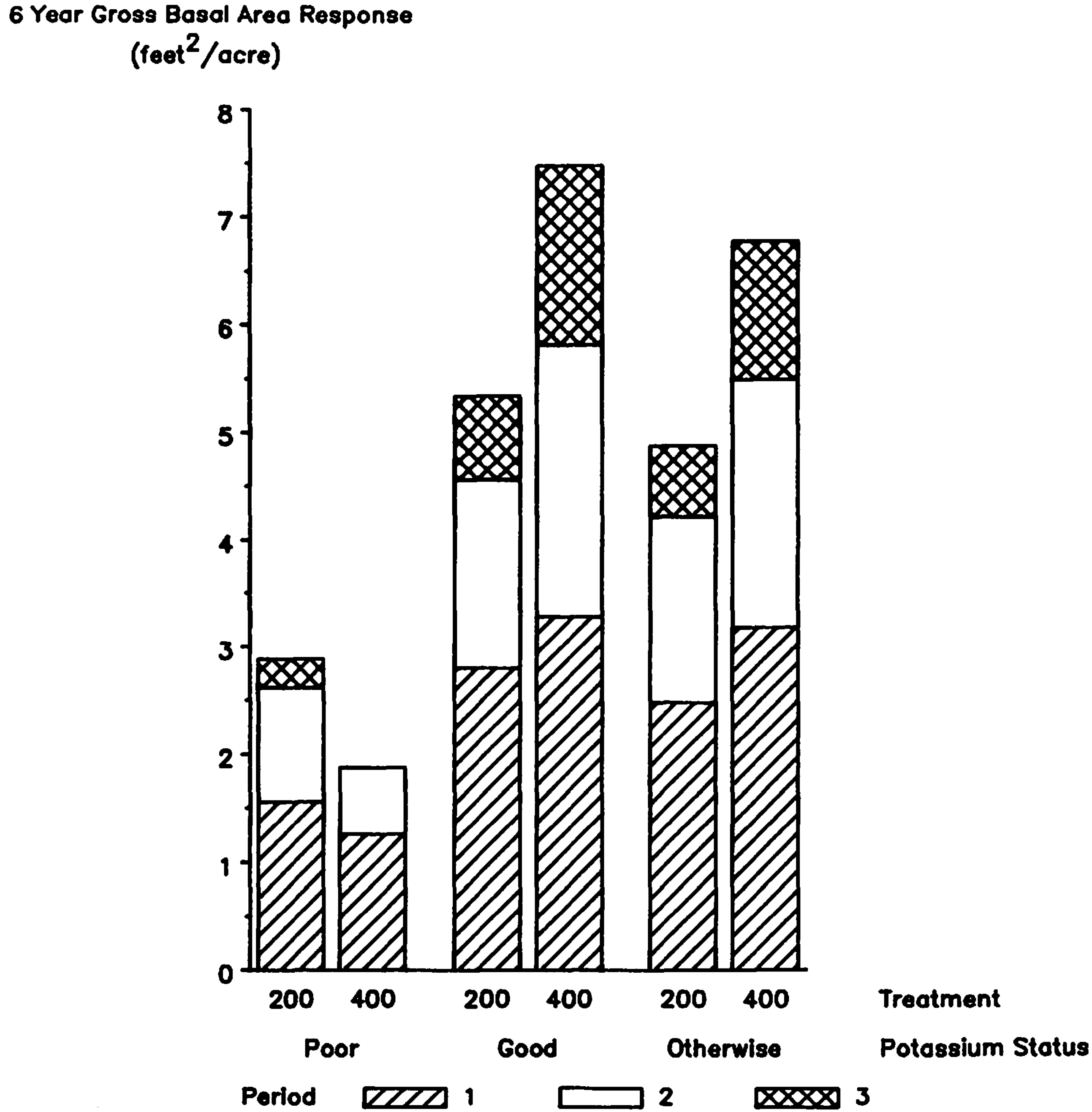

Figure 7. Gross Basal Area Response by Treatment, Time Period, and Pre-treatment Foliar Potassium Class.

between nitrogen treatments was statistically significant. The 400 lb. N treatment in the poor K-status, which sustained substantial mortality particularly during the third 2-year period, was significantly less than the same treatment in the other "K-classes". This is an interesting result in light of the hypothesized function of potassium in tree defense mechanisms against insects and diseases.

The gross basal area response to both nitrogen treatments was significantly different from the controls for all three K-status classes during the first two-year period. Response continued to be significant for the intermediate and good K-status classes during periods two and three. However, response was not significant during the second and third two-year periods for the poor K-status class. This result is important when considering duration of response estimates derived from the entire experiment. Installations with good K-status continue to produce significant response after the first two years; those with poor K-status do not.

