TENTH ANNUAL REPORT

Intermountain Forest Tree
Nutrition Cooperative

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INTERMOUNTAIN FOREST TREE
NUTRITION COOPERATIVE

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SUMMARY

The data available for this report are:

- Eight-year response to nitrogen fertilization for one-half of the Douglas-fir experiment originally established in 1981 (and 4 sites in 1980).

- Two-year response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir installations originally established in 1981.

- Eight-year response to both spring and fall applications of nitrogen or nitrogen plus sulphur for four Douglas-fir sites established in 1980.

- Four-year response to nitrogen fertilization for the ten ponderosa pine installations established in northeastern Oregon and central Washington during 1985.

- Two-year response to nitrogen or nitrogen plus potassium for six ponderosa pine installations established in Montana during 1987.

Results based on analysis of the above data indicate the following:

(A) There continues to be significant differences in response to nitrogen fertilization between geographic regions for Douglas-fir after eight years.

(B) Northeastern Washington 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) At least one of the nitrogen fertilization rates produced significant gross basal area and volume growth response for all regions except Montana after eight years. However, for net basal area and volume response, only northern Idaho and central Washington showed a significant response to either nitrogen treatment. Further, both nitrogen treatments produced significant gross basal area response in northern Idaho and central Washington during years 7 and 8 after treatment. The same was true for the 400 pound nitrogen treatment in northeastern Washington. Only the 400 pound treatment in northern Idaho resulted in a significant net response during years 7 and 8.

(D) Two-year nitrogen effects for the retreatments were not as large as the two-year effects of the original nitrogen treatments.

(E) Both nitrogen treatments produced significant gross volume and basal area response after four years for ponderosa pine in central Washington. Only the four-year basal area response was significant on the average in northeastern Oregon. The only significant positive net effect after four years was the 200 pound treatment in central Washington. The average two-year response to the 200 pound nitrogen treatment for ponderosa pine in Montana was not significant.

(F) Although not statistically significant, the potassium retreatment effects for the Douglas-fir trials and the two-year potassium effects of the original treatments for ponderosa pine in Montana reduced mortality rates after treatment compared to nitrogen alone treatments.

(G) The potassium retreatment effects were greatest for those installations with poor pre-treatment foliar potassium status

(H) Results F and G above suggest that our hypothesis regarding the relationship between potassium nutrition and tree mortality rates may still be true. Perhaps the failure to demonstrate statistical significance is due to the small sample size with only one-half of the Douglas-fir data currently available.

Introduction

This year's report includes estimates of eight-year basal area and volume growth response to nitrogen fertilization treatments as well as two-year response to retreatments with nitrogen and nitrogen plus potassium for one-half of the 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, years 7 and 8) for one-half of the Douglas-fir experiment. The eight-year response of the four Douglas-fir installations that include fall versus spring applications of both nitrogen and nitrogen plus sulphur are reported. New data, showing the effect of nitrogen and nitrogen plus potassium fertilization on foliar nutrients after treatment for all of the Douglas-fir installations and six western Montana ponderosa pine sites will be provided later as an addendum to this report. Four-year response to two levels of nitrogen fertilization for ponderosa pine installations in northeastern Oregon and central Washington as well as two-year response to nitrogen and nitrogen plus potassium for ponderosa pine in Montana are also reported.

Experimental design models:

The design models took the general form:

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

where:

INC = the growth occurring in a variable number of years depending on the experiment under analysis (between 2 and 8 years);

Region = the geographic region of the cooperative;

Treatment = the level of nitrogen or potassium fertilizer applied;

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

The model form was similar but not identical depending on the responses considered, including gross and net basal area increment (ft^2/A), and gross and net volume increment (ft^3/A) and the data set being analyzed (i.e., continuing Douglas-fir response, Douglas-fir retreatment response, or the ponderosa pine data).

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 15 of the Technical Documentation Report.

DOUGLAS-FIR RESULTS

General Description of the Experiment:

The Douglas-fir experiment was changed starting in 1987. A variable number of plots at each installation, about one-half of the plots overall, were retreated with: (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. The original experiment is now continued on somewhat less than one-half of the plots. Furthermore, some of the retreatment effects for nitrogen and potassium are available from only about one-third of the installations. We should, therefore, be cautious about interpreting the results based on only one-half of the Douglas-fir experiment. This is particularly true for some of the regional retreatment response estimates since in some cases they are based on only a few plots.

Eight-year Basal Area Growth Response to Nitrogen Fertilization for One-half of the Douglas-fir Installations:

Eight-year 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 and shown in Figure 1. The six-year gross basal area per acre increments for both the 200 and 400 lb nitrogen treatments were statistically different from the controls for northern Idaho, central Washington, and northeastern Washington.

Table 1. Average eight-year net and gross basal area growth response to nitrogen fertilization by region and treatment for the Douglas-fir installations established in 1980 and 1981.[1]

		Net Basal Area			Gross Basal Area		
Region	Treatment	Increment ft^2/acre	Response ft^2/acre	Response percent	Increment ft^2/acre	Response ft^2/acre	Response percent
Northern Idaho	Control	34.7			41.4		
	200 # N	46.3	11.6	33.4	54.3	12.9	31.2
	400 # N	51.4	16.7	48.1	50.7	9.3	22.5
	400 # vs 200 #		5.1	11.0		-3.6 NS	-6.6
Montana	Control	26.6			27.8		
	200 # N	28.7	2.1 NS	7.9	29.3	1.5 NS	5.4
	400 # N	23.8	-2.8 NS	-10.5	30.4	2.6 NS	9.4
	400 # vs 200 #		-4.9 NS	-17.1		1.1 NS	3.8
Central Idaho	Control	28.1			31.2		
	200 # N	30.4	2.3 NS	8.2	34.4	3.2 NS	10.3
	400 # N	29.6	1.5 NS	5.3	36.5	5.3	17.0
	400 # vs 200 #		-0.8 NS	-2.6		2.1 NS	6.1
Northeast Oregon	Control	20.9			25.5		
	200 # N	20.8	-0.1 NS	-0.5	30.8	5.3	20.8
	400 # N	23.2	2.3 NS	11.0	29.6	4.1 NS	16.1
	400 # vs 200 #		2.4 NS	11.5		-1.2 NS	-3.5
Central Washington	Control	28.1			31.0		
	200 # N	33.2	5.1 NS	18.1	36.1	5.1	16.5
	400 # N	35.4	7.3	26.0	40.4	9.4	30.3
	400 # vs 200 #		2.2 NS	6.6		4.3	11.9

Table 1. (cont.)

Region	Treatment	Net Basal Area Increment ft^2/acre	Net Basal Area Response ft^2/acre	Net Basal Area Response percent	Gross Basal Area Increment ft^2/acre	Gross Basal Area Response ft^2/acre	Gross Basal Area Response percent
Northeast	Control	27.9			34.6		
Washington	200 # N	29.1	1.3 NS	4.7	38.8	4.1	11.9
	400 # N	33.0	5.1 NS	18.3	44.0	9.4	27.2
	400 # vs 200 #		3.8 NS	13.1		5.3	13.7
Overall	Control	27.5			31.5		
	200 # N	30.7	3.2 NS	11.6	36.3	4.8	15.2
	400 # N	31.8	4.4	16.0	38.3	6.7	21.3
	400 # vs 200 #		1.2 NS	3.9		1.9 NS	5.2

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

NS = Not Significant (α = .1)

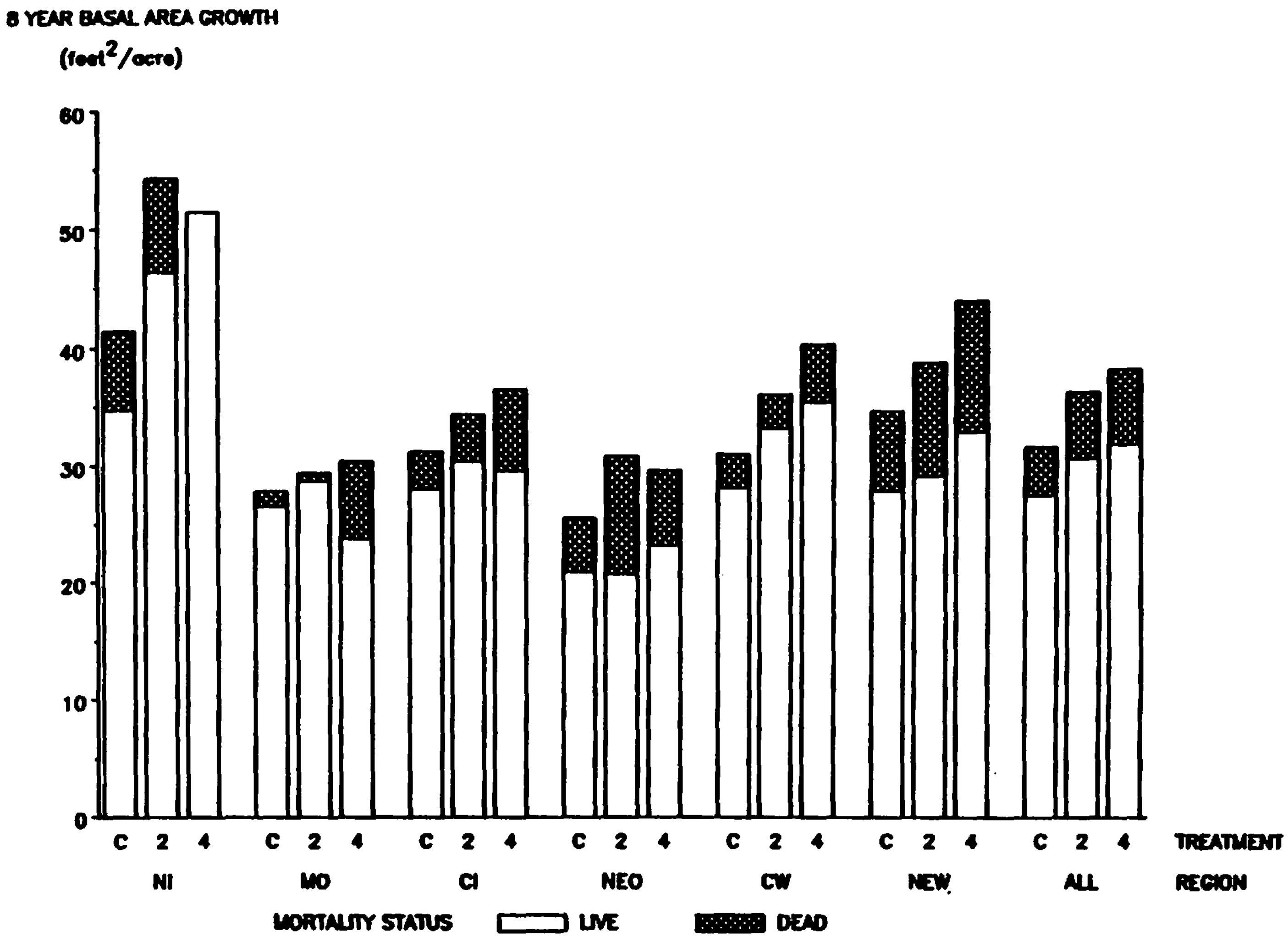

Figure 1. Eight-year Basal Area Increment by Region and Treatment Partitioned into Live (Net) and Dead Components for One-half of the Douglas-fir Installations.

The 200 lb treatment produced a significant gross basal area response in northeastern Oregon, while the 400 lb treatment did so in central Idaho. Neither treatment was significantly different from the controls after eight years in Montana. Only in northeastern Washington and central Washington were the gross increments for the 400 lb treatment significantly greater than the 200 lb treatment. These results are somewhat different than for the six-year basal area response (1989 IFTNC Annual Report), particularly for northeast Washington. These differences in regional response estimates are likely partially due to the reduced subset of plots that are now included in the analysis since retreatments were applied.

The results are different for net basal area increment. There is no statistical difference in net basal area increment between either nitrogen treatment and the controls for the Montana, central Idaho, northeast Oregon, and northeast Washington regions. In central Washington, the 400 lb treatment average net basal area increment was significantly greater than the controls, but the 200 lb treatment was not. Both nitrogen treatments produced a significant net basal area growth response in northern Idaho after eight years, and the 400 lb nitrogen treatment was also significantly greater than the 200 lb treatment for this region. Northern Idaho now shows the largest net growth response to both nitrogen treatments. After six years, analysis of the complete Douglas-fir experiment indicated that central Washington produced the largest response to both treatments. Again this difference is likely because we are currently working with a subset of the data. Most regions showed large decreases from gross to net basal area response for the 400 lb treatment, particularly Montana. The reason for the different results for gross and net basal area growth response is that fertilized plots had significantly higher mortality rates during years 3 through 8 than the control plots. Mortality differences will be even more evident during discussion of response duration 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.

Eight-year Volume Growth Response to Nitrogen Fertilization for One-half of the Douglas-fir Installations:

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 2 and shown in Figure 2. The gross volume per acre increments for both nitrogen treatments are significantly greater than the controls for northern Idaho, central Washington, and northeastern Washington. For central Washington and northern Idaho the gross volume growth for the 400 lb treatment was significantly greater than the 200 lb treatment.

Only in northern Idaho and central Washington is there a statistical difference in net volume increment for both nitrogen treatments and the controls. Northern Idaho showed the greatest average net volume growth response to both nitrogen treatments (200 lb N = 353 ft^3, 23.6%; 400 lb N = 697 ft^3, 46.7%). The net

Table 2. Average eight-year net and gross cubic foot volume growth response to nitrogen fertilization by region and treatment for the Douglas-fir installations established in 1980 and 1981.[1]

		Net Volume			Gross Volume		
Region	Treatment	Increment ft^3/acre	Response ft^3/acre	Response percent	Increment ft^3/acre	Response ft^3/acre	Response percent
Northern Idaho	Control	1493			1700		
	200 # N	1846	353	23.6	2030	330	19.4
	400 # N	2190	697	46.7	2095	395	23.2
	400 # vs 200 #	----	345 NS	18.7		65 NS	3.2
Montana	Control	1066			1094		
	200 # N	1197	131 NS	12.3	1196	103 NS	9.4
	400 # N	1043	-23 NS	-2.2	1199	105 NS	9.6
	400 # vs 200 #	----	-154 NS	12.9		2 NS	0.2
Central Idaho	Control	1025			1137		
	200 # N	1154	129 NS	12.6	1270	133 NS	11.7
	400 # N	1137	113 NS	11.0	1356	218	19.2
	400 # vs 200 #	----	-16 NS	-1.4		85 NS	6.7
Northeast Oregon	Control	1072			1087		
	200 # N	1048	-24 NS	-2.2	1233	146 NS	13.4
	400 # N	1085	13 NS	1.2	1217	131 NS	12.1
	400 # vs 200 #	----	37 NS	3.5		-15 NS	-1.2
Central Washington	Control	1192			1281		
	200 # N	1426	234	19.6	1508	227	17.7
	400 # N	1489	297	24.9	1653	372	29.0
	400 # vs 200 #	----	63 NS	4.4		145	9.6

Table 2. (cont.)

Region	Treatment	Net Volume Increment ft³/acre	Net Volume Response ft³/acre	Net Volume Response percent	Gross Volume Increment ft³/acre	Gross Volume Response ft³/acre	Gross Volume Response percent
Northeast Washington	Control	1180			1356		
	200 # N	1288	108 NS	9.2	1514	159	11.7
	400 # N	1353	172 NS	14.6	1642	286	21.1
	400 # vs 200 #	----	64 NS	5.0		127 NS	8.4
Overall	Control	1152			1254		
	200 # N	1299	147	12.8	1428	174	13.9
	400 # N	1338	186	16.2	1505	251	20.0
	400 # vs 200 #	----	39 NS	3.0		77 NS	5.4

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

NS = Not Significant (α = .1)

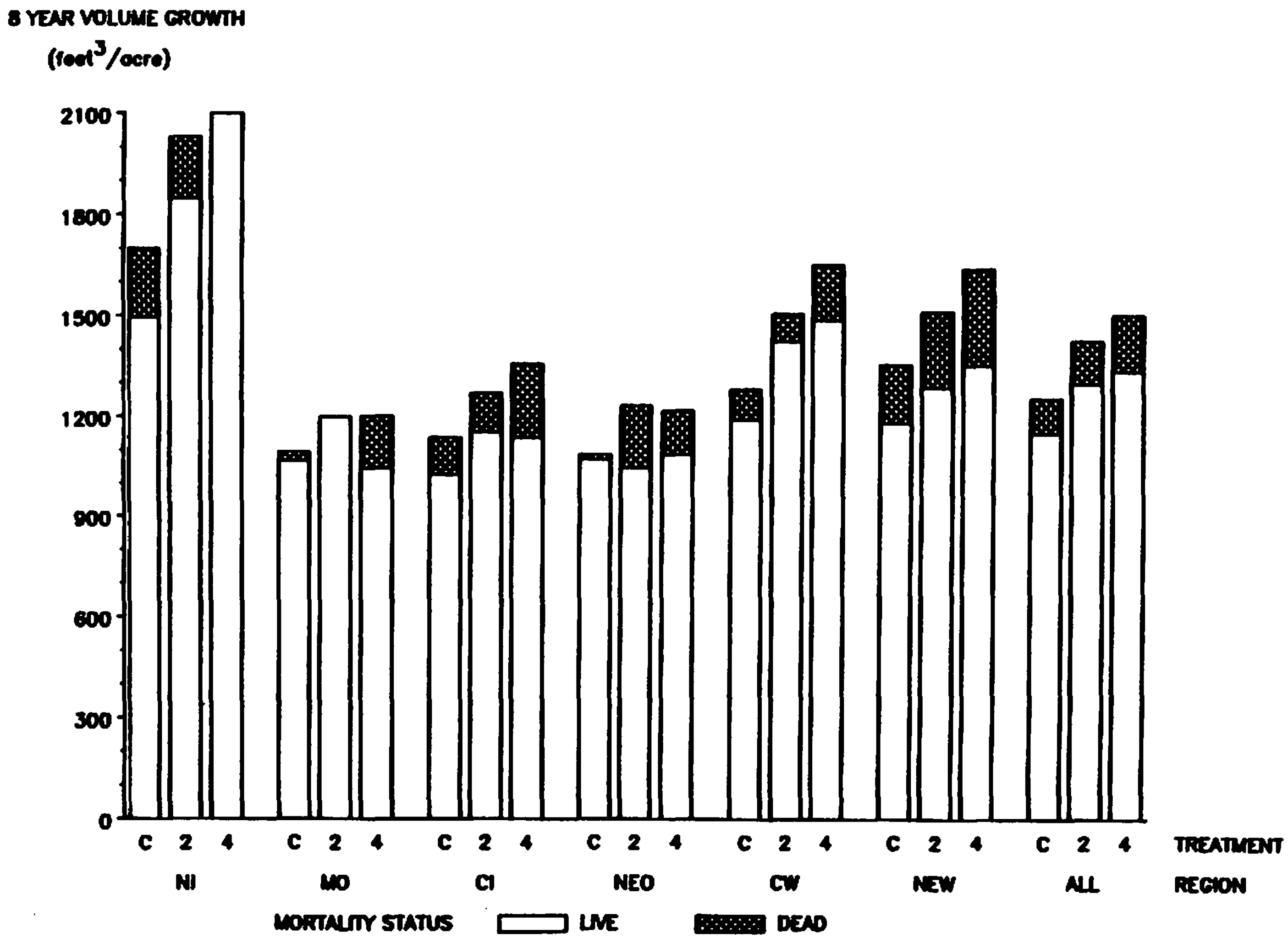

Figure 2. Eight-year Volume Increment by Region and Treatment Partitioned into Live (Net) and Dead Components for One-half of the Douglas-fir Installations.

volume growth for the 400 lb treatment was not significantly greater than the 200 lb treatment for any geographic region.

Eight-year height increment response:

Both nitrogen treatments produced significant height growth response in Montana and central Washington (Table 3). Height growth for the 200 lb treatment was significantly greater than the controls in northeastern Washington; however, the response to the 400 lb treatment was not significant. Neither nitrogen treatment produced significant height growth response after eight years in northern Idaho, central Idaho, or northeastern Oregon. There was no significant difference between the two nitrogen treatments for any geographic region.

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, was partially the reasons that we retreated with potassium. The second mortality type can be called "competition-related". Larger trees within a stand respond more to fertilization than small trees. 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 4 and illustrated in Figure 3.

