Eleventh Annual Report

Intermountain Forest Tree Nutrition Cooperative

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College of Forestry, Wildlife and Range Sciences
University of Idaho
Moscow, Idaho 83843

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Summary

The data available for this report are:

Eight-year response to nitrogen fertilization for all of the Douglas-fir experiments.

Two-year response to retreatment with nitrogen or nitrogen plus potassium for all of the Douglas-fir installations.

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

(A) Response to nitrogen fertilization continues to be significant after eight years for the Douglas-fir experiment, and differences in regional response continue.

(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 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 nitrogen treatment in northern Idaho and northeastern Oregon 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) Although not statistically significant, the potassium retreatment effect for the Douglas-fir trials was to reduce mortality rates after treatment compared to nitrogen alone treatments, and the effects were greatest for those installations with

poor pre-treatment foliar potassium status.

(F) Evidence continues to be strong that potassium status before treatment affects amount and duration of nitrogen fertilizer response; however, we have not demonstrated a significant ability to change potassium status with the fertilization treatments we have employed.

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 all 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). This is our first opportunity to analyze retreatment and potassium effects for all of the Douglas-fir experiment.

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 or the Douglas-fir retreatment response). Alternative models and/or analytic approaches were considered and will be in the future.

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 29 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. The eight-year results and duration of response analyses are based on plots that have not been retreated.

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

Eight-year average basal area response to the nitrogen treatments (adjusted to a common initial basal area of 150 ft^2/A) for both gross and net basal area are given in Table 1 and shown in Figure 1. The eight-year gross basal area per acre response for both the 200 and 400 lb nitrogen treatments was statistically different from the controls for northern Idaho, central Washington, central Idaho and northeastern Washington. The 200 lb treatment produced a significant gross basal area response in northeastern Oregon, while the 400 lb treatment did so in Montana. At least one and usually both nitrogen treatments were significantly different from the controls after eight years in every region. 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 similar to the six-year basal area response (1989 IFTNC Annual Report).

Compared with gross basal area, the results are different for net basal area response. Only the 400 lb treatment in northern Idaho produced a significant net basal area response after eight years. Six-year results indicated that central Washington produced the largest net basal area response to both treatments. This difference derives from increased mortality rates in central

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

		Net Basal Area		Gross Basal Area	
		Response[2]		Response[2]	
Region	Treatment	ft²/acre	percent	ft²/acre	percent
Northern Idaho	200 # N	4.0 (.306)	10.0	9.1 (.000)	20.8
	400 # N	11.0 (.005)	27.4	11.3 (.000)	25.7
	400 # vs 200 #	7.0 (.104)	15.8	2.2 (.260)	4.1
Montana	200 # N	3.7 (.333)	18.7	2.0 (.252)	8.2
	400 # N	-1.0 (.815)	-4.9	3.2 (.087)	13.4
	400 # vs 200 #	-4.7 (.295)	-19.9	1.2 (.539)	4.7
Central Idaho	200 # N	0.5 (.914)	1.6	3.4 (.086)	10.9
	400 # N	-2.5 (.555)	-8.2	3.6 (.054)	11.7
	400 # vs 200 #	-2.9 (.539)	-9.6	0.2 (.914)	0.7
Northeast Oregon	200 # N	0.3 (.958)	2.3	5.1 (.056)	21.5
	400 # N	2.0 (.737)	14.8	3.2 (.230)	13.4
	400 # vs 200 #	1.7 (.805)	12.2	-2.0 (.522)	-6.7
Central Washington	200 # N	4.9 (.181)	17.5	7.8 (.000)	25.7
	400 # N	5.3 (.150)	18.8	10.9 (.000)	35.7
	400 # vs 200 #	0.4 (.929)	1.1	3.1 (.000)	8.0
Northeast Washington	200 # N	4.6 (.264)	18.3	4.2 (.026)	13.2
	400 # N	2.8 (.444)	11.4	7.9 (.000)	25.2
	400 # vs 200 #	-1.7 (.684)	-5.9	3.8 (.052)	10.6
Overall	200 # N	3.4 (.125)	12.3	5.5 (.000)	17.3
	400 # N	3.5 (.102)	12.6	7.3 (.000)	23.0
	400 # vs 200 #	0.1 (.972)	0.3	1.8 (.098)	4.8

[1] Averages are adjusted to a common initial basal area of 150 ft²/A.