Pre-treatment Foliage Potassium Status and Six-year Response to Nitrogen Treatments

The six-year response for both net and gross volume, basal area, and average stand diameter by nitrogen treatment and potassium status are provided in Table 8. There are statistically significant differences between each K status class for both nitrogen treatments for gross volume, gross basal area, and average stand diameter! The average responses directly correspond to the poor, intermediate, and good K-status classes. The only significant differences by K-status for net volume and basal area was the 400 # N treatment for poor K-status class versus the other two K classes. The six-year results support the same conclusions as the four-year results relative to the influence of potassium on response to nitrogen treatments.

Variation in Growth Response to Nitrogen Fertilization Across Installations

In previous IFTNC annual reports we made the point that average responses by region and treatment are useful for making general comparisons and conclusions, but, since we intentionally selected installations to cover a broad range of site and stand conditions, it would be unlikely that all installations would respond to nitrogen fertilization. Understanding why sites and stands do or do not respond is important to devising an effective operational fertilization or nutrient management program. In every region some stands responded well to nitrogen fertilization and others did not respond at all or negatively. The variation

Table 8. Six-year responses per acre by pre-treatment foliage potassium status and nitrogen treatment.

K Status	Treatment	Volume (Ft^3/A) Net	Volume (Ft^3/A) Gross	Basal Area (Ft^2/A) Net	Basal Area (Ft^2/A) Gross	Average Stand Diameter (in.)
Poor (K<6000 ppm; K/N < 50%)	200 lb N.	101	126	1.89	2.91	0.07
	400 lb N.	-3	114	-0.88	1.83	0.02
Medium [K is otherwise]	200 lb N.	141	162	3.84	4.88	0.17
	400 lb N.	148	211	4.08	6.78	0.26
Good (K > 6000 ppm; K/N > 65%)	200 lb N.	137	190	3.56	5.39	0.20
	400 lb N.	213	252	6.05	7.51	0.32

in treatment response across the entire experiment is shown in Figure 8. This figure is the cumulative distribution of gross six-year volume growth response to the nitrogen treatments. The variation in response has increased compared to four-year results. Previously responding installations continue to respond after six years while others now show little or even negative response. 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. Based on four-year results, we could explain much of the variation in response by using factors such as: geographic region, soil parent material, crown ratio, and foliar K status. We have no indications that the relationships are different for the six-year results.

The variation in volume response by geographic region is shown in Figures 9 through 14. One interesting characteristic is the increasing difference in the response C.D.F.'s for the 200 lb. N and the 400 lb. N treatments in northern Idaho and central Washington. Perhaps a higher proportion of installations in these two regions are limited by nitrogen alone and thus produce additional volume response to the higher nitrogen treatment.

The 75th percentile of the response distribution may be a good estimate of the expected response to nitrogen treatments if we were successful in using what we have learned to target mostly responding stands in an operational fertilization program. The value of the 75th percentile for gross volume response by geographic region is provided in Table 9. The 75th percentile