The increase in average stand diameter resulting from both nitrogen treatments was significantly different from the controls

Table 3. Average eight-year height increment response to nitrogen fertilization per tree by region and treatment for the Douglas-fir installations established in 1980 and 1981.[1]

		Height Increment		
		Total	Response	
Region	Treatment	ft/tree	ft/tree	percent
Northern Idaho	Control	10.2		
	200 # N	11.1	0.9 NS	8.8
	400 # N	11.2	1.0 NS	9.8
Montana	Control	5.8		
	200 # N	6.6	0.8	13.8
	400 # N	6.8	1.0	17.2
Central Idaho	Control	5.2		
	200 # N	6.0	0.8 NS	15.4
	400 # N	5.8	0.6 NS	11.5
Northeast Oregon	Control	6.9		
	200 # N	7.4	0.5 NS	7.2
	400 # N	7.2	0.2 NS	2.9
Central Washington	Control	6.2		
	200 # N	7.7	1.5	24.2
	400 # N	7.8	1.6	25.8
Northeast Washington	Control	8.3		
	200 # N	9.1	0.9	10.8
	400 # N	8.9	0.7 NS	8.4
Overall	Control	6.9		
	200 # N	7.8	0.9	13.0
	400 # N	7.8	0.9	13.0

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

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

Table 4. Eight-year response in average stand diameter to nitrogen fertilization by region and treatment for the Douglas-fir installations established in 1980 and 1981.

		Change in Average Stand Diameter		
Region	Treatment	Growth (inches)	Response (inches)	percent
Northern Idaho	Control	1.5		
	200 # N	1.9	0.4 NS	26.7
	400 # N	1.8	0.3 NS	20.0
Montana	Control	0.9		
	200 # N	1.0	0.1 NS	11.1
	400 # N	1.2	0.3 NS	33.3
Central Idaho	Control	0.9		
	200 # N	1.1	0.2 NS	22.2
	400 # N	1.2	0.3	33.3
Northeast Oregon	Control	1.3		
	200 # N	1.4	0.1 NS	7.7
	400 # N	1.3	0.0 NS	0.0
Central Washington	Control	1.2		
	200 # N	1.5	0.3	25.0
	400 # N	1.6	0.4	33.3
Northeast Washington	Control	1.2		
	200 # N	1.4	0.2 NS	16.7
	400 # N	1.6	0.4	33.3
Overall	Control	1.1		
	200 # N	1.3	0.2	18.2
	400 # N	1.4	0.3	27.3

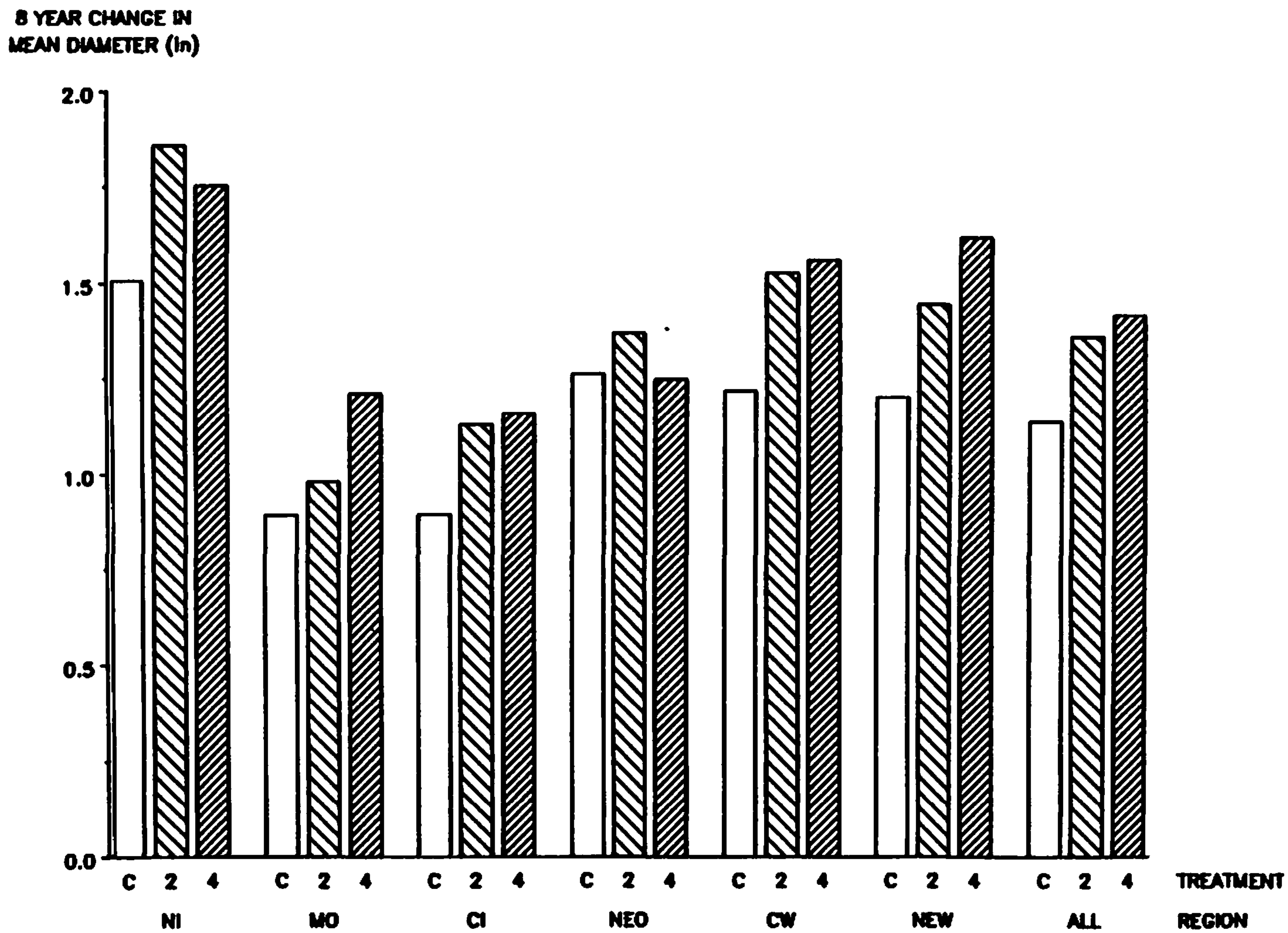

Figure 3. Eight-year Change in Average Stand Diameter by Region and Treatment for One-half of the Douglas-fir Installations.

only for central Washington. The 400 # N treatment produced a significant increase in average stand diameter for Montana, central Idaho, and northeast Washington. Neither treatment produced a significant effect on average stand diameter in northern Idaho or northeastern Oregon. These results continue to suggest that even in those regions where net per acre response is not significant, the nitrogen treatments are having significant effects within stands.

Duration of Response:

Since only diameters were remeasured for all trees after every two year growth period, duration of response is based on periodic basal area growth, rather than volume growth. Basal area increments for the first, second, third, and fourth two-year periods are compared in Table 5. The gross and net basal area increments by treatment and region are shown in Figures 4 through 10 for each geographic region and over all regions.

Gross basal area response has declined for each successive two-year period in all regions. Both nitrogen treatments continue to produce a significant gross basal area response for each of the four two year periods in northern Idaho and central Washington. Montana did not show a significant average response during any growth period. Neither treatment produced a significant average gross basal area response in central Idaho and northeast Oregon after the first four years. For northeast Washington, the 400 lb treatment response was significant for each of the four growth periods; however, average response to the

Table 5. Average net and gross basal area response to nitrogen fertilization for each two-year period by region and treatment for the Douglas-fir installations established in 1980 and 1981.

Region	Treatment	Growth $ft^2/A/Yr.$	Net Response $ft^2/A/Yr.$	Net Response percent	Growth $ft^2/A/Yr.$	Gross Response $ft^2/A/Yr.$	Gross Response percent
	Basal area increment in the first two years						
Northern Idaho	Control	5.6			5.5		
	200 # N	7.1	1.5	26.8	8.1	2.6	47.3
	400 # N	6.9	1.3	23.2	7.4	1.9	34.5
	400 # vs 200 #		-0.2 NS	-2.8		-0.7 NS	8.6
Montana	Control	4.5			4.4		
	200 # N	5.0	0.5 NS	11.1	4.9	0.5 NS	11.4
	400 # N	5.1	0.6 NS	13.3	5.0	0.6 NS	13.6
	400 # vs 200 #		0.1 NS	0.2		0.1 NS	2.0
Central Idaho	Control	4.4			4.4		
	200 # N	5.4	1.0	22.7	5.3	0.9	20.4
	400 # N	5.8	1.4	31.8	5.8	1.4	31.8
	400 # vs 200 #		0.4	7.4		0.5 NS	9.4
Northeast Oregon	Control	3.3			3.6		
	200 # N	4.3	1.0 NS	30.3	4.7	1.1	30.6
	400 # N	4.4	1.1	33.3	4.7	1.1	30.6
	400 # vs 200 #		0.1 NS	2.3		0.0 NS	0.0
Central Washington	Control	4.1			4.1		
	200 # N	5.3	1.2	29.3	5.1	1.0	24.4
	400 # N	5.5	1.4	34.2	5.7	1.6	39.0
	400 # vs 200 #		0.2 NS	3.8		0.6	11.8
Northeast Washington	Control	5.0			5.0		
	200 # N	5.7	0.7 NS	14.0	6.0	1.0	20.0
	400 # N	6.9	1.9	38.0	6.9	1.9	38.0
	400 # vs 200 #		1.2	21.1		0.9	15.0
Overall	Control	4.4			4.5		
	200 # N	5.4	1.0	22.7	5.6	1.1	24.4
	400 # N	5.8	1.4	31.8	5.9	1.4	31.1
	400 # vs 200 #		0.4 NS	7.4		0.3 NS	5.4

Table 5. (cont.)

Basal area increment in the second two years

Region	Treatment	Growth ft^2/A/Yr.	Net Response ft^2/A/Yr.	Net Response percent	Growth ft^2/A/Yr.	Gross Response ft^2/A/Yr.	Gross Response percent
Northern Idaho	Control	3.6			5.1		
	200 # N	7.1	3.5	97.2	7.1	2.0	39.2
	400 # N	7.2	3.6	100.0	6.6	1.5	29.4
	400 # vs 200 #		0.1 NS	1.4		-0.5 NS	-7.0
Montana	Control	3.3			3.2		
	200 # N	3.2	-0.1 NS	-3.0	3.4	0.2 NS	6.3
	400 # N	2.2	-1.1 NS	-51.5	3.2	0.0 NS	0.0
	400 # vs 200 #		-1.0 NS	-31.2		-0.2 NS	-5.9
Central Idaho	Control	4.1			4.6		
	200 # N	4.6	0.4 NS	9.8	4.8	0.2 NS	4.3
	400 # N	3.5	-0.6 NS	14.6	5.1	0.5	10.9
	400 # vs 200 #		-1.0 NS	-21.7		0.3 NS	6.5
Northeast Oregon	Control	3.7			3.9		
	200 # N	3.5	-0.2 NS	-5.4	4.6	0.7	17.9
	400 # N	3.1	-0.6 NS	-16.2	4.3	0.4 NS	10.3
	400 # vs 200 #		-0.4 NS	-11.4		-0.3 NS	-6.5
Central Washington	Control	4.5			4.7		
	200 # N	5.6	1.1 NS	24.4	5.5	0.8	17.0
	400 # N	5.2	0.7 NS	15.6	6.3	1.6	34.0
	400 # vs 200 #		-0.4 NS	-7.1		0.8	14.5
Northeast Washington	Control	4.4			5.2		
	200 # N	4.0	-0.4 NS	-9.1	5.7	0.5 NS	9.6
	400 # N	2.8	-1.6 NS	-36.4	6.3	1.1	21.2
	400 # vs 200 #		-1.2 NS	-30.0		0.6	10.5
Overall	Control	4.0			4.5		
	200 # N	4.5	0.5 NS	12.5	5.1	0.6	13.3
	400 # N	3.8	-0.2 NS	-5.0	5.4	0.9	20.0
	400 # vs 200 #		-0.7 NS	-15.6		0.3 NS	5.4

Table 5. (cont.)

Basal area increment in the third two years

Region	Treatment	Growth ft^2/A/Yr.	Net Response ft^2/A/Yr.	Net Response percent	Growth ft^2/A/Yr.	Gross Response ft^2/A/Yr.	Gross Response percent
Northern Idaho	Control	5.0			5.4		
	200 # N	6.4	1.4 NS	28.0	6.5	1.1	20.4
	400 # N	5.7	0.7 NS	14.0	6.0	0.6	11.1
	400 # vs 200 #		-0.7 NS	-10.9		-0.5 NS	-7.7
Montana	Control	3.6			3.5		
	200 # N	4.2	0.6 NS	16.7	3.6	0.1 NS	2.9
	400 # N	3.0	-0.6 NS	-16.7	3.6	0.1 NS	2.9
	400 # vs 200 #		-1.2 NS	-28.6		0.0 NS	0.0
Central Idaho	Control	2.9			3.5		
	200 # N	4.2	1.3 NS	44.8	3.8	0.3 NS	8.6
	400 # N	3.2	0.3 NS	10.3	3.9	0.4 NS	11.4
	400 # vs 200 #		-1.0 NS	-23.8		0.1 NS	2.6
Northeast Oregon	Control	3.0			3.0		
	200 # N	4.7	1.8 NS	60.0	3.5	0.5 NS	16.7
	400 # N	2.0	-0.9 NS	-30.0	3.2	0.2 NS	6.7
	400 # vs 200 #		-2.7	-57.4		-0.3 NS	-8.6
Central Washington	Control	2.6			3.6		
	200 # N	3.1	0.4 NS	15.4	3.8	0.2 NS	5.6
	400 # N	4.1	1.4	53.8	4.5	0.9	25.0
	400 # vs 200 #		1.0 NS	32.3		0.7	18.4
Northeast Washington	Control	2.5			4.1		
	200 # N	4.1	1.6	64.0	4.5	0.4 NS	9.8
	400 # N	4.9	2.3	92.0	5.1	1.0	24.4
	400 # vs 200 #		0.8	19.5		0.6	13.5
Overall	Control	3.1			3.8		
	200 # N	4.2	1.1	35.5	4.2	0.4	10.5
	400 # N	3.8	0.7 NS	22.6	4.4	0.6	15.8
	400 # vs 200 #		-0.4 NS	-9.5		0.2 NS	4.8

Table 5. (cont.)

Region	Treatment	Growth $ft^2/A/Yr.$	Net Response $ft^2/A/Yr.$	Net Response percent	Growth $ft^2/A/Yr.$	Gross Response $ft^2/A/Yr.$	Gross Response percent
Basal area increment in the fourth two years							
Northern Idaho	Control	3.3			4.8		
	200 # N	2.7	-0.6 NS	18.2	5.6	0.8	16.7
	400 # N	6.0	2.7	81.8	5.4	0.6	12.5
	400 # vs 200 #		3.3	122.2		-0.2 NS	-3.6
Montana	Control	2.3			2.9		
	200 # N	2.2	-0.1 NS	-0.4	3.0	0.1 NS	3.4
	400 # N	1.1	-1.2 NS	-52.2	3.0	0.1 NS	3.4
	400 # vs 200 #		-1.1 NS	-50.0		0.0 NS	0.0
Central Idaho	Control	2.9			3.3		
	200 # N	1.1	-1.8 NS	-62.1	3.3	0.0 NS	0.0
	400 # N	2.5	-0.4 NS	-13.8	3.5	0.2 NS	6.1
	400 # vs 200 #		1.4 NS	127.3		0.2 NS	6.1
Northeast Oregon	Control	0.6			2.4		
	200 # N	-2.1	-2.7	-450.0	2.6	0.2 NS	8.3
	400 # N	2.2	1.6 NS	266.7	2.6	0.2 NS	8.3
	400 # vs 200 #		4.4	209.5		0.0 NS	0.0
Central Washington	Control	3.1			3.3		
	200 # N	2.7	-0.4 NS	-12.9	3.7	0.4	12.1
	400 # N	3.5	0.4 NS	12.9	3.8	0.5	15.2
	400 # vs 200 #		0.8 NS	29.6		0.1 NS	2.7
Northeast Washington	Control	2.3			3.2		
	200 # N	1.0	-1.3 NS	56.5	3.3	0.1 NS	3.1
	400 # N	2.1	-0.2 NS	-8.7	3.8	0.6	18.8
	400 # vs 200 #		1.1 NS	110.0		0.5	15.2
Overall	Control	2.4			3.2		
	200 # N	1.3	-1.1 NS	-45.8	3.4	0.2 NS	6.3
	400 # N	2.7	0.3 NS	12.5	3.6	0.4	12.6
	400 # vs 200 #		1.4	107.7		0.2 NS	5.9

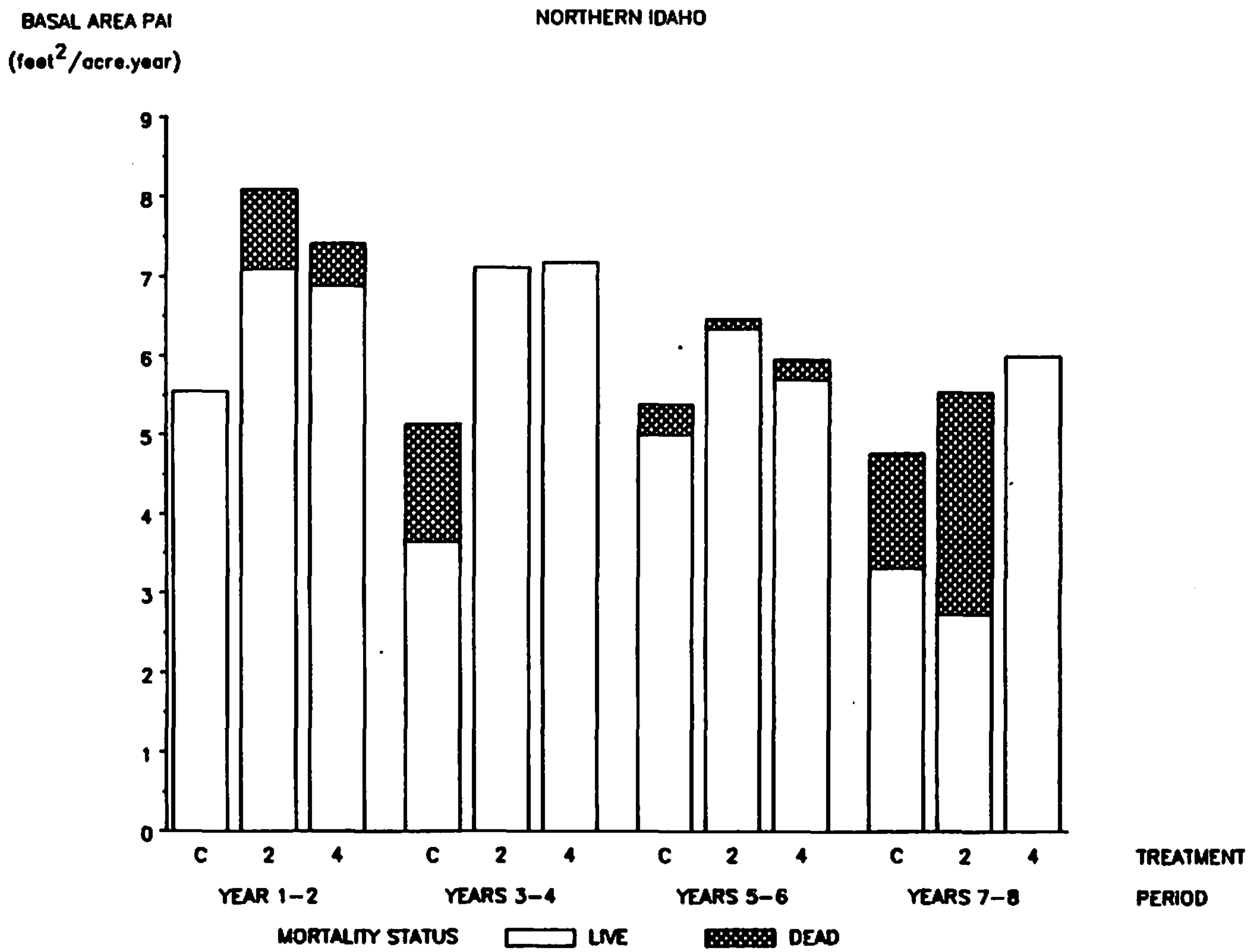

Figure 4. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Northern Idaho Douglas-fir Installations.