[2] Numbers in parentheses are significance levels.

Washington, in fact, most regions showed large decreases from gross to net basal area response. 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. Increased mortality when considered over a longer time frame may not be bad depending on stand density and the relative size of trees that die. However, over a short time period, the loss of a few trees on fertilized plots can erase per acre response due to fertilization. The increased variability resulting from mortality, often unrelated to the experiment, makes it unlikely that we will show statistical significance from the analysis.

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

The net and gross volume response 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 all regions except northeastern Oregon. Part of Oregon's volume non-response derives from no height growth effect of the nitrogen treatments. This will be covered in more detail in a subsequent section of this report. For central Washington, the gross volume growth for the 400 lb treatment was significantly greater than the 200 lb treatment. Compared to the six-year results, average relative response remains about the same, thus absolute response increased for every region.

Only in central Washington is there a statistical difference in net volume increment for both nitrogen treatments and the controls. Northern Idaho showed a significant average net volume growth response to the 400 lb nitrogen treatment. The net volume growth for the 400 lb treatment was significantly greater than the 200 lb treatment only in northern Idaho. Mortality fluctuations and consequent variation make it difficult to show statistical differences between treatments, even though response estimates are fairly large for some regions (ex. Montana and northeast Washington).

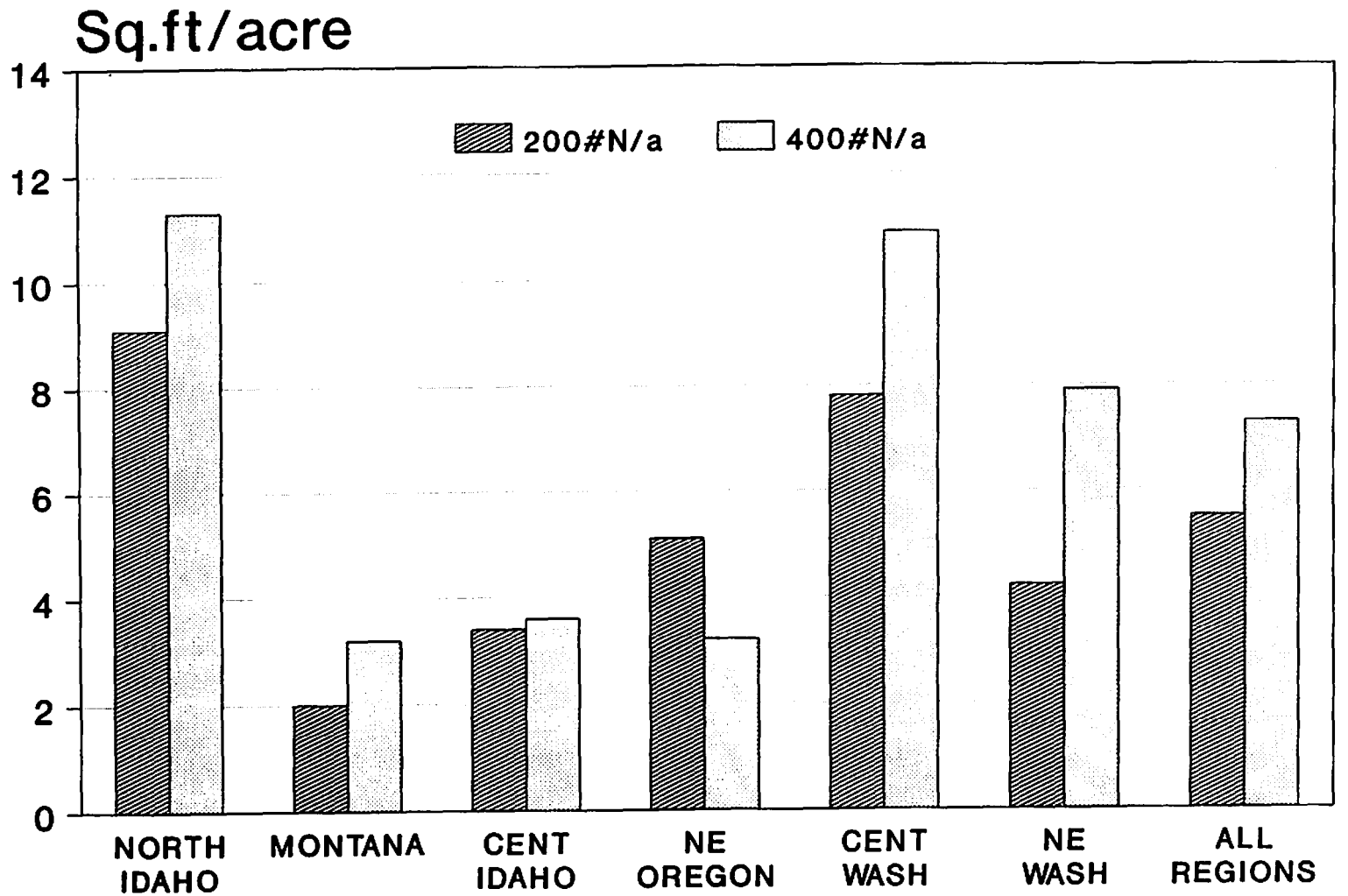

Figure 1a. Average eight-year gross basal area response by region and treatment for the Douglas-fir installations.