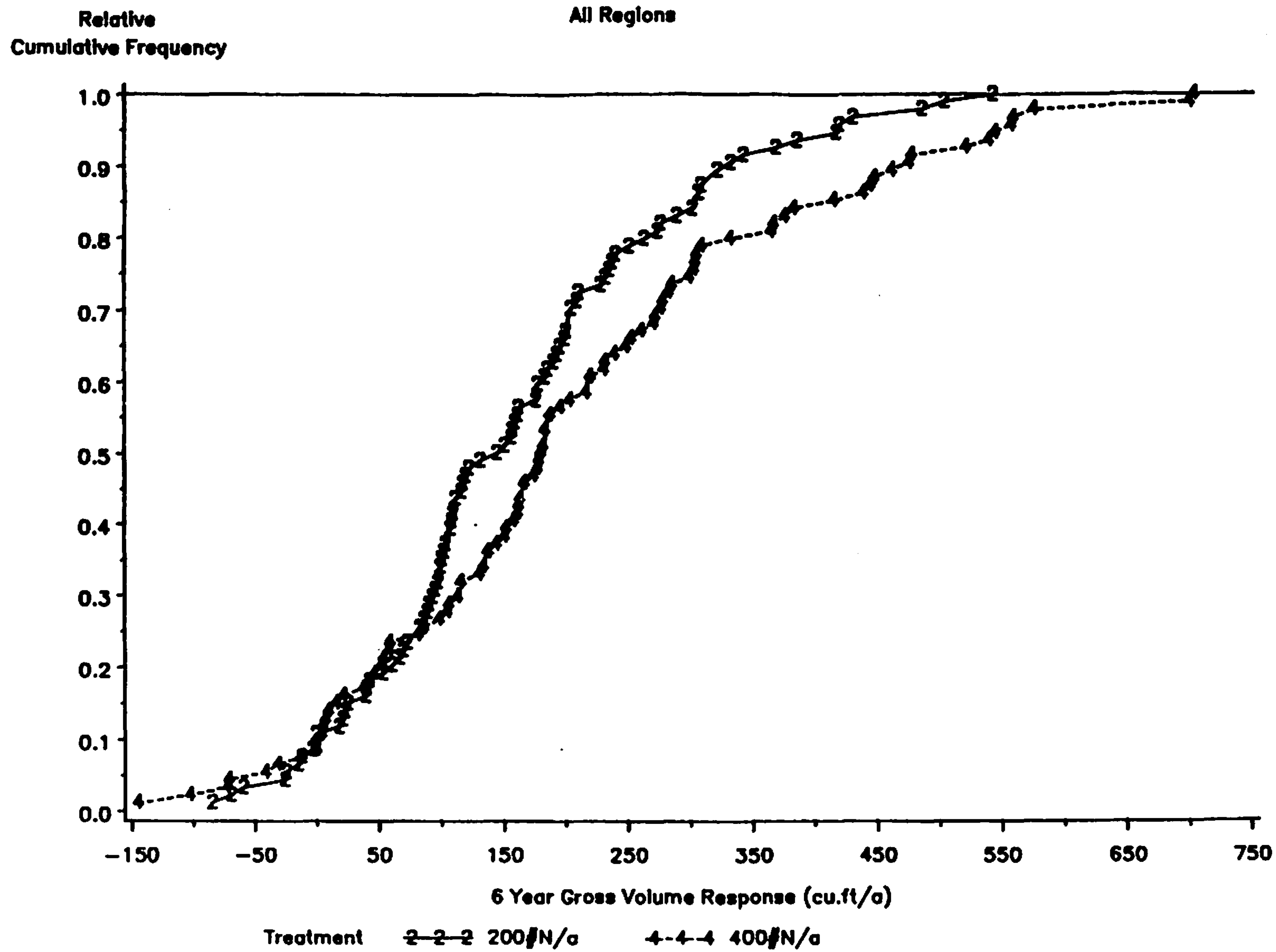

Figure 8. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for the Entire Douglas-fir Experiment.