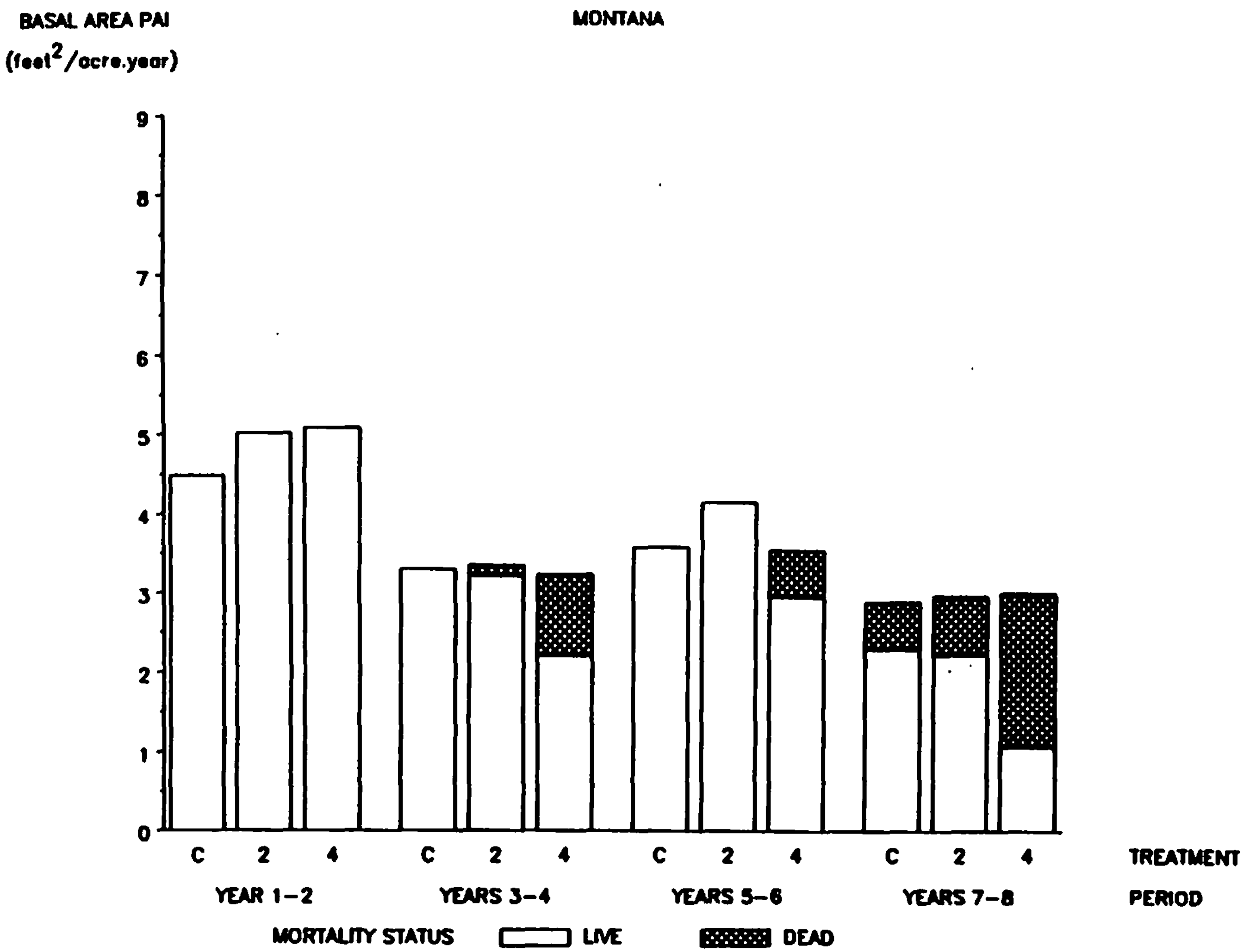

Figure 5. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Montana Douglas-fir Installations.

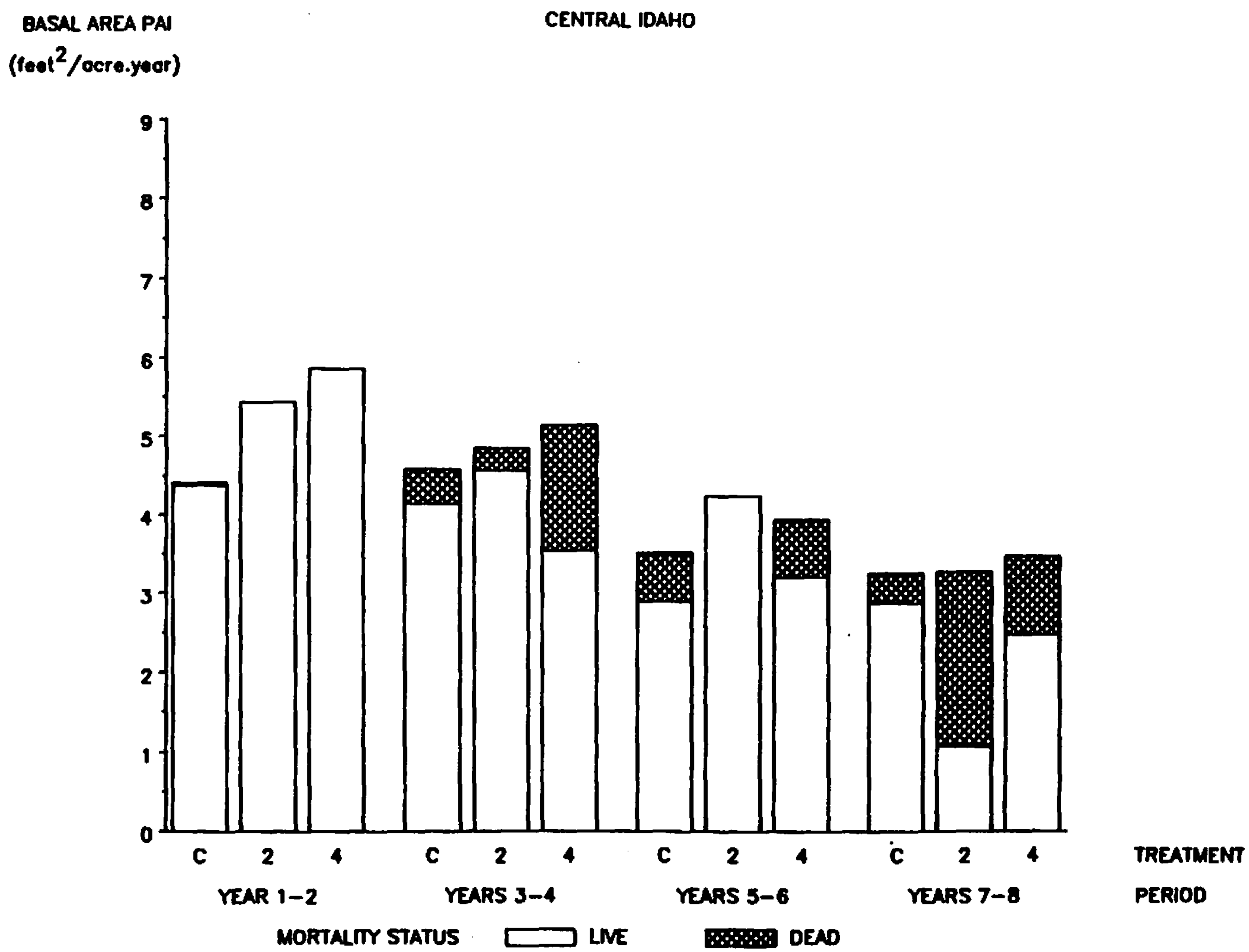

Figure 6. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Central Idaho Douglas-fir Installations.

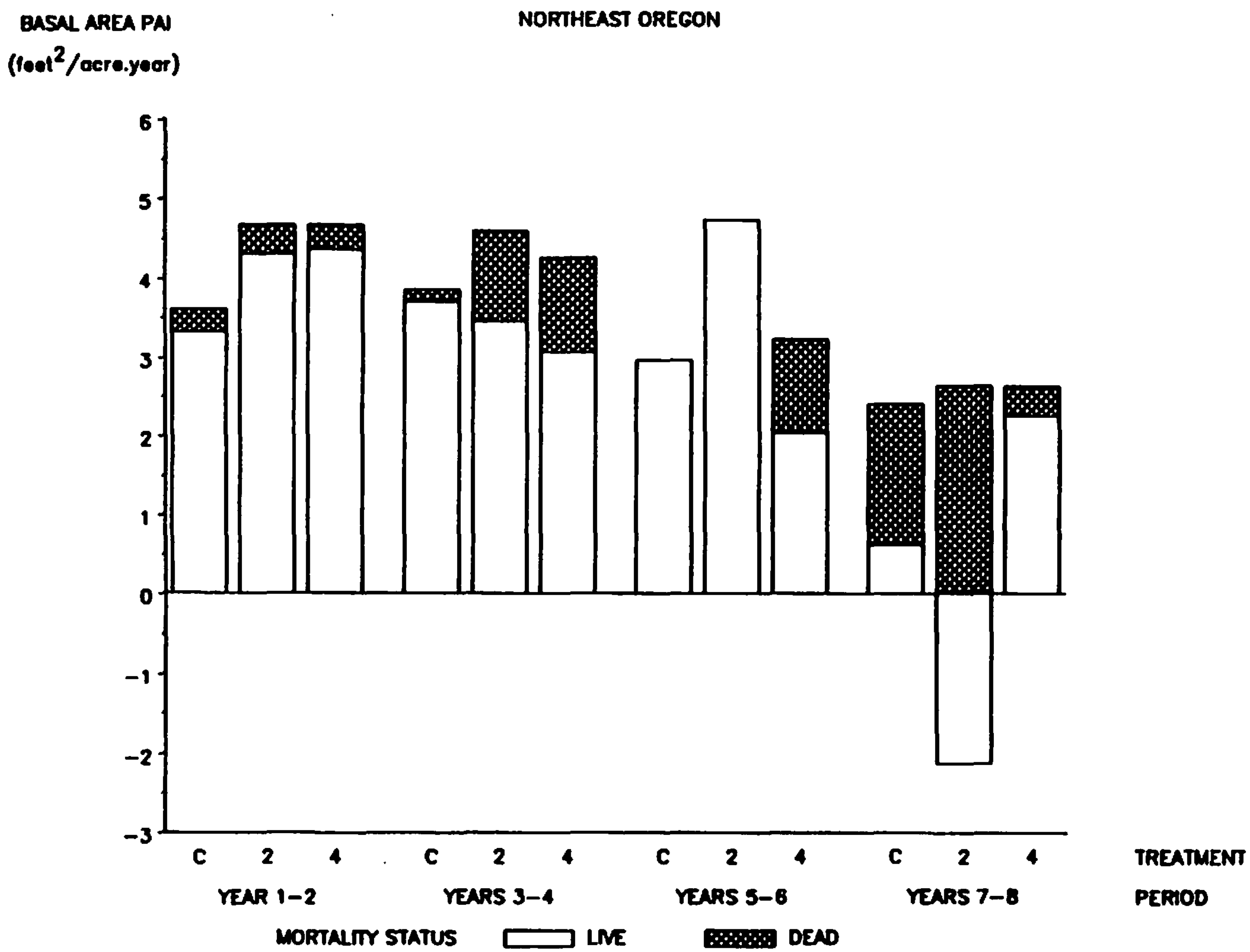

Figure 7. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Northeastern Oregon Douglas-fir Installations.

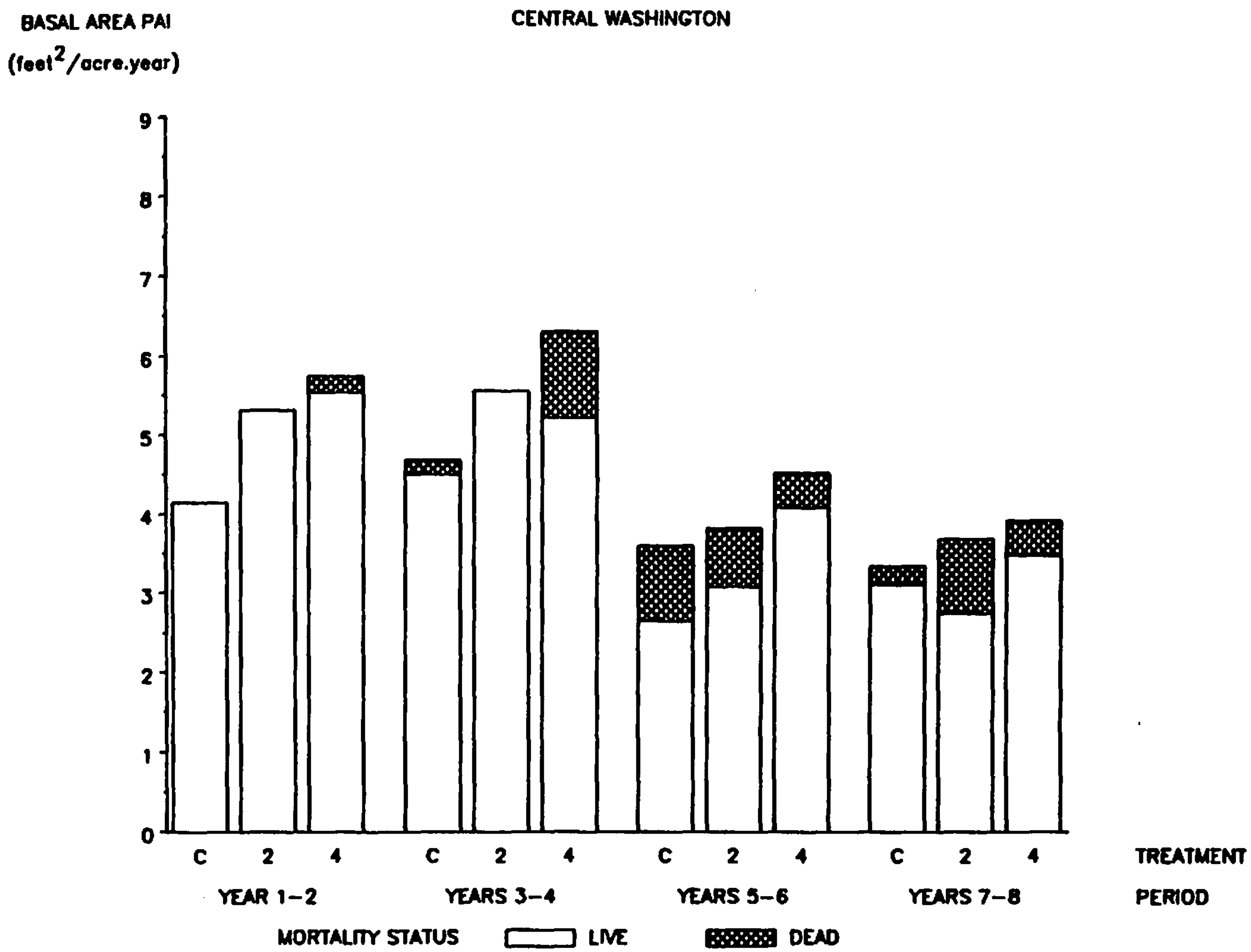

Figure 8. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Central Washington Douglas-fir Installations.

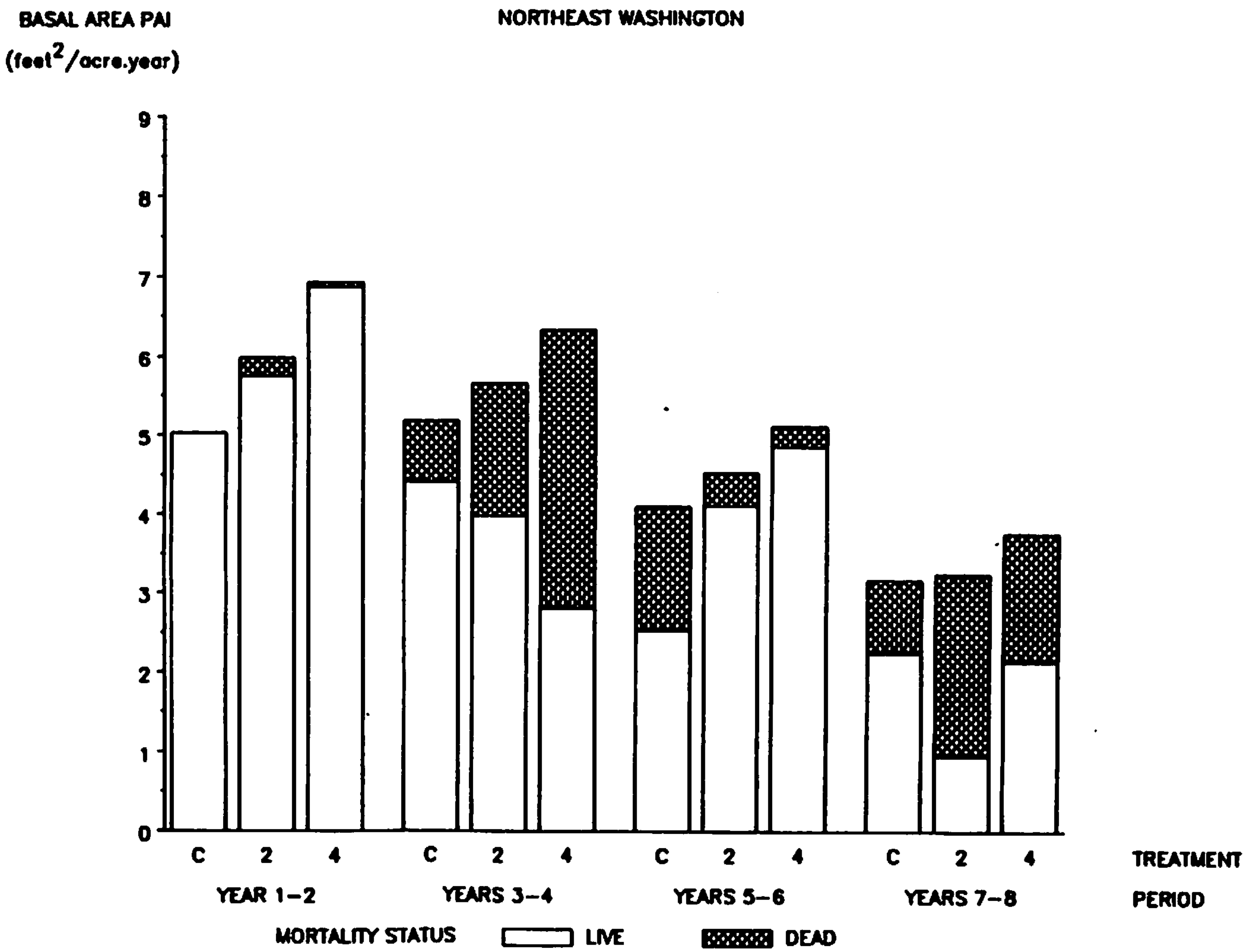

Figure 9. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for the Northeastern Washington Douglas-fir Installations.

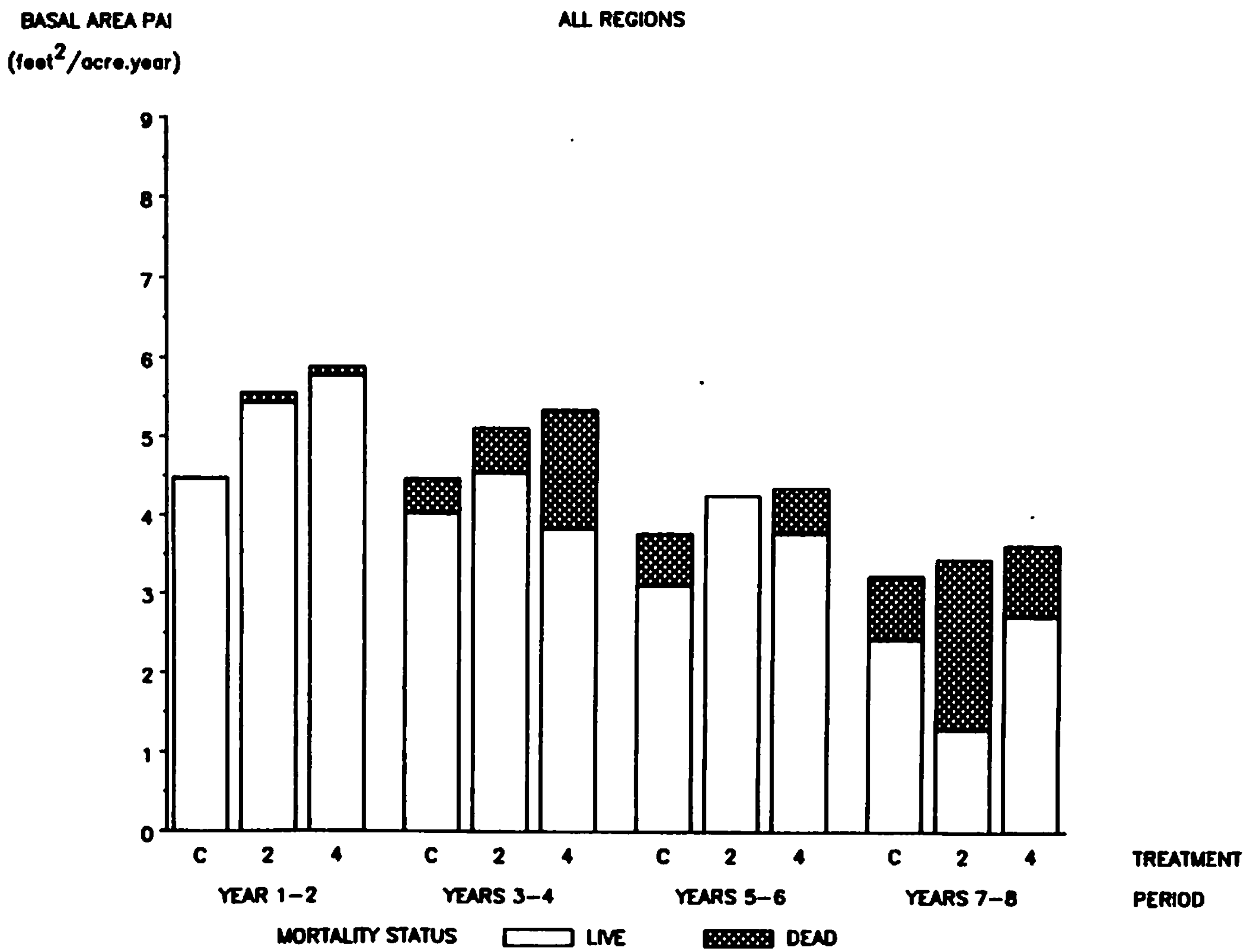

Figure 10. Periodic Basal Area Increment by Treatment Partitioned into Live (Net) and Dead Components for One-half of the Douglas-fir Installations Across All Regions.