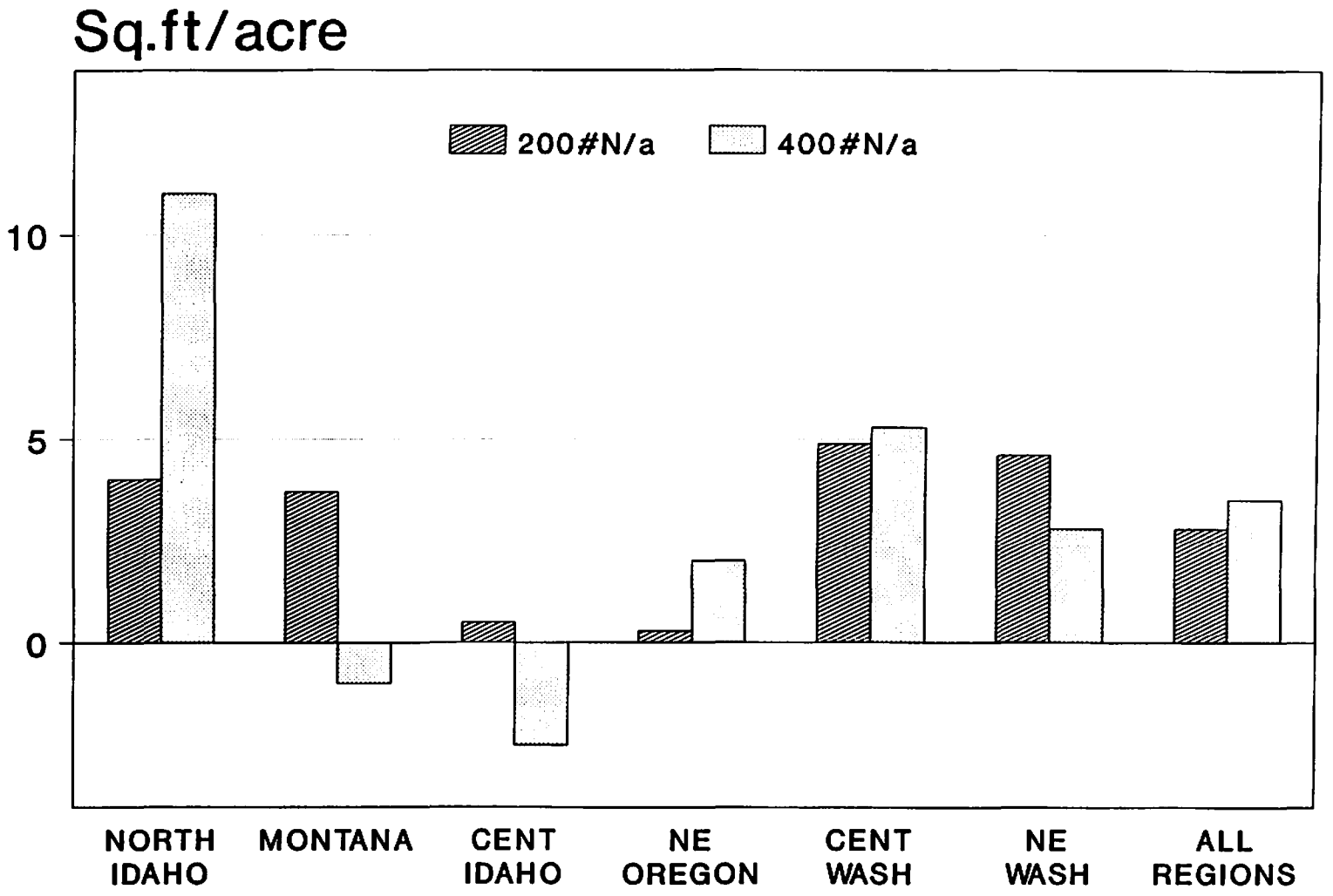

Figure 1b. Average eight-year net basal area response by region and treatment for the Douglas-fir installations.

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.[1]

		Net Volume		Gross Volume	
		Response[2]		Response[2]	
Region	Treatment	ft^3/acre	percent	ft^3/acre	percent
Northern Idaho	200 # N	170 (.188)	10.5	278 (.000)	16.5
	400 # N	418 (.001)	25.8	383 (.000)	22.8
	400 # vs 200 #	249 (.077)	13.9	106 (.144)	5.4
Montana	200 # N	177 (.161)	22.1	121 (.064)	13.2
	400 # N	5 (.970)	0.6	115 (.104)	12.5
	400 # vs 200 #	-172 (.242)	-17.6	-6 (.937)	-0.6
Central Idaho	200 # N	60 (.674)	5.2	130 (.081)	10.9
	400 # N	-60 (.657)	-5.2	115 (.102)	9.7
	400 # vs 200 #	-121 (.440)	-9.9	-14 (.858)	-1.1
Northeast Oregon	200 # N	-2 (.993)	-0.2	132 (.186)	13.3
	400 # N	-66 (.731)	-8.9	43 (.665)	4.3
	400 # vs 200 #	-64 (.770)	-8.7	-89 (.430)	-7.9
Central Washington	200 # N	202 (.095)	17.3	304 (.000)	24.7
	400 # N	226 (.060)	19.4	429 (.000)	34.8
	400 # vs 200 #	25 (.849)	1.8	125 (.062)	8.2
Northeast Washington	200 # N	180 (.181)	16.3	139 (.046)	11.0
	400 # N	92 (.451)	8.3	216 (.001)	17.0
	400 # vs 200 #	-88 (.528)	-6.9	76 (.293)	5.4
Overall	200 # N	147 (.042)	12.8	195 (.000)	15.7
	400 # N	133 (.056)	11.6	244 (.000)	19.6
	400 # vs 200 #	-14 (.857)	-1.1	49 (.231)	3.4

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

[2] Numbers in parentheses are significance levels.