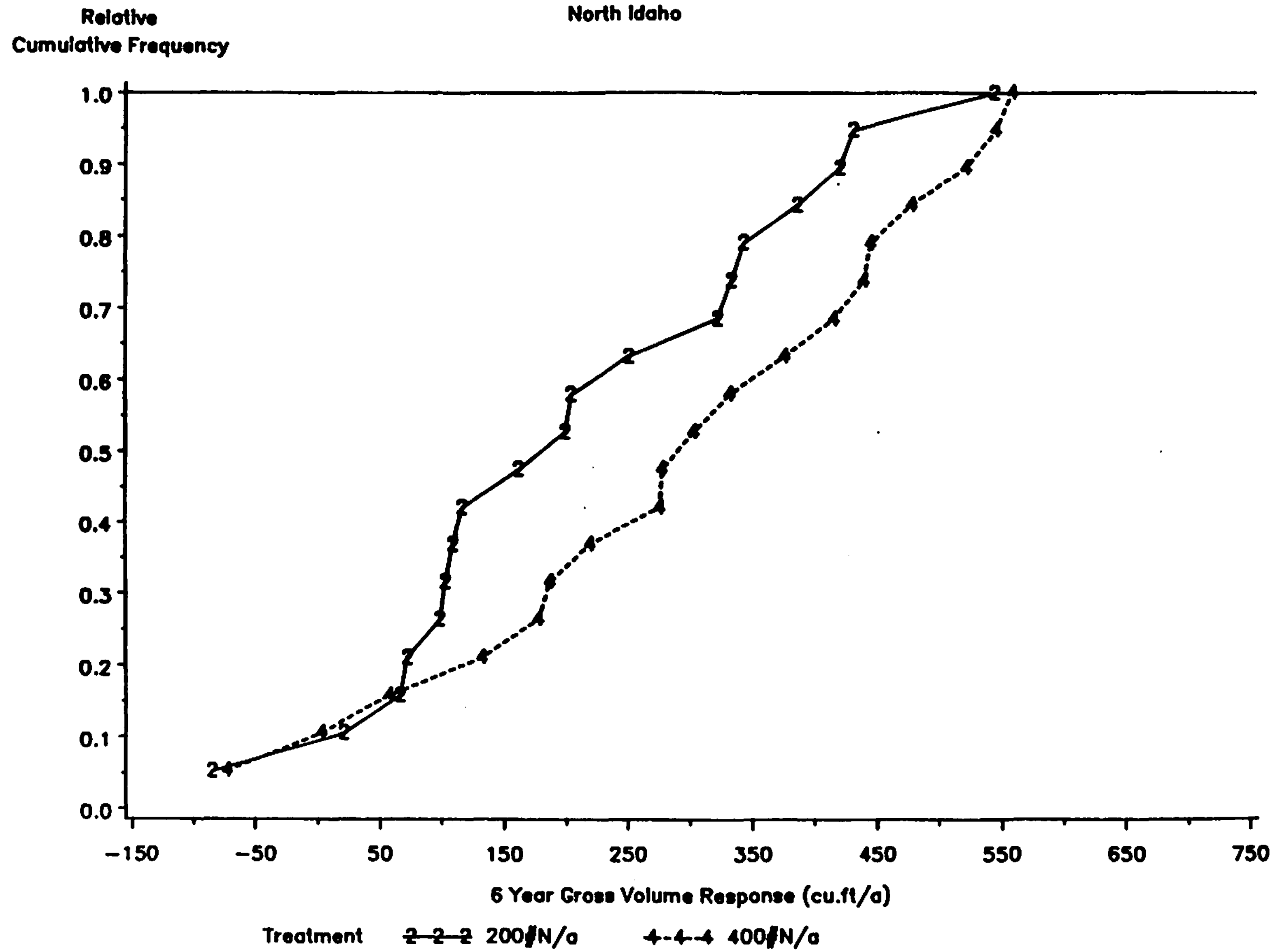

Figure 9. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for northern Idaho.