200 lb treatment alternated between statistical significance by growth period. Over all regions, the average gross basal area response to the 400 lb nitrogen treatment was still significant during years 7 and 8, while the response to the 200 lb treatment was not longer significant. This is the first evidence we have that response duration may be longer with the 400 lb treatment.

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 7 and 8 was the 400 lb nitrogen treatment in northern Idaho. Most regions show negative net basal area responses to both nitrogen treatments during the last two year growth period. Perhaps this result is to be expected given what seems to be happening with treatment related mortality. Mortality associated with accelerated stand dynamics is perhaps beginning in a substantial way and when combined with previously discussed "nutrient-related" mortality explains 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 7 and 8 for all geographic regions. For all regions, there have been successive declines in control plots growth for each two-year period. This reduced growth rate of the control plots is likely associated with a decline in precipitation over the period, and may explain some of the reduced response to the nitrogen treatments over time.

Variation in Eight-year Volume Growth Response to Nitrogen Fertilization for One-half of the Douglas-fir Installations:

As time since treatment increases, the variation in response to nitrogen fertilization also increases (Figures 11 and 12). Installations that produced high response in the past generally continue to do so, similarly, previously non-responding installations produce no or even negative response. After eight years the differences between the two nitrogen treatments seems to be increasing. Duration of response may be longer with the 400 lb nitrogen treatment. This is illustrated in Figures 11 and 12 by the shift to the right for the cumulative distribution curve for the 400 lb treatment. Fortunately, as we have discussed in previous reports and meetings, this response variation is not all random. We continue to increase our understanding, thereby hopefully reducing the number of non-responding stands in the population.

Eight-year growth response of the 1980 test sites:

Boise Cascade Corporation supported the installation of four test sites on their lands beginning in the fall of 1980. There is one installation each in the central Idaho, northeast Oregon, central Washington, and northeast Washington regions. Each installation consists of eight one-tenth acre plots. Treatments were applied in the fall of 1980 or the spring of 1981. These test sites contained several additional treatments not tested in other IFTNC installations. The treatments consisted of two control plots and one plot for each of the following: 1) 200

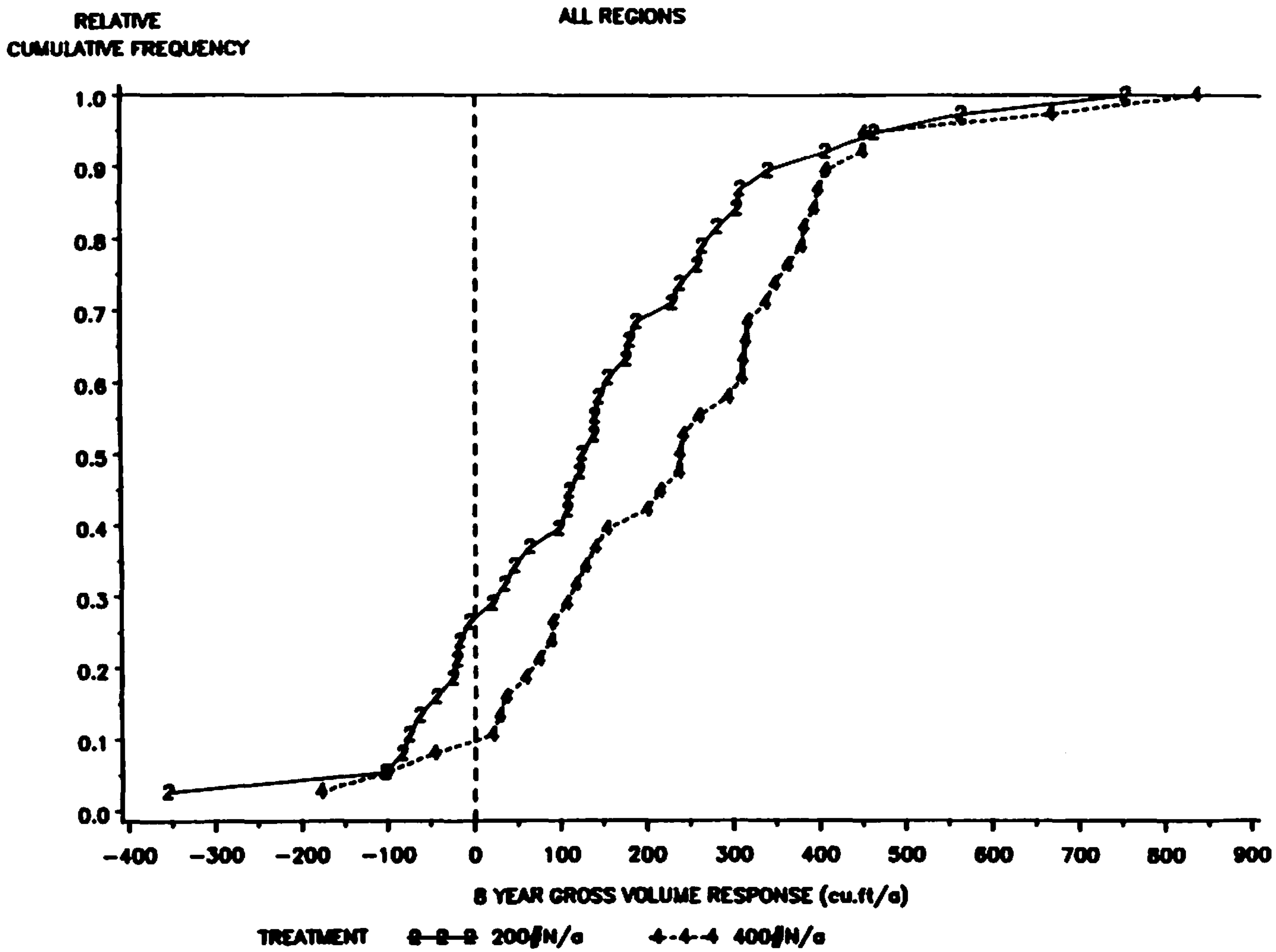

Figure 11. The Cumulative Distribution of Gross Eight-year Volume Growth Response to the Nitrogen Treatments for One-half of the Douglas-fir Installations.

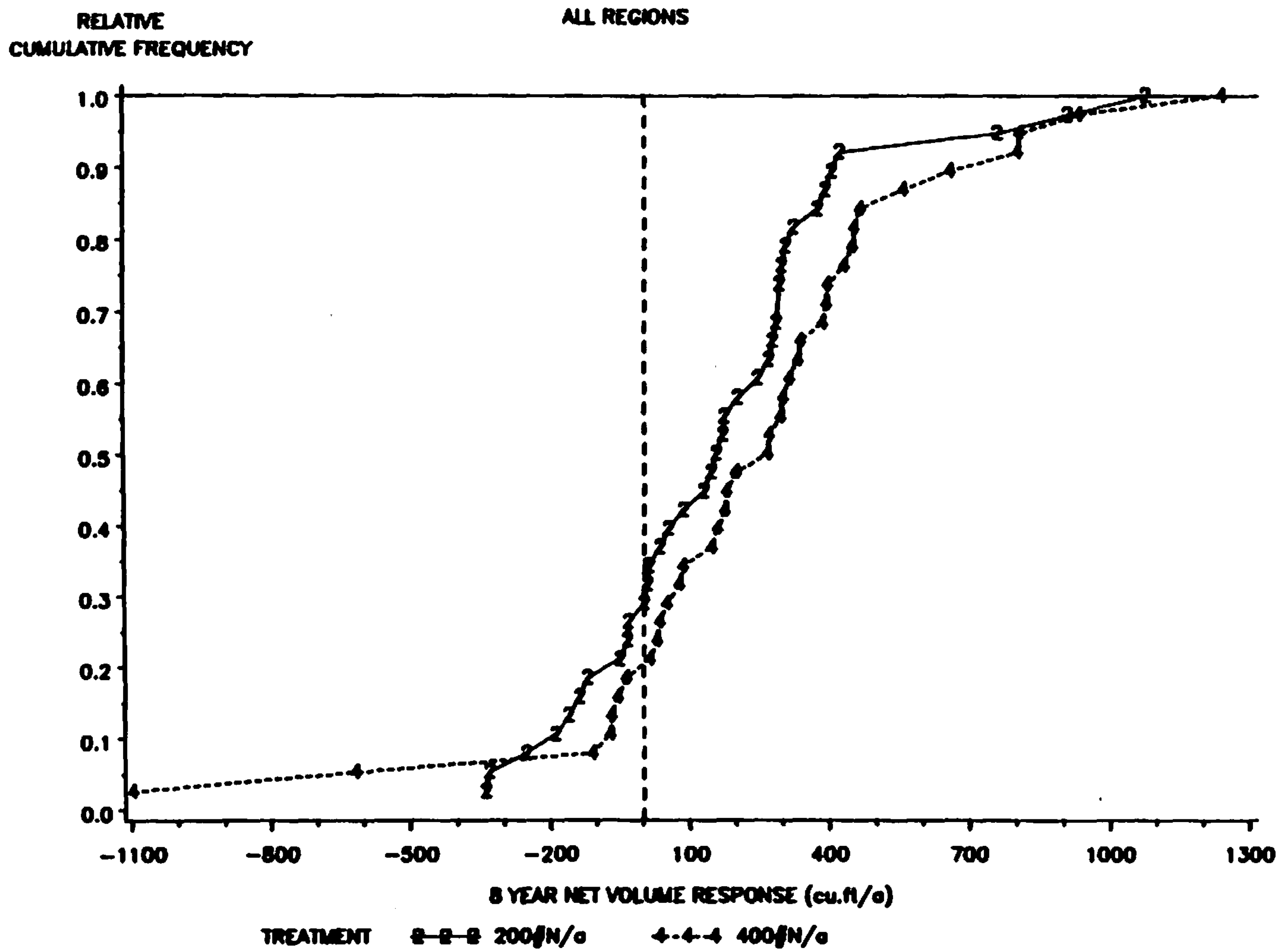

Figure 12. The Cumulative Distribution of Net Eight-year Volume Growth Response to the Nitrogen Treatments for One-half of the Douglas-fir Experiment.

lbs./A of nitrogen applied in the fall; 2) 400 lbs./A of nitrogen applied in the fall; 3) 200 lbs./A of nitrogen and 50 lbs./A of sulphur applied in the fall; 4) 200 lbs./A of nitrogen applied in the spring; 5) 400 lbs./A of nitrogen applied in the spring; and 6) 400 lbs./A of nitrogen and 50 lbs./A of sulphur applied in the fall. Urea and sulphur-coated urea were the sources for nitrogen and sulphur. The analysis reported here is based on total cubic foot volume growth for eight years after treatment.

The eight-year gross cubic foot volume increment for all the treatments, except 200 lbs of nitrogen applied in the spring, were significantly different from the controls (Table 6). There was no difference between the 400 lb and 200 lb nitrogen treatments as well as no significant season of application or sulphur effect. The same results are true for net volume response. Only three of the treatments produced a significant net volume response: 200 lb nitrogen plus 50 lb sulphur applied in either spring or fall, and 400 lb nitrogen applied in the spring.

The results of this limited experiment suggest that there is no difference in growth response from fall or spring fertilizer applications as conducted in this study. That is, the spring treatments were applied in early April and substantial precipitation probably occurred after the treatments were applied. If the material were applied later in the spring, nitrogen losses due to volatilization and nitrification may have occurred.

Table 6. Eight year average cubic foot volume per acre response to nitrogen and nitrogen plus sulphur treatments applied in spring and fall.

Treatment	Increment (Ft.^{3}/A)	Net Response (Ft.^{3}/A)	Percent	Inc. (Ft.^{3}/A)	Gross Response (Ft.^{3}/A)	Percent
Control	1097	-	-	1192	-	-
200 lb N/A-Fall	1176	79 NS	7.2	1487	295	24.7
400 lb N + Fall	1266	169 NS	15.4	1402	210	17.6
200 lb N + 50 lb S/A-Fall	1303	206	18.8	1380	188	15.8
200 lb N/A-Spr.	1220	124 NS	11.3	1293	102 NS	8.6
400 lb N/A-Spr.	1385	288	26.3	1435	244	20.5
200 lb N + 50 lb S/A-Spr.	1318	222	20.2	1356	165	13.8
400 lb vs. 200 lb		127 NS	10.8		28 NS	2.0
Spr. vs. Fall		60 NS	4.8		-61 NS	-4.3
Sulphur effect		112 NS	9.3		-22 NS	-1.6

Two-year Basal Area and Volume Growth Response to Retreatment with Nitrogen or Nitrogen Plus Potassium for One-half of the Douglas-fir Installations:

Two-year average basal area increment and response to the nitrogen and nitrogen plus potassium retreatments are provided for each geographic region in Tables 7a through 7g and for volume increment and response in Tables 8a through 8g. The results for all regions are illustrated in Figures 13 and 14. The cumulative effects of both the old and new treatments were significant for both gross basal area and volume increment for all regions combined. However, for net basal area and volume increment, none of these overall cumulative effects were significant. These results, with few exceptions, were also true for each of the individual geographic regions.

Retreatments with Nitrogen Alone

The two-year effects of the new nitrogen retreatments on both original nitrogen dosages (i.e., 200 lb and 400 lb nitrogen) were significant for gross basal area and volume increments for all regions combined. However, there was no significant net response to the nitrogen retreatments. Interestingly, the net average effect of an additional 200 pounds of nitrogen on plots previously treated with 400 pounds was negative. The average net effect of the nitrogen retreatment on plots previously treated with 200 pounds of nitrogen was positive. As discussed in previous IFTNC Annual Reports and at our meetings, the original 400 lb nitrogen treatment sometimes produced a negative response. Perhaps it is not surprising that an additional 200 pounds of

Table 7a. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northern Idaho.

-Treatments-		Growth	Response: Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
Net Basal Area Increment								
0 # N	None	6.9						
200 # N	None	8.7	1.8 NS	69.6				
400 # N	None	14.0	7.0	101.4				
200 # N	200 # N	12.6	5.6 NS	81.2	3.9 NS	64.4		
400 # N	200 # N	12.5	5.6 NS	81.2	-1.5 NS	-10.7		
0 # N	N + K	12.1	5.2 NS	75.4				
200 # N	N + K	11.6	4.6 NS	66.7			-1.0 NS	-8.6
400 # N	N + K	8.8	1.9 NS	27.5			-3.6 NS	-28.8
Gross Basal Area Increment								
0 # N	None	9.2						
200 # N	None	10.4	1.2	13.0				
400 # N	None	10.4	1.3	14.1				
200 # N	200 # N	11.9	2.7	29.3	1.5	14.4		
400 # N	200 # N	13.0	3.9	42.4	2.6	25.0		
0 # N	N + K	11.6	2.4	26.1				
200 # N	N + K	1136	2.2	23.9			-1.0 NS	-4.2
400 # N	N + K	10.7	1.6	17.4			-3.6	-17.7

Table 7b. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in Montana.

-Treatments-			---Response---					
		Growth	Cumulative ----Effect----		Effect of new ----Nitrogen----		Effect of new ----Potassium----	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
Net Basal Area Increment								
0 # N	None	4.8						
200 # N	None	5.5	0.7 NS	14.6				
400 # N	None	2.9	-2.0 NS	-41.7				
200 # N	200 # N	6.7	1.8 NS	37.5	1.2 NS	21.8		
400 # N	200 # N	5.5	0.6 NS	12.5	2.6 NS	89.7		
0 # N	N + K	5.9	1.1 NS	22.9				
200 # N	N + K	1.9	-2.9 NS	-60.4			-4.8 NS	-71.6
400 # N	N + K	5.1	0.2 NS	4.2			-0.4 NS	-7.3
Gross Basal Area Increment								
0 # N	None	5.8						
200 # N	None	5.9	0.1 NS	1.7				
400 # N	None	5.8	0.1 NS	1.7				
200 # N	200 # N	6.4	0.6 NS	10.3	0.5 NS	8.6		
400 # N	200 # N	6.4	0.7 NS	12.1	0.6 NS	10.3		
0 # N	N + K	6.8	1.0	17.2				
200 # N	N + K	6.5	0.7 NS	12.1			0.1 NS	1.6
400 # N	N + K	6.8	1.0 NS	17.2			0.4 NS	6.3

Table 7c. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in central Idaho.

-Treatments-		Growth	Response: Cumulative Effect		Response: Effect of new Nitrogen		Response: Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area Increment					
0 # N	None	5.3						
200 # N	None	3.3	-2.0 NS	-37.8				
400 # N	None	5.4	0.1 NS	1.9				
200 # N	200 # N	6.3	1.1 NS	20.8	3.1 NS	93.9		
400 # N	200 # N	-2.5	-7.8	-147.5	-7.9	-143.6		
0 # N	N + K	3.7	-1.6 NS	-30.2				
200 # N	N + K	6.3	1.0 NS	18.9			0.0 NS	0.0
400 # N	N + K	5.1	-0.2 NS	-3.8			7.6	304.0
			Gross Basal Area Increment					
0 # N	None	6.4						
200 # N	None	6.4	0.0 NS	0.0				
400 # N	None	7.0	0.5 NS	7.8				
200 # N	200 # N	7.4	0.9 NS	14.1	11.0 NS	171.9		
400 # N	200 # N	6.3	-0.1 NS	-1.2	-0.6 NS	-8.6		
0 # N	N + K	7.0	0.6	9.4				
200 # N	N + K	7.5	1.1 NS	17.2			0.2 NS	2.7
400 # N	N + K	7.1	0.7 NS	10.9			0.8 NS	12.7

Table 7d. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northeastern Oregon.

-Treatments-		Growth	Response: Cumulative Effect		Response: Effect of new Nitrogen		Response: Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
Net Basal Area Increment								
0 # N	None	1.5						
200 # N	None	-3.8	-5.3 NS	-353.3				
400 # N	None	9.1	7.6	506.7				
200 # N	200 # N	1.4	-0.1 NS	-6.7	5.2 NS	136.8		
400 # N	200 # N	-3.3	-4.8 NS	-320.0	12.4	136.3		
0 # N	N + K	-2.0	-3.5 NS	-233.3				
200 # N	N + K	0.9	-0.6 NS	-40.0			-0.5 NS	35.7
400 # N	N + K	2.9	1.4 NS	93.3			6.2 NS	187.9
Gross Basal Area Increment								
0 # N	None	4.5						
200 # N	None	4.7	0.2 NS	4.4				
400 # N	None	5.4	0.9 NS	20.0				
200 # N	200 # N	4.5	0.0 NS	0.0	-0.2 NS	-4.3		
400 # N	200 # N	4.4	-0.1 NS	-2.2	-1.0 NS	-18.5		
0 # N	N + K	4.7	0.2 NS	4.4				
200 # N	N + K	5.0	0.5 NS	11.1			0.5 NS	11.1
400 # N	N + K	5.9	1.4	31.1			1.5 NS	34.1

Table 7e. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in central Washington.

-Treatments-		Growth	Response					
			Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area Increment					
0 # N	None	5.7						
200 # N	None	6.0	0.3 NS	5.3				
400 # N	None	7.1	1.4 NS	24.5				
200 # N	200 # N	4.2	-1.5 NS	-26.3	-1.8 NS	38.6		
400 # N	200 # N	5.8	0.2 NS	3.5	-12.4	174.6		
0 # N	N + K	1.3	-4.4	-77.2				
200 # N	N + K	6.5	0.8 NS	14.0			2.3 NS	54.8
400 # N	N + K	8.9	3.2 NS	56.1			3.0 NS	51.7
			Gross Basal Area Increment					
0 # N	None	6.6						
200 # N	None	6.7	0.1 NS	1.5				
400 # N	None	7.1	0.5 NS	7.6				
200 # N	200 # N	7.7	1.2	18.2	1.0	14.9		
400 # N	200 # N	8.2	1.6	24.2	-1.0 NS	-14.1		
0 # N	N + K	7.4	0.8	12.1				
200 # N	N + K	7.1	0.6 NS	9.1			-0.6 NS	-7.8
400 # N	N + K	7.7	1.2	18.2			-0.4 NS	-4.9

Table 7f. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northeastern Washington.