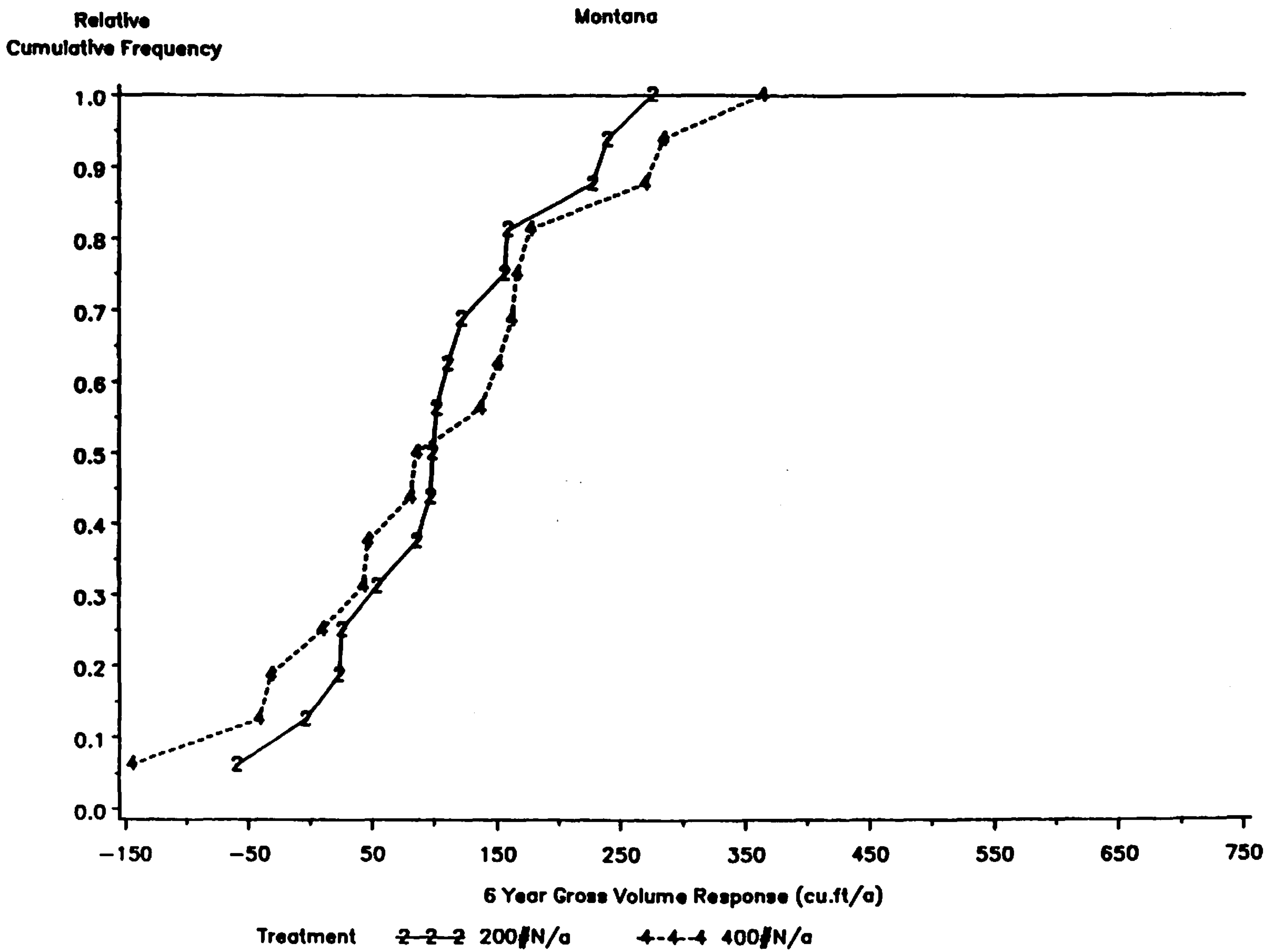

Figure 10. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatment for Montana.