-Treatments-		Growth	Response: Cumulative Effect		Response: Effect of new Nitrogen		Response: Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
Net Basal Area Increment								
0 # N	None	4.2						
200 # N	None	4.1	-0.1 NS	-2.4				
400 # N	None	3.1	-1.1 NS	-26.2				
200 # N	200 # N	5.6	1.4 NS	33.3	1.5 NS	36.6		
400 # N	200 # N	6.7	2.5 NS	59.5	3.6 NS	116.1		
0 # N	N + K	6.1	1.9 NS	45.2				
200 # N	N + K	6.4	2.2 NS	52.4			0.8 NS	14.3
400 # N	N + K	3.0	-1.2 NS	-28.6			-3.7 NS	-55.2
Gross Basal Area Increment								
0 # N	None	6.0						
200 # N	None	6.1	0.1 NS	1.7				
400 # N	None	6.9	0.9	15.0				
200 # N	200 # N	7.3	1.3	21.7	1.2	19.7		
400 # N	200 # N	7.6	1.6	26.7	0.7 NS	10.1		
0 # N	N + K	7.7	1.7	28.3				
200 # N	N + K	8.2	2.2	36.7			0.9 NS	12.3
400 # N	N + K	6.6	0.6 NS	10.0			-1.0	-13.2

Table 7g. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in all regions.

-Treatments-		Growth	Response: Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area Increment					
0 # N	None	4.7						
200 # N	None	4.0	-0.7 NS	-14.9				
400 # N	None	6.3	1.5 NS	31.9				
200 # N	200 # N	5.9	1.1 NS	23.4	1.8 NS	45.0		
400 # N	200 # N	4.0	-0.8 NS	-17.0	-2.3 NS	-36.5		
0 # N	N + K	4.3	-0.5 NS	-10.6				
200 # N	N + K	5.4	0.7 NS	14.9			-0.4 NS	-6.8
400 # N	N + K	5.6	0.8 NS	17.0			1.6 NS	40.0
			Gross Basal Area Increment					
0 # N	None	6.3						
200 # N	None	6.5	0.2 NS	3.2				
400 # N	None	7.0	0.6	9.5				
200 # N	200 # N	7.4	1.1	17.5	0.9	13.8		
400 # N	200 # N	7.5	1.1	17.5	0.5 NS	7.1		
0 # N	N + K	7.4	1.1	17.5				
200 # N	N + K	7.5	1.2	19.0			0.1 NS	1.4
400 # N	N + K	7.3	1.0	15.9			-0.1 NS	-1.3

Table 8a. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northern Idaho.

-Treatments-		Growth	Response					
			Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft³/A	ft³/A	Percent	ft³/A	Percent	ft³/A	Percent
			Net Volume Increment					
0 # N	None	310						
200 # N	None	376	66 NS	21.3				
400 # N	None	545	235	75.8				
200 # N	200 # N	525	215	69.4	149 NS	39.6		
400 # N	200 # N	582	272	87.7	37 NS	6.8		
0 # N	N + K	494	185	59.7				
200 # N	N + K	517	207	66.8			-8 NS	-1.5
400 # N	N + K	377	67 NS	21.6			-205 NS	-35.2
			Gross Volume Increment					
0 # N	None	389						
200 # N	None	412	23 NS	5.9				
400 # N	None	440	51	13.1				
200 # N	200 # N	490	101	26.0	78	18.9		
400 # N	200 # N	588	198	50.9	147	33.4		
0 # N	N + K	479	90	23.1				
200 # N	N + K	516	127	32.6			26 NS	5.3
400 # N	N + K	437	48 NS	12.3			-150	-25.5

Table 8b. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in Montana.

-Treatments-		Growth	Response: Cumulative Effect		Response: Effect of new Nitrogen		Response: Effect of new Potassium	
Old	New	ft^3/A	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
Net Volume Increment								
0 # N	None	212						
200 # N	None	227	15 NS	7.1				
400 # N	None	159	-53 NS	-25.0				
200 # N	200 # N	258	47 NS	22.2	31 NS	13.7		
400 # N	200 # N	236	24 NS	11.3	77 NS	48.4		
0 # N	N + K	242	30 NS	14.2				
200 # N	N + K	133	-79 NS	-37.3			-126 NS	48.8
400 # N	N + K	218	7 NS	3.3			-17 NS	-7.2
Gross Volume Increment								
0 # N	None	229						
200 # N	None	235	6 NS	2.6				
400 # N	None	222	-7 NS	-3.1				
200 # N	200 # N	255	26 NS	11.4	20 NS	8.5		
400 # N	200 # N	259	30 NS	13.1	38 NS	17.1		
0 # N	N + K	267	38	16.6				
200 # N	N + K	247	18 NS	7.9			-8 NS	-3.1
400 # N	N + K	266	37 NS	16.2			7	2.7

Table 8c. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in central Idaho.

-Treatments-			Response					
			Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	Growth ft^3/A	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
Net Volume Increment								
0 # N	None	196						
200 # N	None	138	-57 NS	-29.1				
400 # N	None	194	-2 NS	-1.0				
200 # N	200 # N	240	44 NS	22.4	102 NS	73.9		
400 # N	200 # N	4	-192	-98.0	-190	97.0		
0 # N	N + K	156	-40 NS	-20.4				
200 # N	N + K	233	37 NS	18.9			-7 NS	-2.9
400 # N	N + K	221	25 NS	12.8			217	5425.0
Gross Volume Increment								
0 # N	None	223						
200 # N	None	223	-1 NS	-0.4				
400 # N	None	240	16 NS	7.2				
200 # N	200 # N	266	42	18.8	43	19.3		
400 # N	200 # N	216	-8 NS	-3.6	-24 NS	-10.0		
0 # N	N + K	246	23 NS	10.3				
200 # N	N + K	266	43	19.3			0 NS	0.0
400 # N	N + K	261	38	17.0			46	21.3

Table 8d. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northeastern Oregon.

-Treatments- Old	New	Growth ft^3/A	Response: Cumulative Effect ft^3/A	Cumulative Effect Percent	Effect of new Nitrogen ft^3/A	Effect of new Nitrogen Percent	Effect of new Potassium ft^3/A	Effect of new Potassium Percent
Net Volume Increment								
0 # N	None	157						
200 # N	None	-8	-165 NS	-105.1				
400 # N	None	370	214	136.3				
200 # N	200 # N	85	-72 NS	-45.9	93 NS	1162.5		
400 # N	200 # N	44	-112 NS	-72.0	-326	-88.1		
0 # N	N + K	11	-145 NS	-92.4				
200 # N	N + K	162	6 NS	3.8			77 NS	90.6
400 # N	N + K	209	52 NS	33.1			165 NS	375.0
Gross Volume Increment								
0 # N	None	209						
200 # N	None	201	-8 NS	-3.8				
400 # N	None	245	35 NS	16.7				
200 # N	200 # N	190	-19 NS	-9.1	-11 NS	-5.5		
400 # N	200 # N	220	11 NS	5.3	-24 NS	-9.8		
0 # N	N + K	223	14 NS	6.7				
200 # N	N + K	235	26 NS	12.4			45 NS	23.7
400 # N	N + K	262	52	24.9			41 NS	18.6

Table 8e. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in central Washington.

-Treatments-		Growth	----Response----					
			Cumulative ----Effect----		Effect of new ----Nitrogen----		Effect of new ----Potassium----	
Old	New	ft^3/A	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume Increment					
0 # N	None	247						
200 # N	None	254	7 NS	2.8				
400 # N	None	288	40 NS	16.2				
200 # N	200 # N	218	-29 NS	-11.7	-36 NS	-14.2		
400 # N	200 # N	257	10 NS	4.0	-326	-113.2		
0 # N	N + K	124	-124	-50.2				
200 # N	N + K	281	34 NS	13.8			63 NS	28.9
400 # N	N + K	332	84 NS	34.0			74 NS	28.8
			Gross Volume Increment					
0 # N	None	268						
200 # N	None	275	7 NS	2.6				
400 # N	None	282	13 NS	4.8				
200 # N	200 # N	306	38	14.2	31 NS	11.3		
400 # N	200 # N	326	57	21.3	-24 NS	-8.5		
0 # N	N + K	307	39	14.6				
200 # N	N + K	296	28 NS	10.4			-11 NS	-3.6
400 # N	N + K	297	29 NS	10.8			-29 NS	-8.9

Table 8f. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in northeastern Washington.

-Treatments-		Growth	Response					
			Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
Net Volume Increment								
0 # N	None	217						
200 # N	None	199	-17 NS	-7.8				
400 # N	None	178	-38 NS	-17.5				
200 # N	200 # N	242	26 NS	12.0	43 NS	21.6		
400 # N	200 # N	285	68 NS	31.3	107 NS	60.1		
0 # N	N + K	266	49 NS	22.6				
200 # N	N + K	292	75 NS	34.6			49 NS	20.2
400 # N	N + K	180	-36 NS	-16.6			-104 NS	36.5
Gross Volume Increment								
0 # N	None	252						
200 # N	None	250	-2 NS	-0.8				
400 # N	None	272	20 NS	7.9				
200 # N	200 # N	287	35	13.9	37	14.8		
400 # N	200 # N	305	53	21.0	33 NS	12.1		
0 # N	N + K	312	60	23.8				
200 # N	N + K	333	81	32.1			47	16.4
400 # N	N + K	277	26 NS	10.3			-27 NS	-8.8

Table 8g. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for one-half of the Douglas-fir sites in all regions.

-Treatments-		Growth	Response: Cumulative Effect		Response: Effect of new Nitrogen		Response: Effect of new Potassium	
Old	New	ft^3/A	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
Net Volume Increment								
0 # N	None	221						
200 # N	None	196	-24 NS	-10.9				
400 # N	None	266	45 NS	20.4				
200 # N	200 # N	250	30 NS	13.6	54 NS	27.6		
400 # N	200 # N	221	1 NS	0.4	-44 NS	-16.5		
0 # N	N + K	205	-16 NS	-7.2				
200 # N	N + K	259	38 NS	17.2			8 NS	3.2
400 # N	N + K	250	30 NS	13.6			29 NS	13.1
Gross Volume Increment								
0 # N	None	256						
200 # N	None	259	3 NS	1.2				
400 # N	None	274	18	7.0				
200 # N	200 # N	291	35	13.7	32	12.4		
400 # N	200 # N	305	50	19.5	31	11.3		
0 # N	N + K	298	42	16.4				
200 # N	N + K	306	50	19.5			15 NS	5.2
400 # N	N + K	292	37	14.4			-13 NS	-4.3

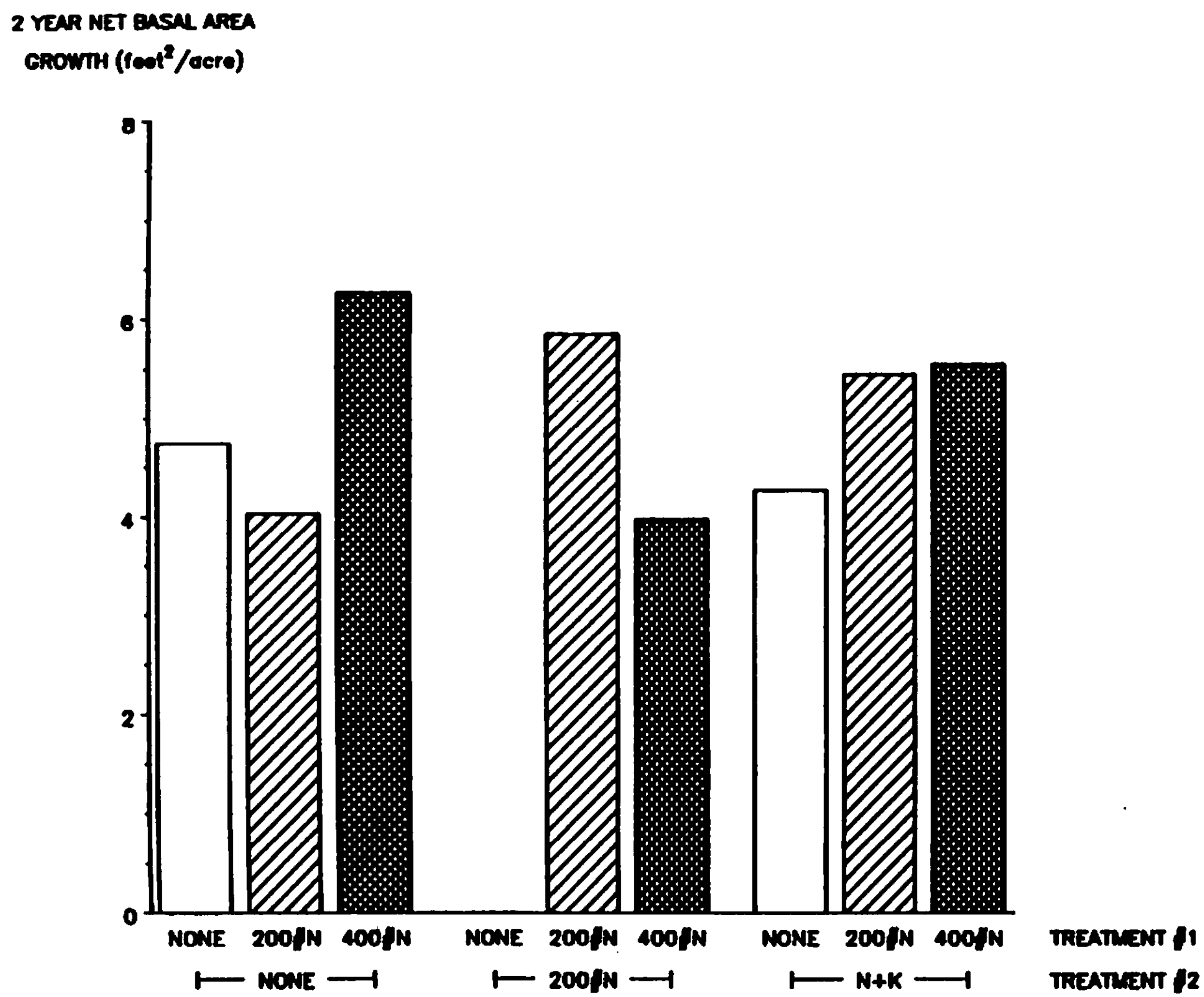

Figure 13. Two-year Average Net Basal Area Increment by Previous Nitrogen Treatment and New Treatment with Nitrogen or Nitrogen Plus Potassium Partitioned into Live (Net) and Dead Components for One-half of the Douglas-fir Installations.

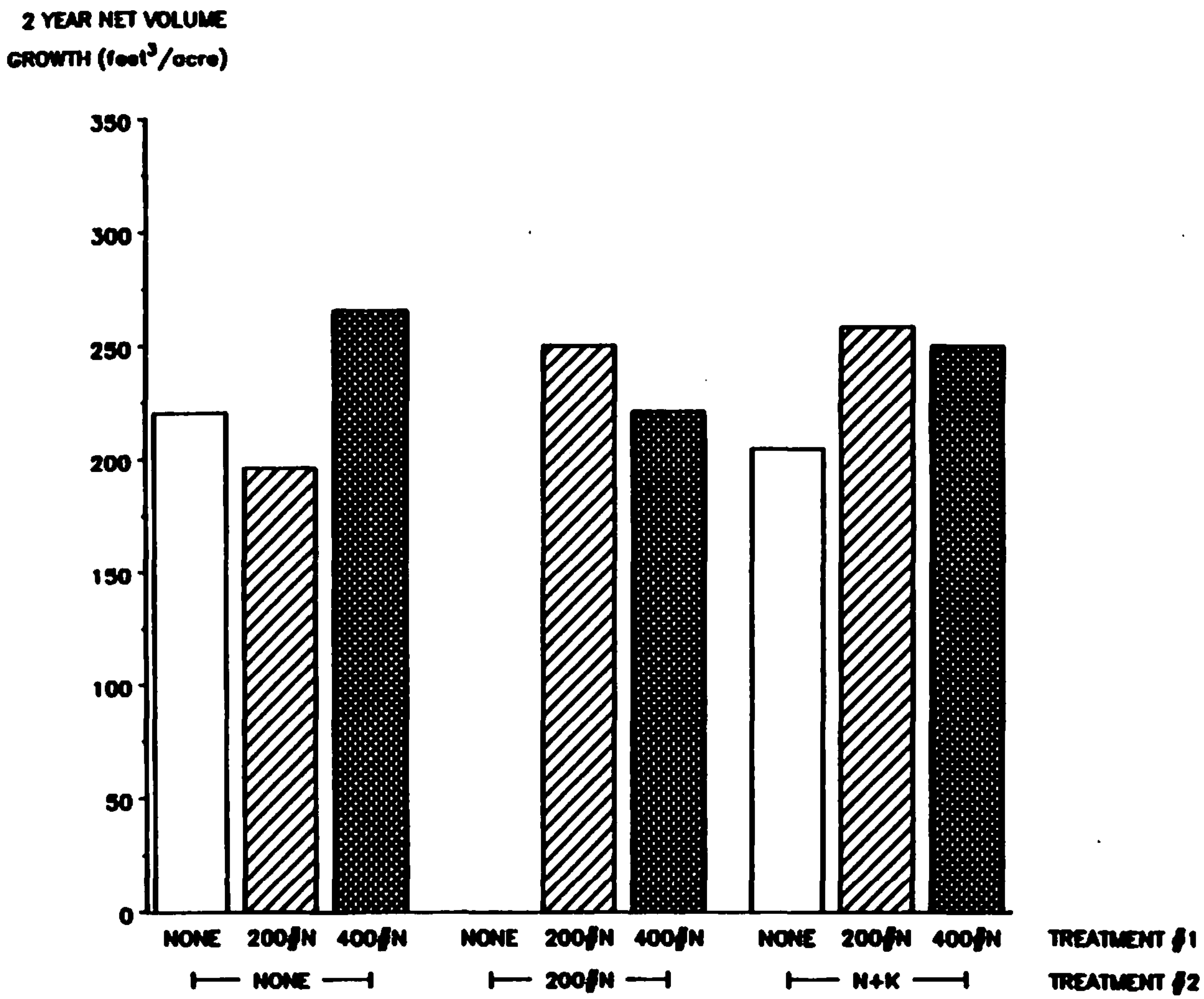

Figure 14. Two-year Average Net Volume Increment by Previous Nitrogen Treatment and New Treatment with Nitrogen or Nitrogen Plus Potassium Partitioned into Live (Net) and Dead Components for One-half of the Douglas-fir Installations by Geographic Region.

nitrogen (a total of 600 pounds per acre in a six-year period) would produce an average negative response.

The average two-year retreatment effects of 200 pounds of nitrogen alone were less than the responses produced by the original 200 lb nitrogen treatments (See 1983 IFTNC Annual Report). Several plausible explanations can be offered; (1) we have observed that growing conditions seem to have declined since our original treatments were applied (see discussion in Duration of Response section of this report); thereby reducing response to nitrogen retreatments, or (2) the previous treatments were still having a significant effect at the time retreatments were applied (i.e., after six years). We know from previous analysis that this is true. Perhaps the combination of the above two factors explains why the average response to nitrogen retreatments was less than for original nitrogen treatment of the same dosage. The variation in two-year net and gross volume response to nitrogen retreatment is displayed by previous nitrogen treatment for combined regions in Figures 15 and 16. There was substantial response variation, particularly for net volume. There were some installations that produced large negative net response, while some showed high positive response. On the average, the nitrogen effects were not significant ($\alpha = .1$).

<u>Retreatments with Nitrogen plus Potassium: K Effects</u>:

The average two-year effects of potassium alone (i.e., 200 lb N + 200 lb K response - 200 lb N response = K alone effect) retreatments were not significant for gross or net basal area or

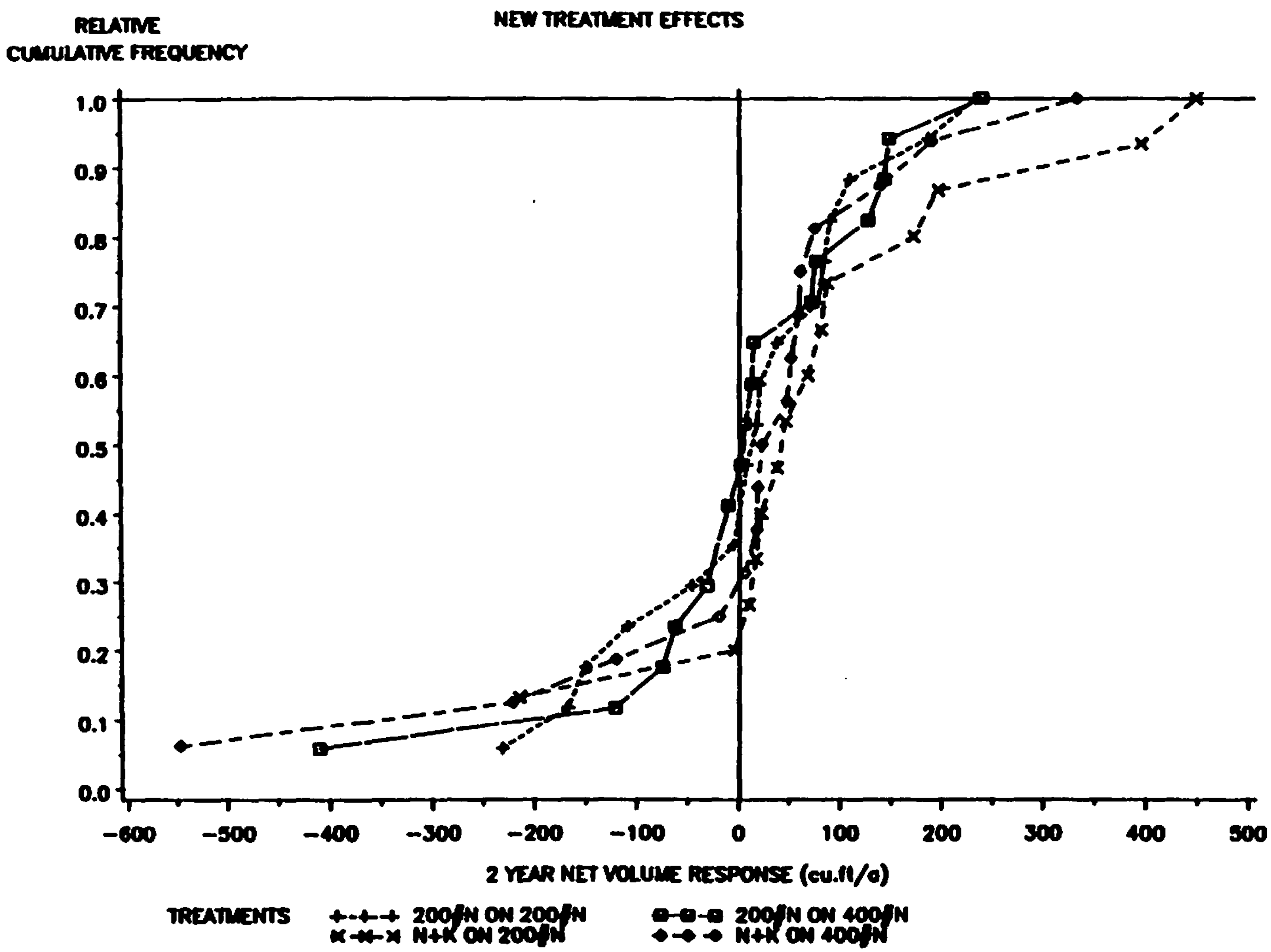

Figure 15. The Cumulative Distribution of Net Two-year Volume Effects of Retreatments for One-half of the Douglas-fir Installations.

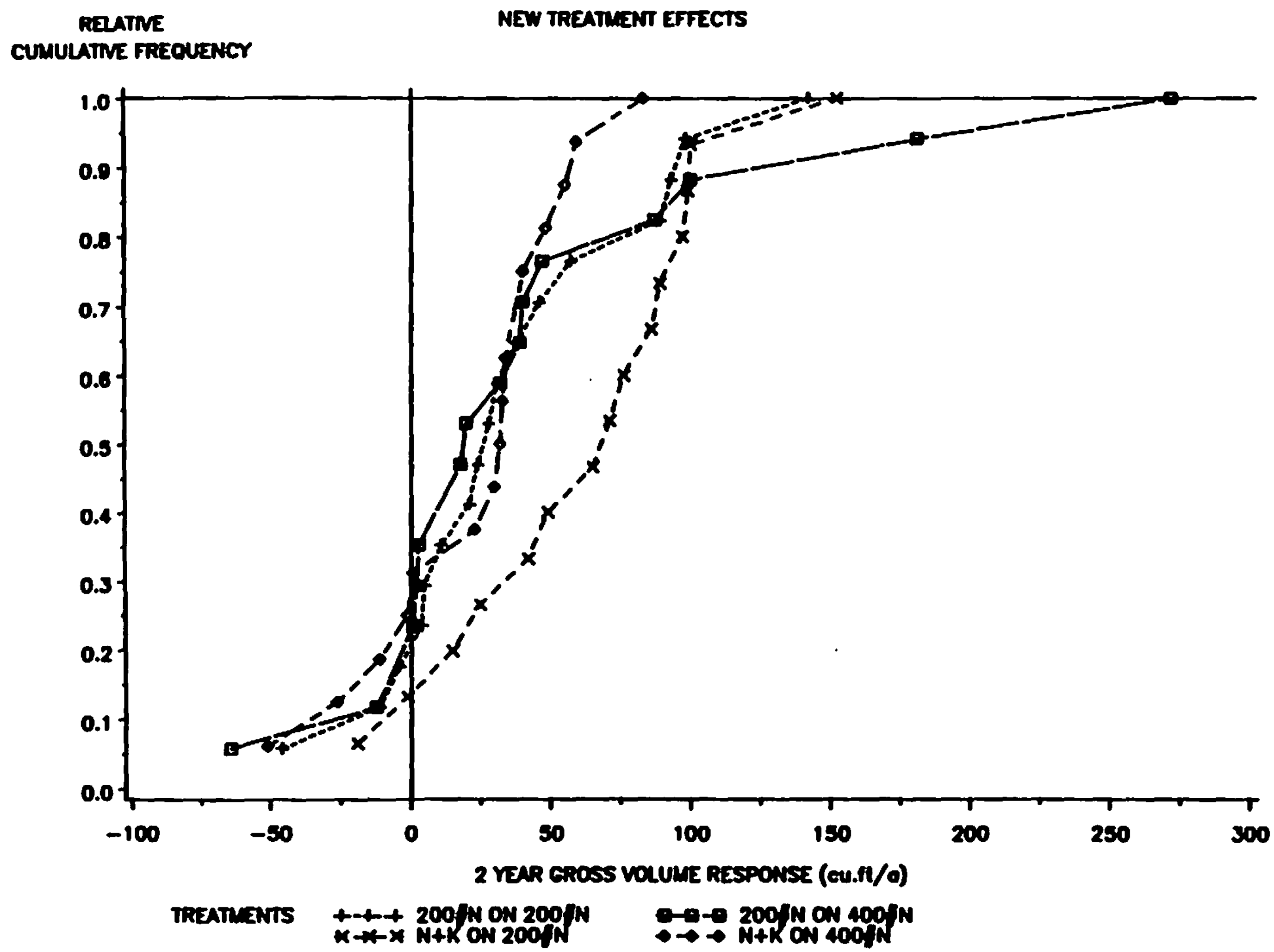

Figure 16. The Cumulative Distribution of Gross Two-year Volume Effects of Retreatments for One-half of the Douglas-fir Installations.

volume on either original nitrogen dosage (Tables 7g or 8g). However, the variation in potassium response shows an interesting difference in K effects depending on the two original nitrogen dosages (Figures 17 and 18). There were no large negative potassium effects if the previous nitrogen rate was 200 pounds. The large negative K responses occurred only on plots with the previous 400 pound nitrogen dosage. Perhaps on those previous 400 lb treatment plots the nutrient status of the trees had been changed by the high nitrogen such that the new N + K treatment sometimes produced a negative effect. Alternatively, we know that some of the previous 400 lb treatment plots incurred significant mortality. Maybe, that effect is still continuing even after retreatment and is not actually related to the retreatments. This is all currently speculation, we need to do much more analysis using all the data to be collected next year to improve our understand of these results.

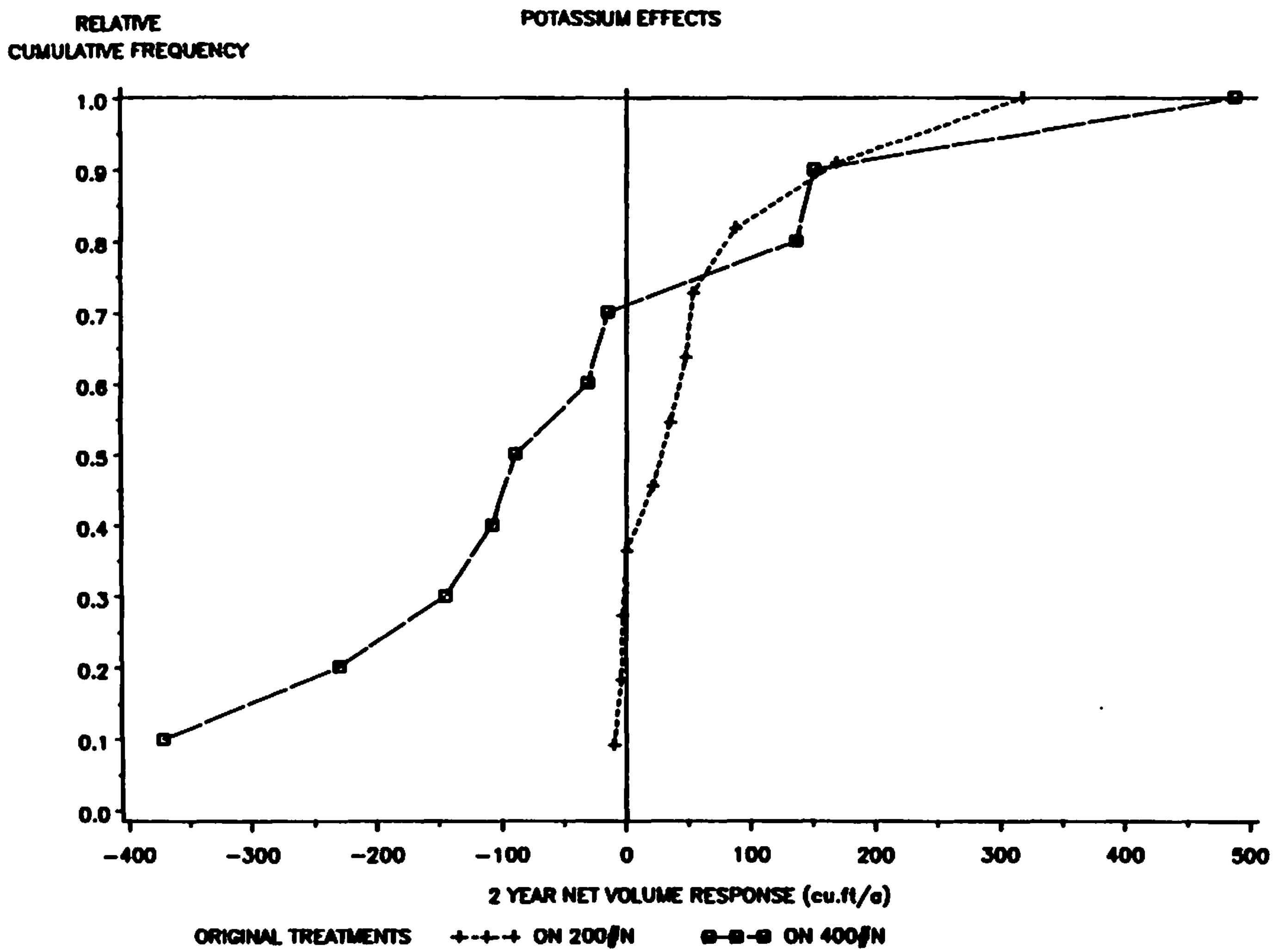

Figure 17. The Cumulative Distribution of Net Two-year Volume Effects of Potassium Retreatments for One-half of the Douglas-fir Installations.

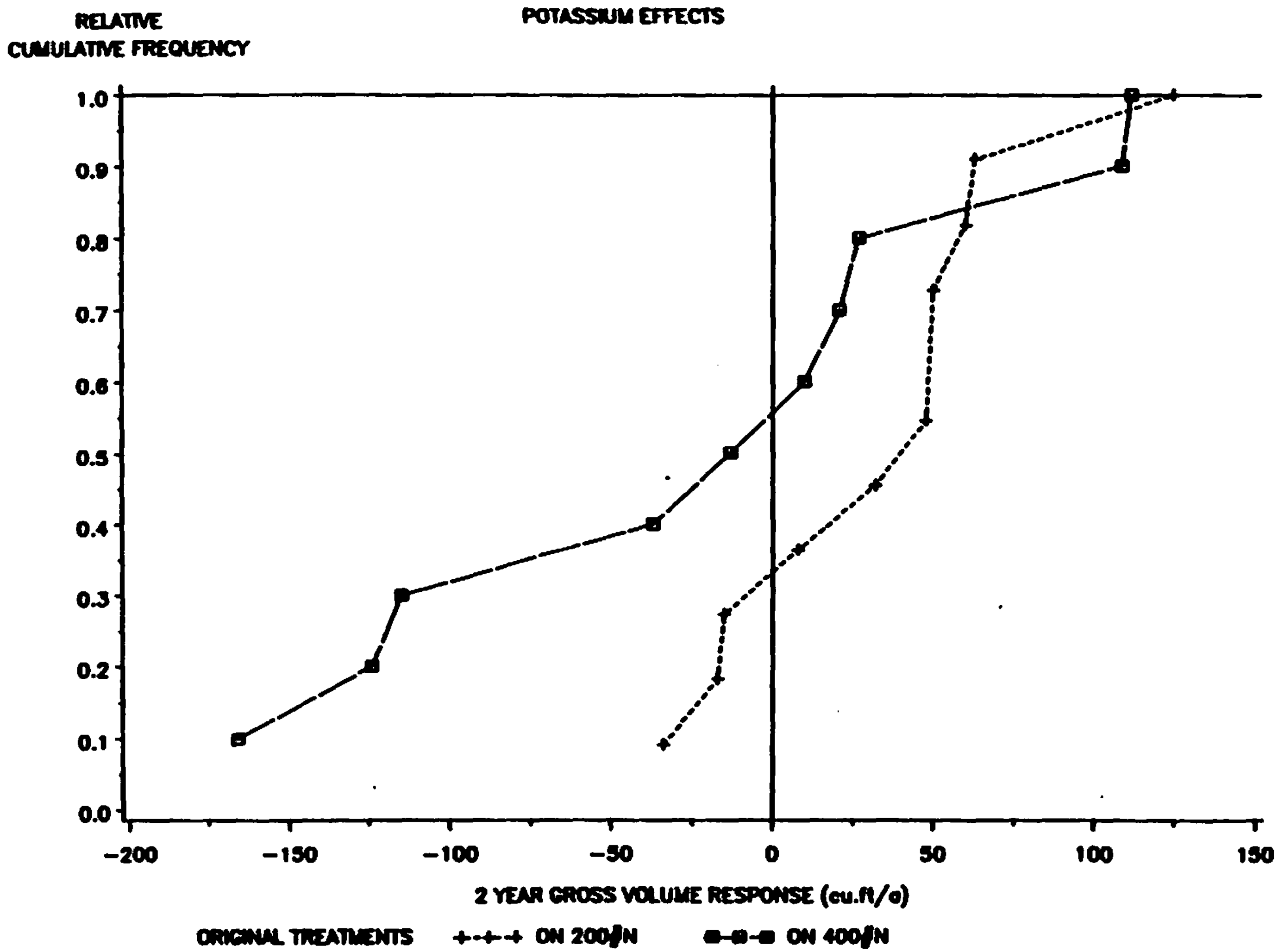

Figure 18. The Cumulative Distribution of Gross Two-year Volume Effects of Potassium Retreatments for One-half of the Douglas-fir Installations.

Pre-Treatment Foliage Potassium Status and Two-year Response to Nitrogen and Nitrogen plus Potassium Fertilization for One-half of the Douglas-fir Installations:

The 1989 IFTNC Annual Report describes in detail the process that we used to develop the following foliar potassium categories. Briefly, the rationale is as follows: 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.

If our hypothesis that inadequate potassium levels limited response to nitrogen fertilization is correct, then we expect that response to the N and N + K retreatments would be different by these K status classes. The two-year gross volume responses to nitrogen or nitrogen plus potassium by pre-treatment foliage potassium status are provided in Table 9 and net and gross volume are illustrated in Figure 19 and 20. The estimates in Table 9 are for the retreatment effects of nitrogen alone or potassium alone (i.e., N + K response - N alone response). The N + K treatment in the poor potassium sites produced a positive average response while the N alone treatment response was negative. The

Table 9. Two-year gross volume per acre estimates of nitrogen or potassium effects by pre-treatment foliage potassium status.

K Status		New Treatment Effects	Response Cu. Ft./A
	K<6000 ppm		
Poor			
	K/N < 50%	200 lb. N Effects	-14 NS
		200 lb. K Effects	39 NS
K is otherwise		200 lb. N Effects	66
		200 lb. K Effects	-21
	K > 6000 ppm		
Good			
	K/N > 65%	200 lb. N Effects	13 NS
		200 lb. K Effects	15 NS

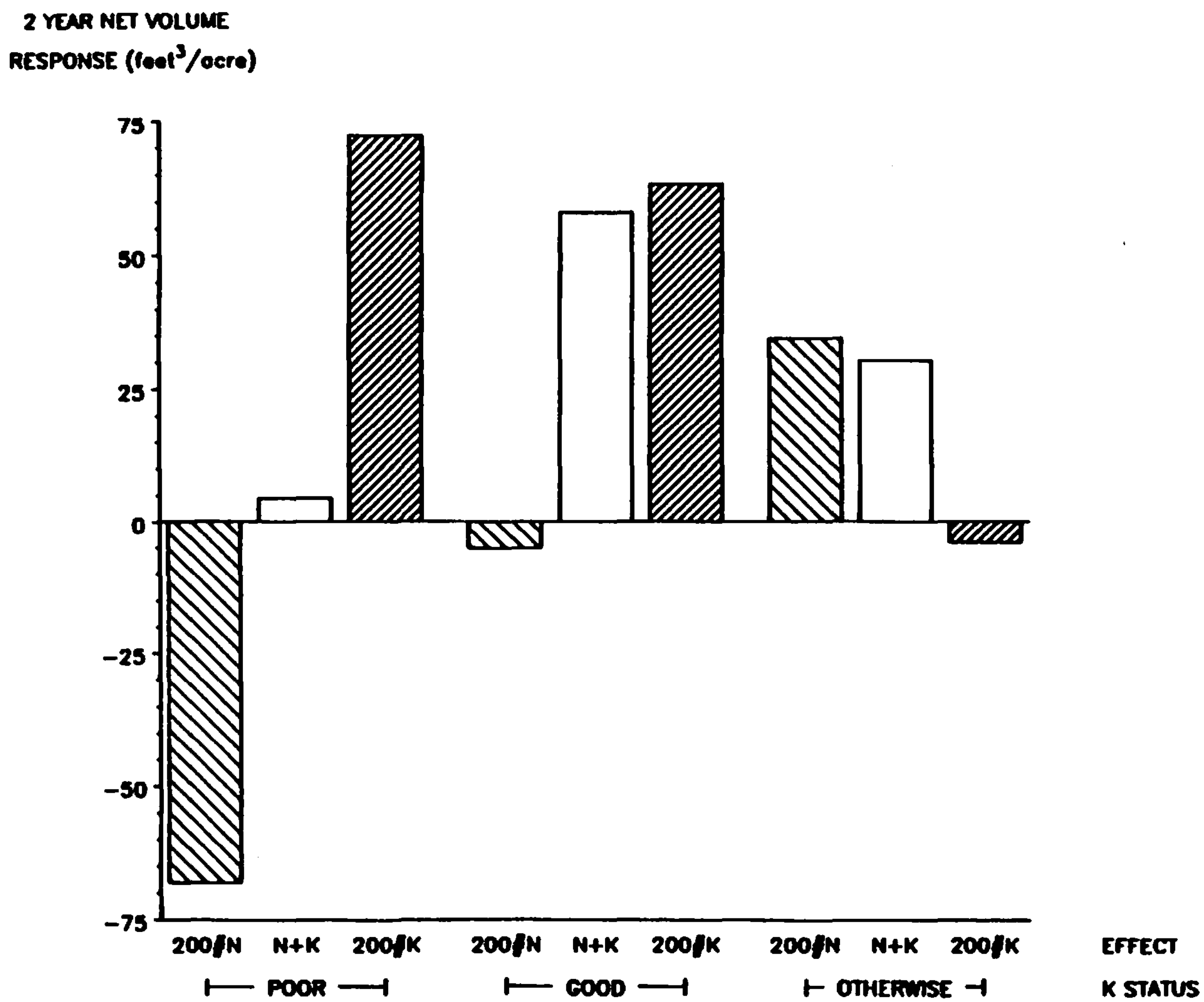

Figure 19. Two-year Average Net Volume Response to Nitrogen and Nitrogen Plus Potassium Retreatments by Previous Potassium Status Categories for One-half of the Douglas-fir Experiment.