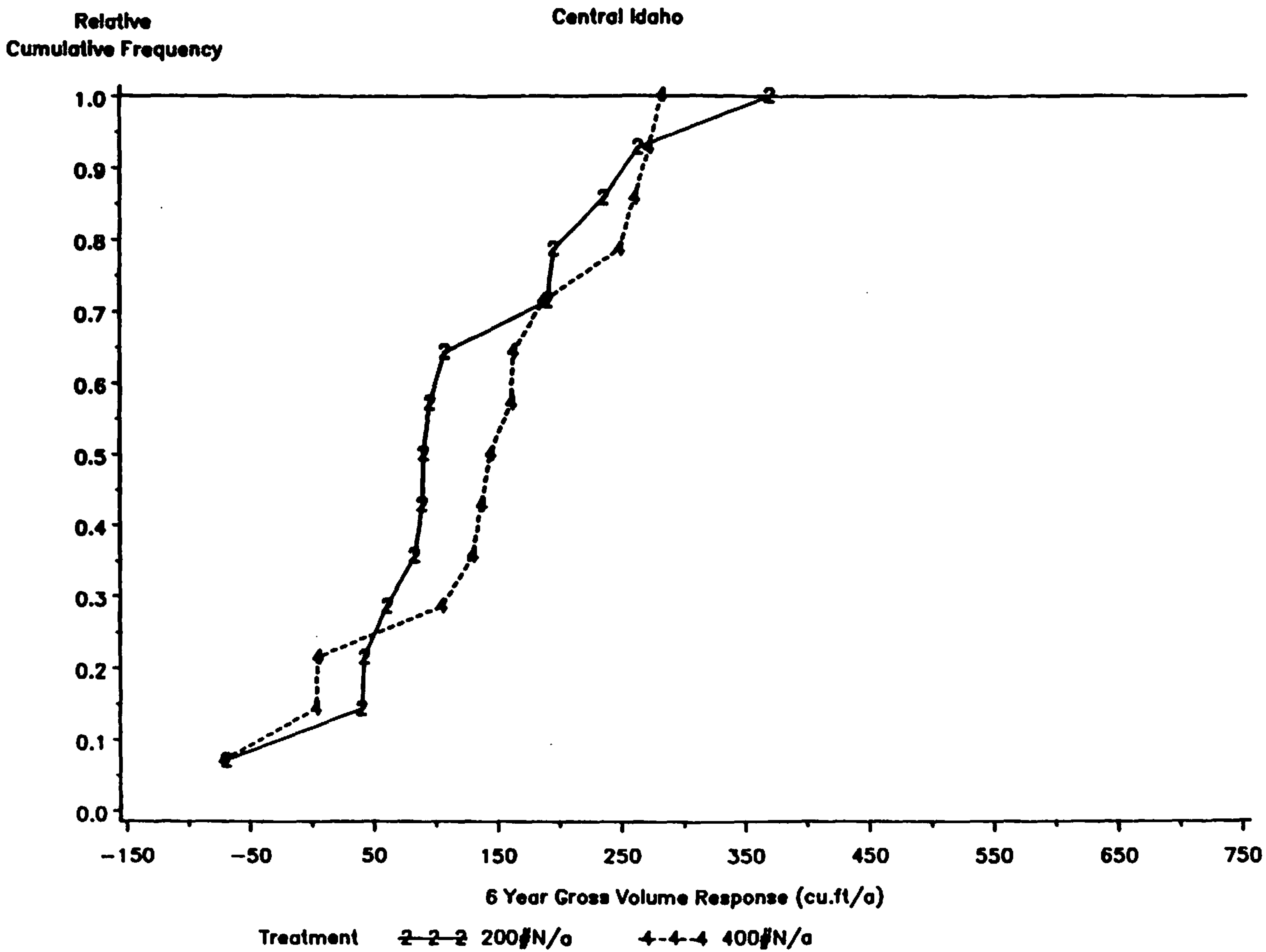

Figure 11. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for central Idaho.

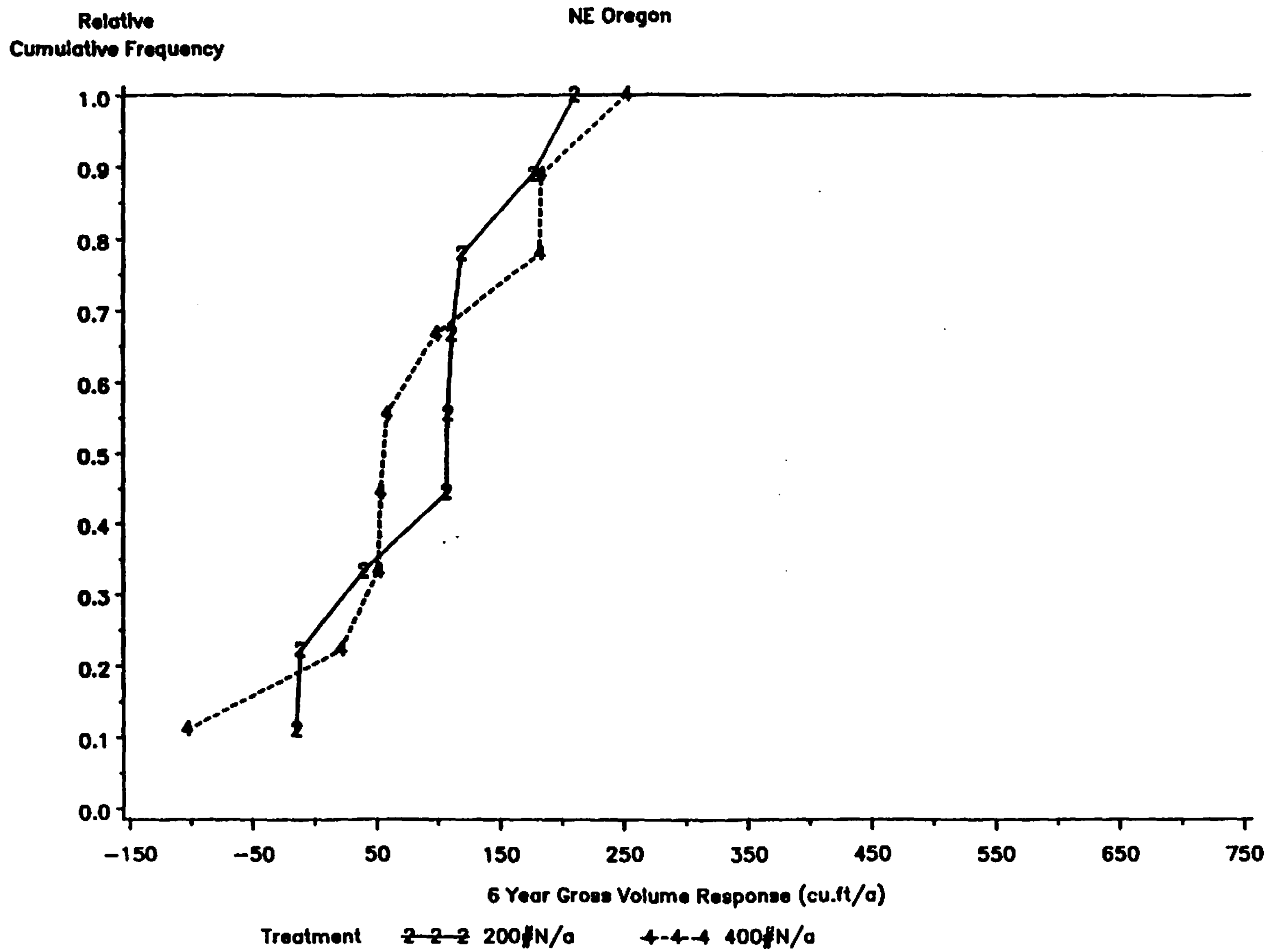

Figure 12. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for northeast Oregon.