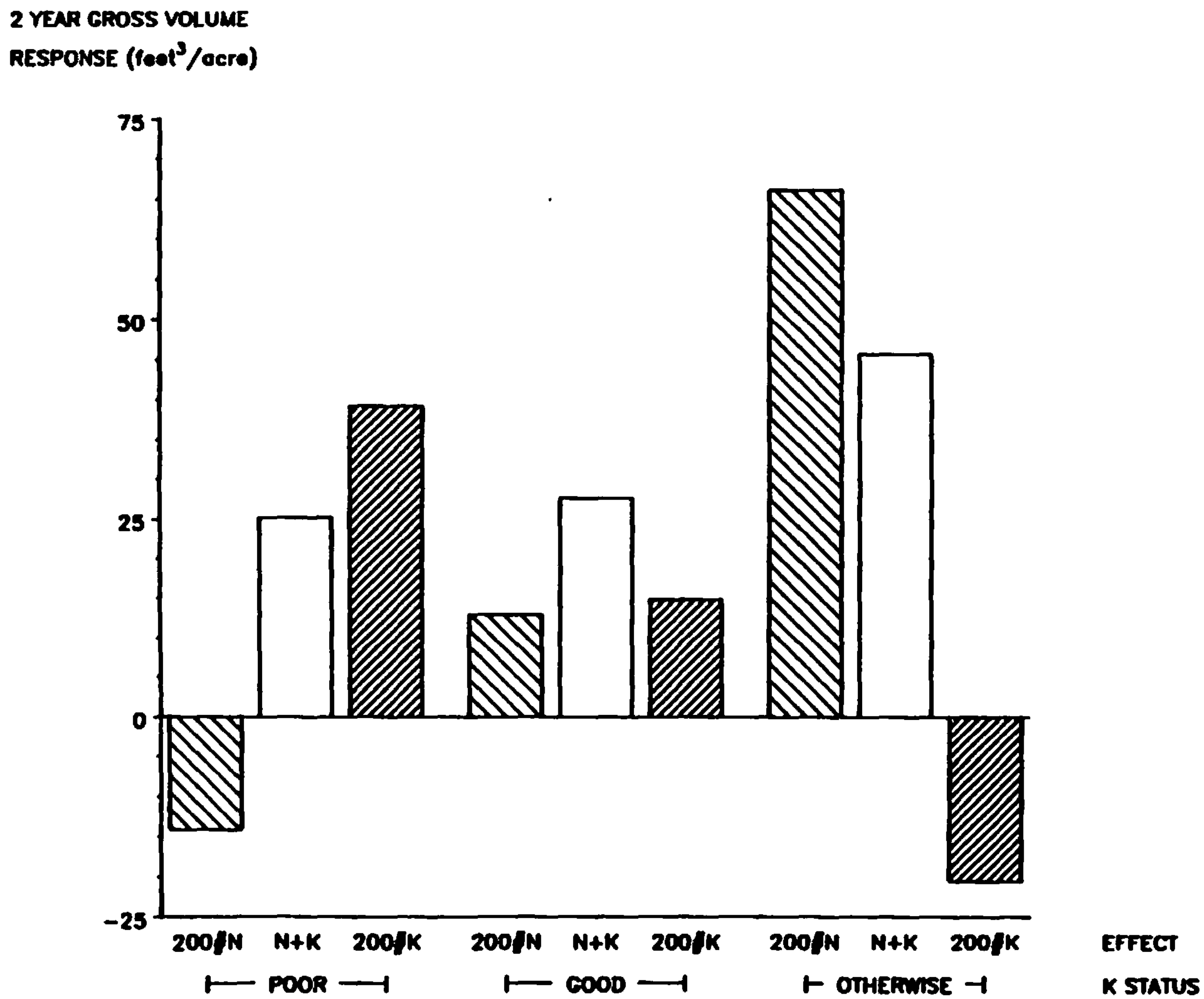

Figure 20. Two-year Average Gross Volume Response to Nitrogen and Nitrogen Plus Potassium Retreatments by Previous Potassium Status Categories for One-half of the Douglas-fir Experiment.

two treatments produced similar responses for the good potassium category. None of these treatments were statistically different ($\alpha = .1$) from each other due to small sample size and high variation within the treatments. Therefore, we should be cautious about these results; however, based on these preliminary data, our potassium hypothesis still seems tenable. The N alone treatment response was substantially higher than the N + K treatment for the "otherwise" potassium category. We have no explanation for this result, we are uncertain of the potassium status for these sites (i.e., otherwise = ??). We need substantially more analysis and time to improve our understanding of potassium nutrition and fertilization.

PONDEROSA PINE RESULTS

General Description of the Experiment:

Ten installations were established in managed ponderosa pine stands during 1985 (5 each located in northeastern Oregon and central Washington). 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 and heights of all sample trees were measured before treatment and again after two and four growing seasons. Six additional ponderosa pine sites were established in Montana during 1987. the design is identical to the other installations except that the 400 pounds per acre nitrogen treatment was replaced with a treatment of 200 pounds per acre of nitrogen and 200 pounds per acre of potassium. Murate of potash was the potassium source.

Total height was measured for all sample trees at the start of the experiment and after the fourth growing season. Height was measured for a subsample of trees after the second growing season. Mortality was recorded by cause at each measurement period. The following analyses are based on basal area and volume growth for four years after treatment for the Oregon and Washington sites and two years for Montana. Volume equations used are from the Prognosis model for individual tree total cubic foot volume.

Basal Area Growth Response for northeastern Oregon and central Washington:

Average basal area increment and response to the nitrogen treatments (adjusted to a common initial basal area of 120 ft^2/A) for both gross and net basal area increments are given in Table 10. The four-year gross basal area per acre increments for both the 200 and 400 lb nitrogen treatments were statistically different from the controls for both geographic regions. The gross increments for the 400 lb treatment significantly greater than the 200 lb treatment. This result is different than for the Douglas-fir trials in central Washington after four years. The 400 lb treatment produced a significant increase over the 200 lb treatment for the Douglas-fir trials in central Washington. For northeastern Oregon, neither the ponderosa pine or Douglas-fir installations showed a significant increase from the 400 lb N treatment over 200 lb treatment after four years.

The results are different for net basal area increment (Table 10). There is no statistical difference in net basal area increment between either nitrogen treatment and the controls nor between the two nitrogen treatments for either regions. There was a large decrease from gross to net basal area response for the 400 lb treatment in central Washington. The reason for the different results for gross and net basal area growth response in central Washington is that fertilized plots had significantly

Table 10. Average four-year net and gross basal area growth response to nitrogen fertilization by treatment for ponderosa pine in northeast Oregon and central Washington.[1]

Region	Treatment	Net Basal Area: Increment ft^2/acre	Net Basal Area: Response ft^2/acre	Net Basal Area: Response percent	Gross Basal Area: Increment ft^2/acre	Gross Basal Area: Response ft^2/acre	Gross Basal Area: Response percent
Northeast Oregon	Control	15.3			14.7		
	200 # N	15.9	0.6 NS	3.9	17.1	2.4	16.3
	400 # N	17.4	2.1 NS	13.7	17.7	3.0	20.4
	400# vs 200#		1.5 NS	9.4		0.6 NS	3.5
Central Washington	Control	14.8			15.7		16.6
	200 # N	16.9	2.1 NS	14.2	18.3	2.6	18.5
	400 # N	9.1	-5.7 NS	38.5	18.6	2.9	1.6
			-7.8 NS	-46.2		0.3 NS	
Overall	Control	15.1			15.2		
	200 # N	16.4	1.3 NS	8.6	17.7	2.5	16.4
	400 # N	3.3	-1.8 NS	-11.9	18.2	2.9	19.1
	400 # vs 200 #		-3.2 NS	-19.5		0.5 NS	2.8

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

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

higher mortality rates during years 3 and 4 than the control plots (Figures 21 and 22). This was particularly true for one installation where most of the trees died after the 400 lb treatment was applied, perhaps because of induced nutrient deficiencies. The loss of a substantial number of trees on one installation can erase average response for the region since there are only 5 total sites per region.

Basal Area Growth Response for Montana:

The two-year gross basal area per acre response was not statistically significant for either the 200 lb N or the 200 lb N plus 200 lb K treatments in Montana (Table 11). There was also no significant difference between the two fertilizer treatments, even though the addition of potassium produced twice as much gross basal area response on the average as nitrogen alone.

There was also no significant net basal area response for either fertilizer treatment in Montana. The two fertilizer treatments did not produce significantly different response even though the nitrogen alone treatment incurred more mortality than did the nitrogen plus potassium treatment (Table 11 and Figure 23).

Four-year Volume Growth Response for northeast Oregon and central Washington:

The results for net and gross volume growth response are similar to those for basal area growth for northeastern Oregon. There are some volume response differences in central Washington.

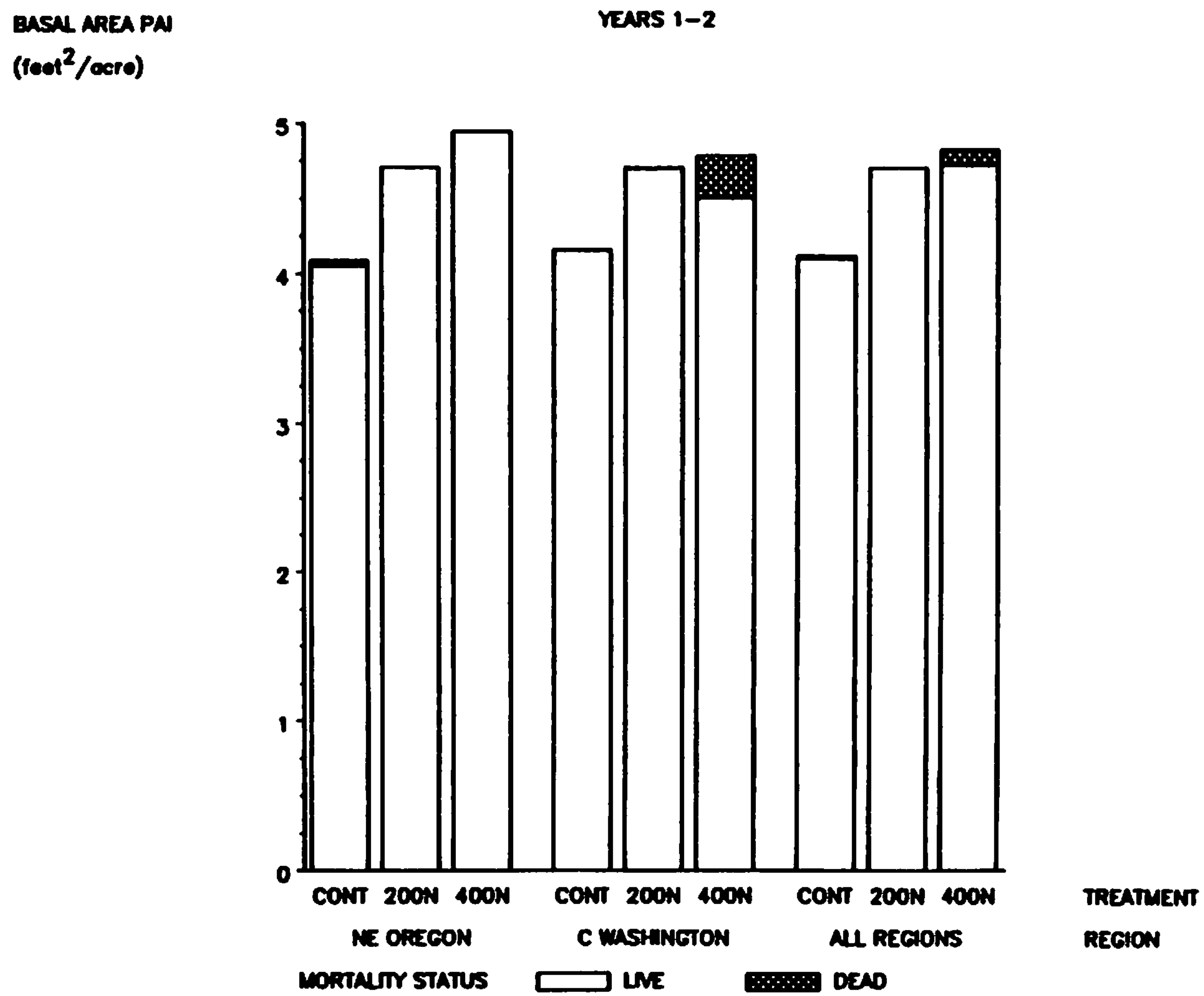

Figure 21. Basal Area Increment by Treatment for the First Two-year Period Following Nitrogen Fertilization of Ponderosa Pine in Northeastern Oregon and Central Washington.

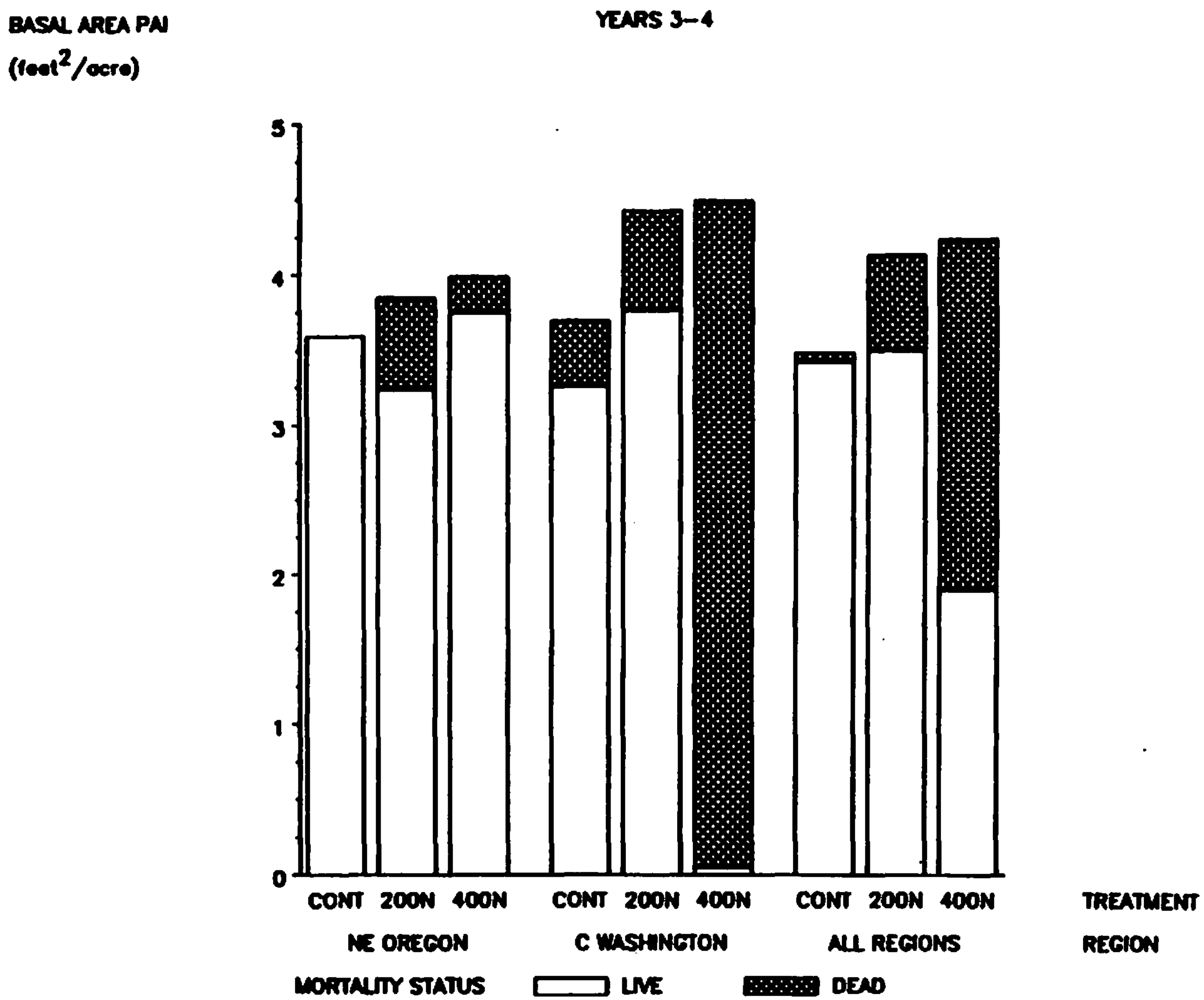

Figure 22. Basal Area Increment for the Second Two-year Period Following Nitrogen Fertilization of Ponderosa Pine in Northeastern Oregon and Central Washington.

Table 11. Average two-year net and gross basal area growth response to nitrogen and nitrogen plus potassium fertilization by treatment for ponderosa pine in Montana.[1]

		Net Basal Area			Gross Basal Area		
		Increment	Response		Increment	Response	
Region	Treatment	ft^2/acre	ft^2/acre	percent	ft^2/acre	ft^2/acre	percent
Montana	Control	6.4			6.8		
	200 # N	5.2	-1.2 NS	-18.8	7.1	0.3 NS	4.4
	200 N + 200 K	7.4	1.0 NS	15.6	7.4	0.6 NS	8.8
	K effect		2.2 NS	42.3		0.3 NS	4.2

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

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

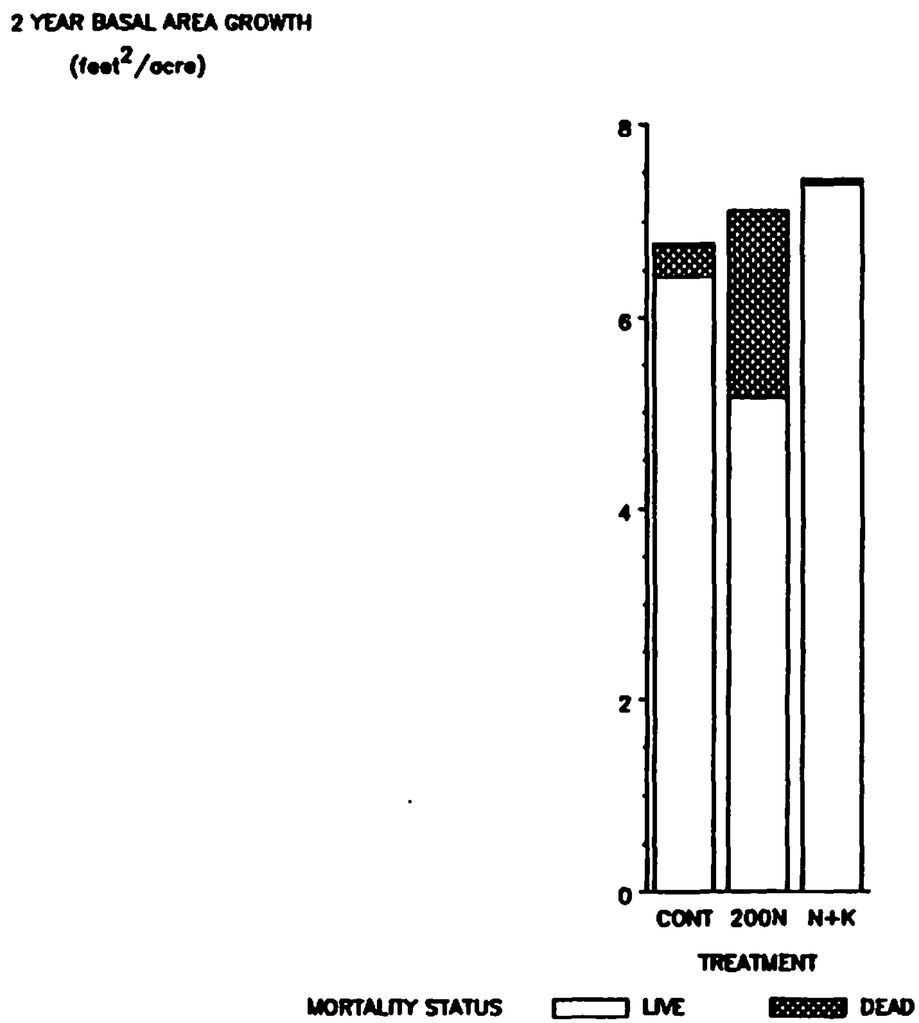

Figure 23. Two-year Basal Area Increment Following Nitrogen and Nitrogen Plus Potassium Fertilization of Ponderosa Pine in Montana.