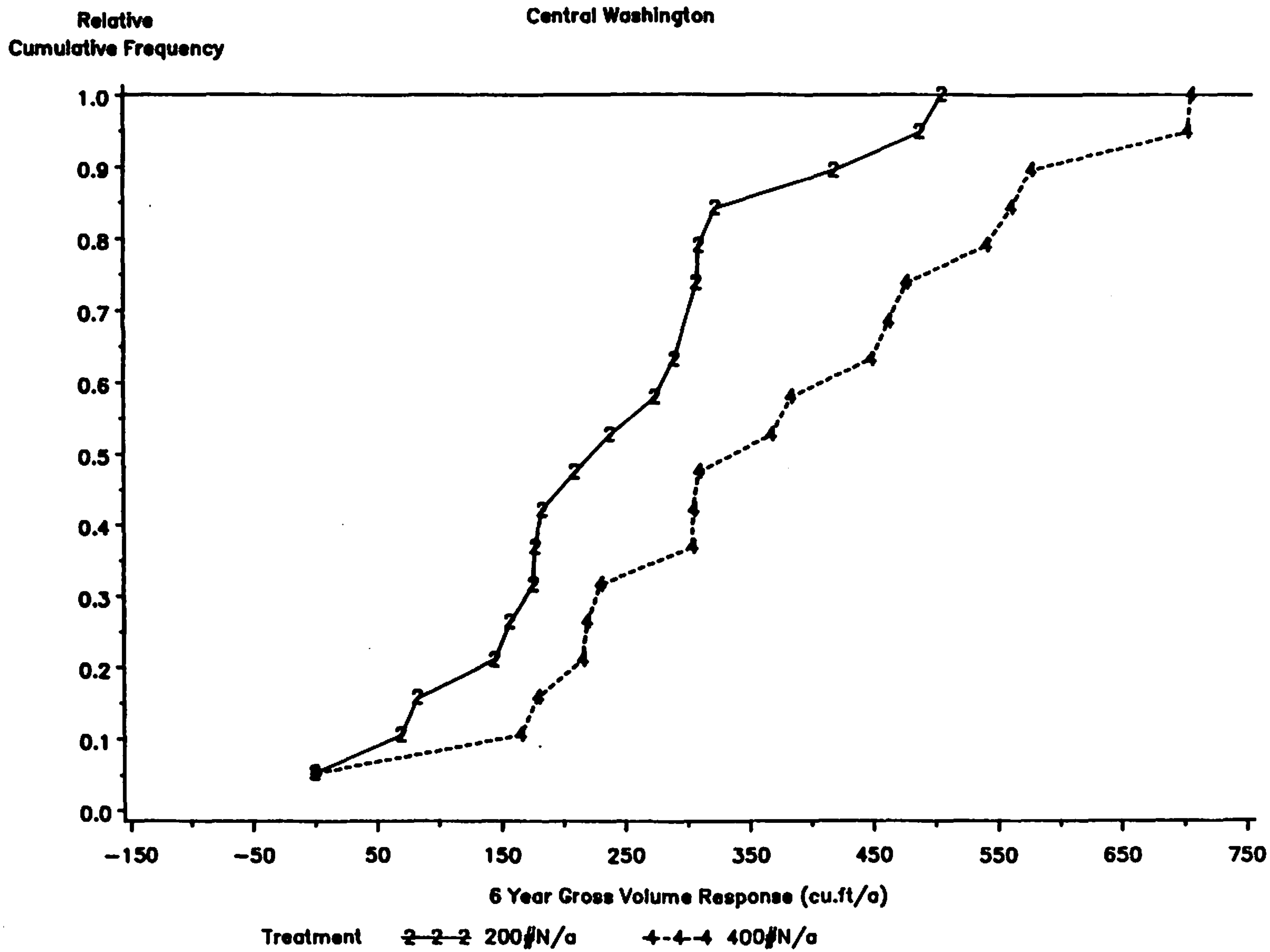

Figure 13. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for central Washington.

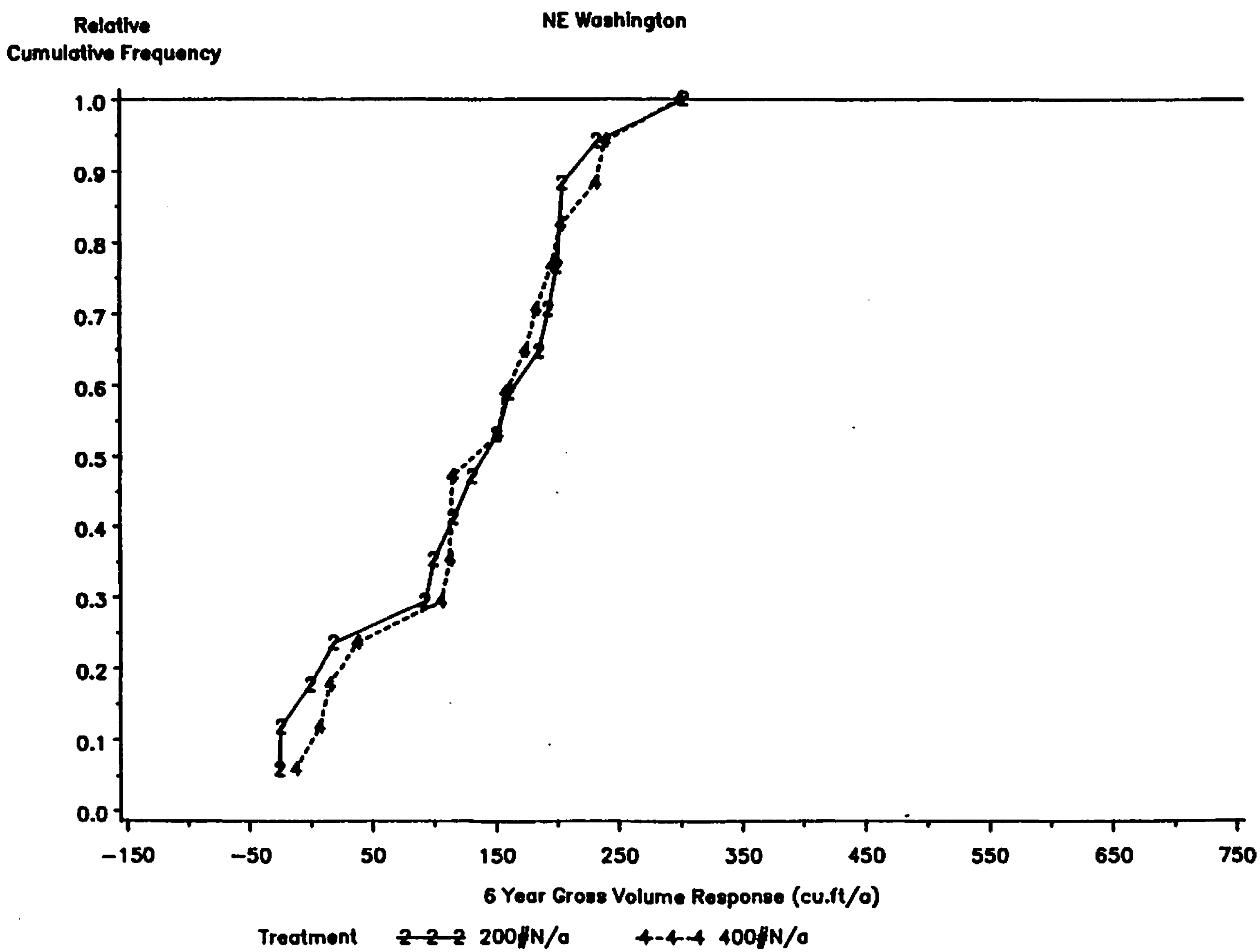

Figure 14. The Cumulative Distribution of Gross Six-year Volume Growth Response to the Nitrogen Treatments for northeast Washington.

Table 9. The Seventy-fifth percentile of gross volume per acre response by region and treatment.

Region	200 # N	400 # N
Northern Idaho	342	444
Montana	157	173
Central Idaho	204	250
Northeast Oregon	147	182
Central Washington	308	540
Northeast Washington	201	198
Overall	235	302

response for the 200 lb. N treatments range from a low of 147 cu. ft. in northeast Oregon to a high of 342 cu. ft. in northern Idaho. For the 400 lb. N treatment, the range was from 173 cu. ft. in Montana to a high of 540 cu. ft. in central Washington. The difference in the 75th percentile for the two treatment response distributions in central Washington was 232 cu. ft.! This may indicate that for central Washington (and perhaps northern Idaho) the 400 lb. N treatment may produce a response of longer duration.

Given the substantial recent interest and activity by some of the cooperators, we felt it would be useful to provide selected references on interactions between forest nutrition and forest health

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