The net and gross volume growth estimates by region and treatment are given in Table 12 and shown in Figure 24. The gross volume per acre increments for both nitrogen treatments are significantly greater than the controls for central Washington but not for northeastern Oregon. Gross volume growth for the 400 lb treatment was not significantly greater than the 200 lb treatment for either region.

There is no statistical difference in net volume increment for either nitrogen treatment and the controls in northeastern Oregon. In central Washington there was a significant increase in volume growth from the 200 lb treatment but a significant decrease resulting from the 400 lb treatment. This partially results from the one site that incurred substantial mortality after the 400 lb treatment mentioned in the discussion of basal area response. Despite these observed differences, there was no significant difference between the average response between the two nitrogen treatments in either region.

The average volume response for the ponderosa pine trials in these regions are much less than the Douglas-fir four-year volume response. We don't know if this results from species or growing season differences or other causes.

Two-year Volume Growth Response for Montana:

The average gross volume per acre response to the 200 lb nitrogen treatment was not statistically significant. However, the 200 lb nitrogen plus 200 lb potassium treatment did produce a significant average gross volume response (Table 13). However,

Table 12. Average four-year net and gross cubic foot volume growth response to nitrogen fertilization by treatment for ponderosa pine in northeast Oregon and central Washington.[1]

		Net Volume			Gross Volume		
		Increment	Response		Increment	Response	
Region	Treatment	ft^3/acre	ft^3/acre	percent	ft^3/acre	ft^3/acre	percent
Northeast Oregon	Control	713			673		
	200 # N	660	-53 NS	-7.4	711	38 NS	5.6
	400 # N	714	1 NS	0.1	732	59 NS	8.8
	400# vs 200#		54 NS	8.2		21 NS	3.0
Central Washington	Control	638			675		
	200 # N	730	91	14.3	778	103	15.3
	400 # N	539	-101	-15.8	770	95	14.1
	400# vs 200#		-192 NS	-26.3		-9 NS	-1.2
Overall							
	Control	676			674		
	200 # N	695	19 NS	2.8	745	71	10.5
	400 # N	626	-50 NS	-7.4	751	77	11.4
	400# vs 200#		-68 NS	-9.8		6 NS	0.8

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

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

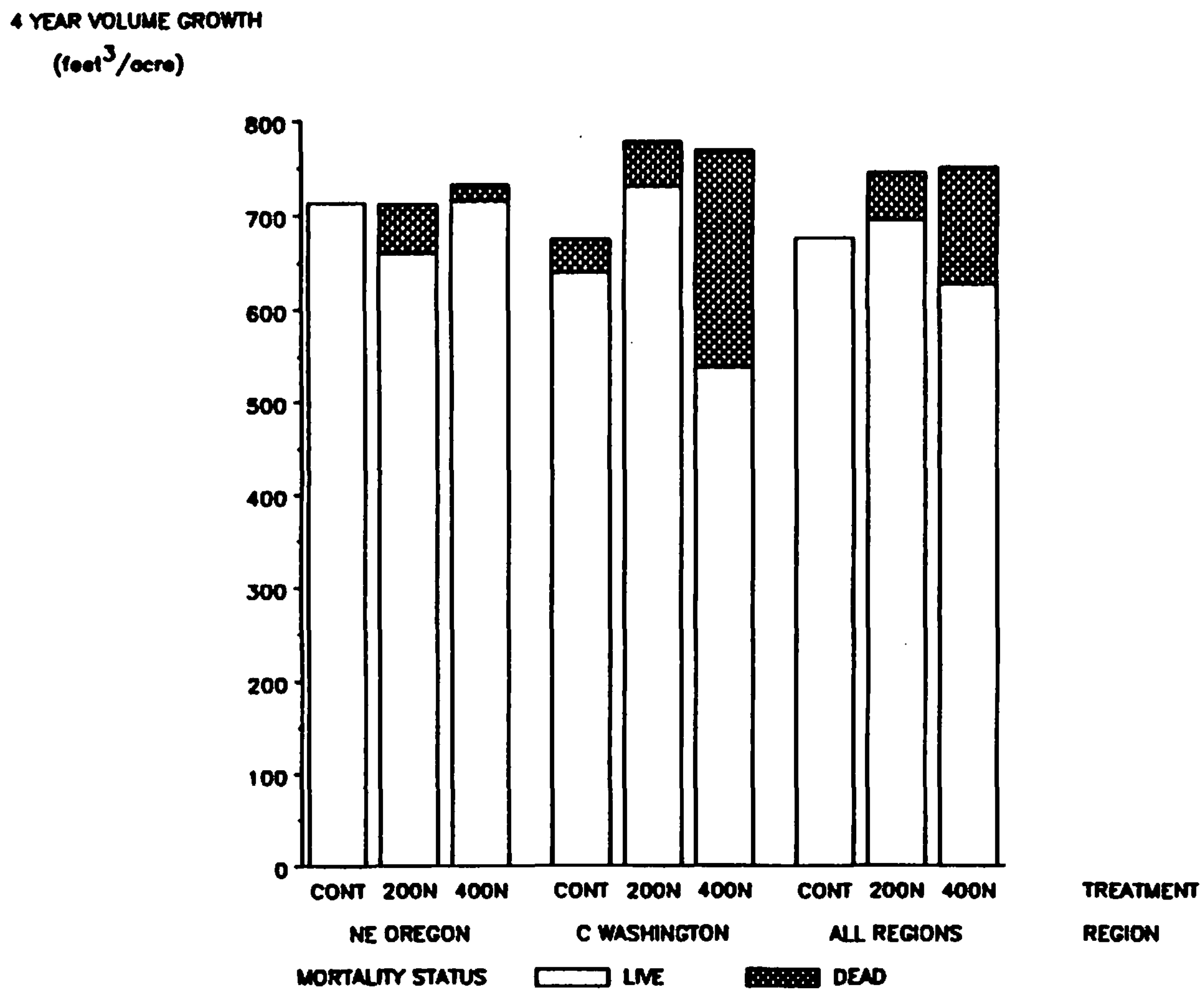

Figure 24. Four-year Volume Increment Following Nitrogen Fertilization of Ponderosa Pine in Northeastern Oregon and Central Washington.

Table 13. Average two-year net and gross cubic foot volume growth response to nitrogen and nitrogen plus potassium fertilization by treatment for ponderosa pine in Montana.[1]

Region	Treatment	Net Volume Increment ft^3/acre	Net Volume Response ft^3/acre	Net Volume Response percent	Gross Volume Increment ft^3/acre	Gross Volume Response ft^3/acre	Gross Volume Response percent
Montana	Control	276			285		
	200 # N	235	-41 NS	-14.9	296	11 NS	3.9
	200N + 200 K	306	30 NS	10.9	309	24	8.4
	K effect		71 NS	30.2		13 NS	4.4

[1]Averages are adjusted to a common initial basal area of 120 ft^2/A.

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

there was not a statistical difference between the two treatments.

Neither of the two fertilizer treatments produced a significant two-year net volume response. Despite the fact that the average net volume response to nitrogen alone was negative (-14.9%) while the nitrogen plus potassium response was positive (10.9%), there was no statistical difference between the two fertilizer treatments.

Four-year Variation in Volume Growth Response to Nitrogen Fertilization for Ponderosa Pine in northeastern Oregon and central Washington:

The variation in net and gross four-year volume response to both nitrogen treatments for ponderosa pine in both northeastern Oregon and central Washington is displayed in Figures 25 and 26. The cumulative distribution of net volume response (Figure 25) shows that one or two of the installations showed large negative response to the nitrogen treatments. With only 5 installations per region, one large negative response (in this case the site is in central Washington) greatly affects the regional mean response (see Tables 10 and 12). Most of the mortality occurred during years 3 and 4 after fertilization (Figures 21 and 22) rather than immediately after treatment. This suggests that the mortality was not caused by direct damage from fertilization but by some other treatment related effect. The temporal pattern of the mortality is similar to that observed in the "poor" potassium status Douglas-fir installations. However, the foliar K

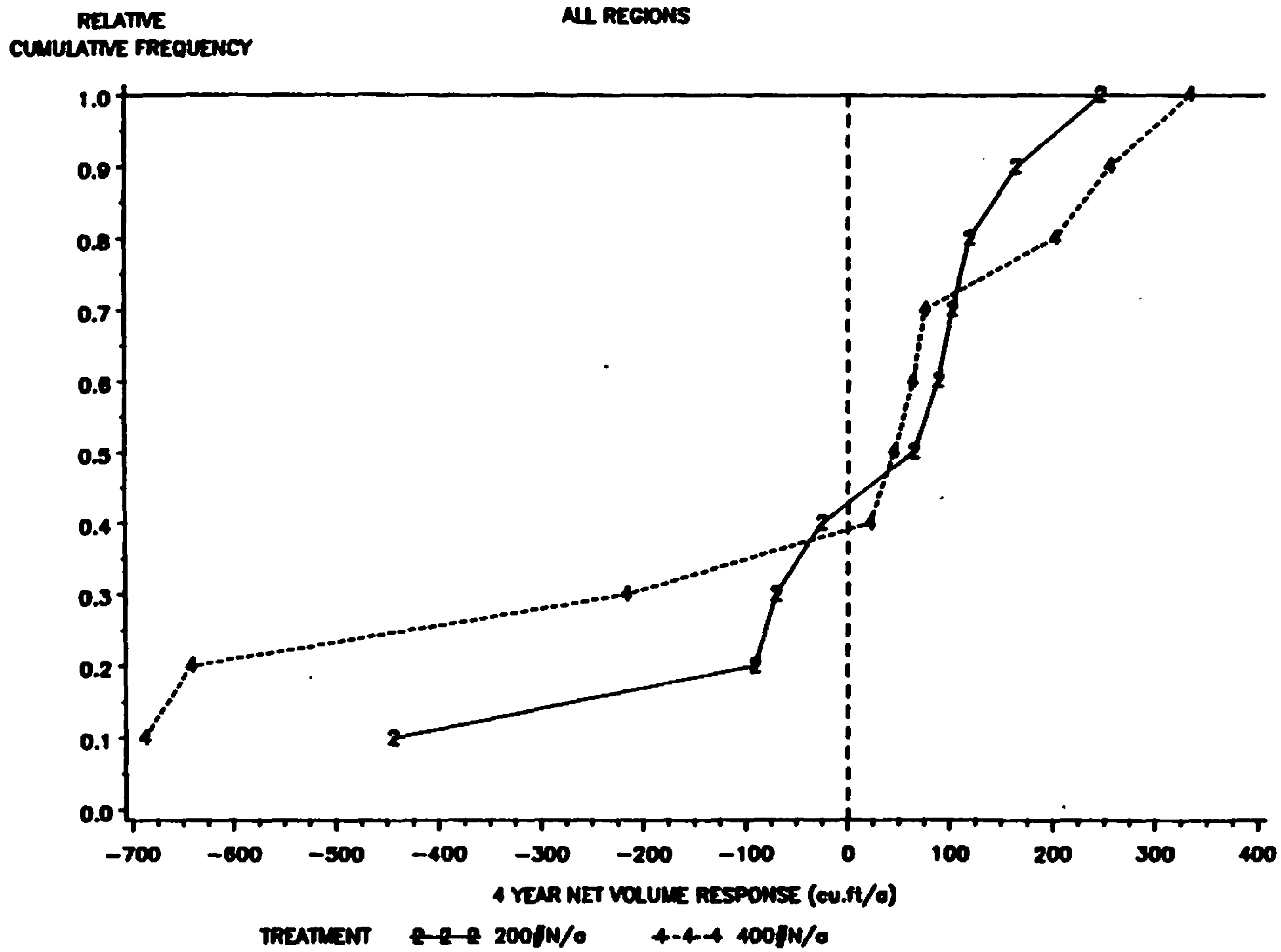

Figure 25. The Cumulative Distribution of Net Four-year Volume Growth Response to the Nitrogen Treatments for Ponderosa Pine in Northeastern Oregon and Central Washington.

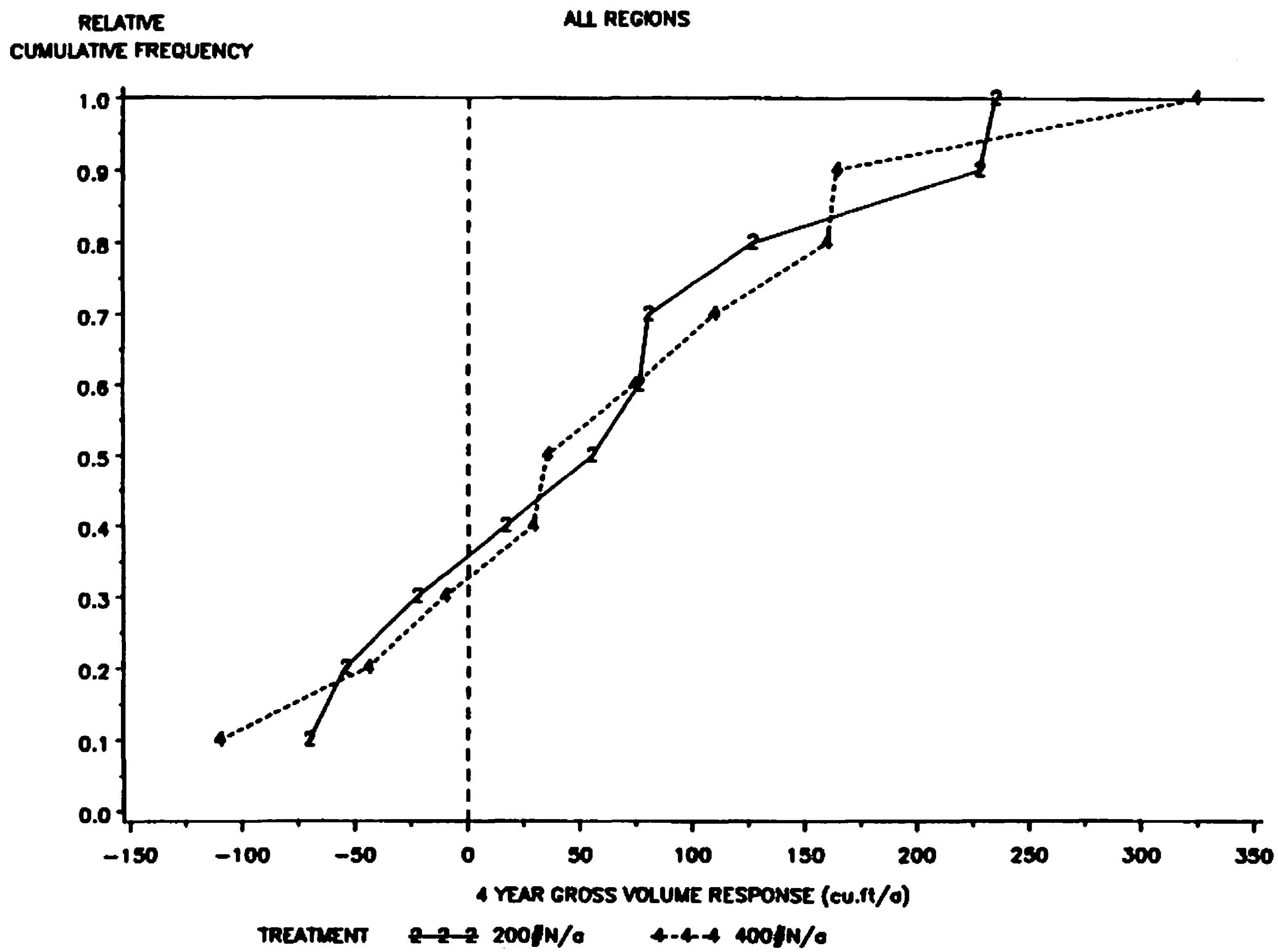

Figure 26. The Cumulative Distribution of Gross Four-year Volume Growth Response to the Nitrogen Treatments for Ponderosa Pine in Northeastern Oregon and Central Washington.

concentrations for this installation were somewhat low, but not that low. The IFTNC Technical Committee visited this installation in the summer of 1988 and found the "rectangular" pattern of the mortality striking. After careful inspection of the trees, we are still not sure what caused the fertilized trees to die. Other ponderosa pine installations showed good response to nitrogen fertilization (Figures 25 and 26), about the same as the Douglas-fir trials in the same geographic regions.

<u>Two-year Variation in Volume Growth Response to Nitrogen and Nitrogen plus Potassium Fertilization for Ponderosa Pine in Montana</u>:

Although there was not significant difference in average volume response between the nitrogen and nitrogen plus potassium treatments (Table 13), the cumulative distributions of two-year net volume response for the two treatments show an interesting difference (Figure 27). The N + K treatment did not produce negative responders as the nitrogen treatment did. Perhaps this is preliminary evidence that supports our hypothesis about the role of potassium in influencing tree mortality rates, particularly in nitrogen fertilized stands.

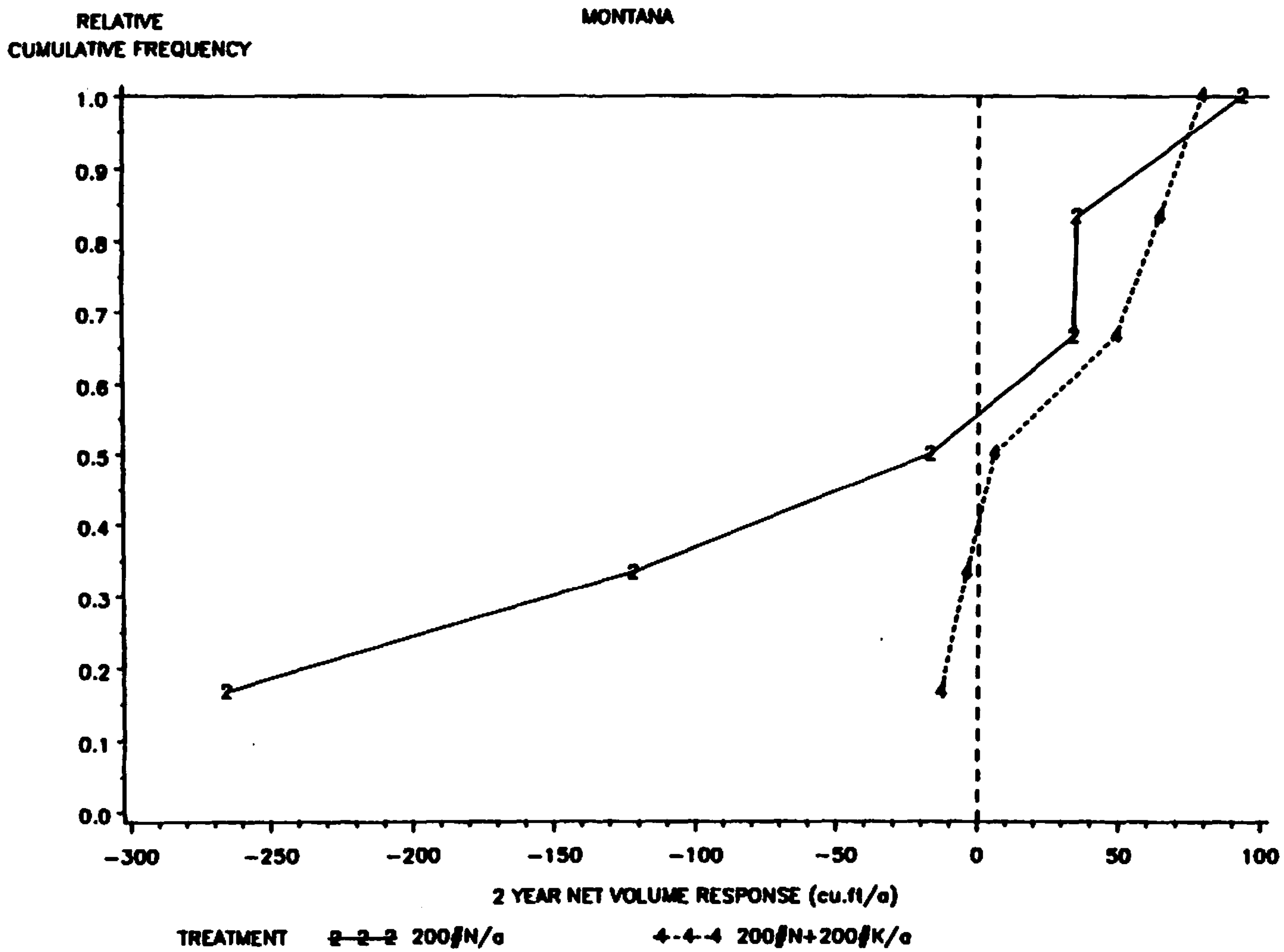

Figure 27. The Cumulative Distribution of Net Two-year Volume Growth Response to the Nitrogen and Nitrogen Plus Potassium Treatments for Ponderosa Pine in Montana.