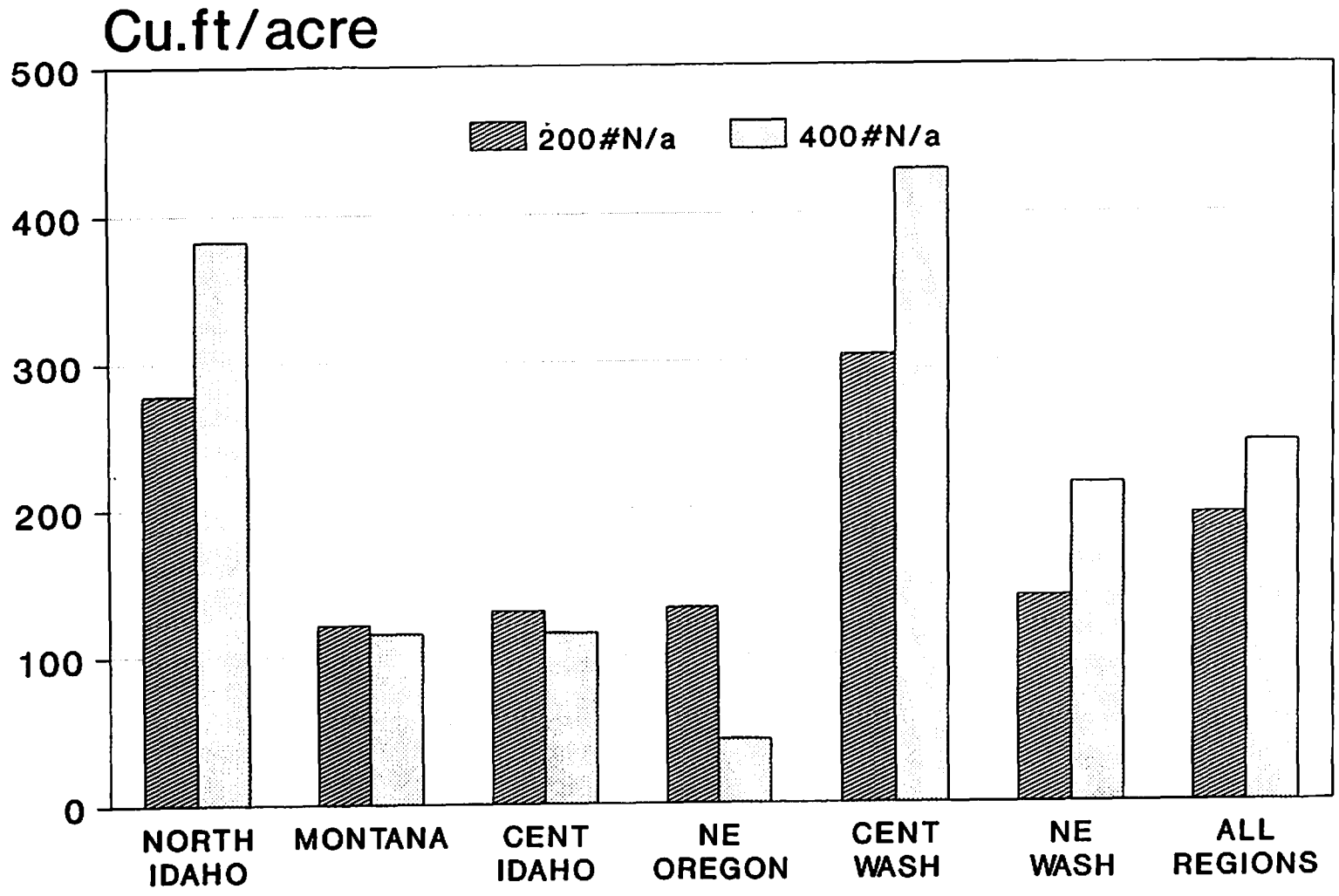

Figure 2a. Average eight-year gross volume response by region and treatment for the Douglas-fir installations.

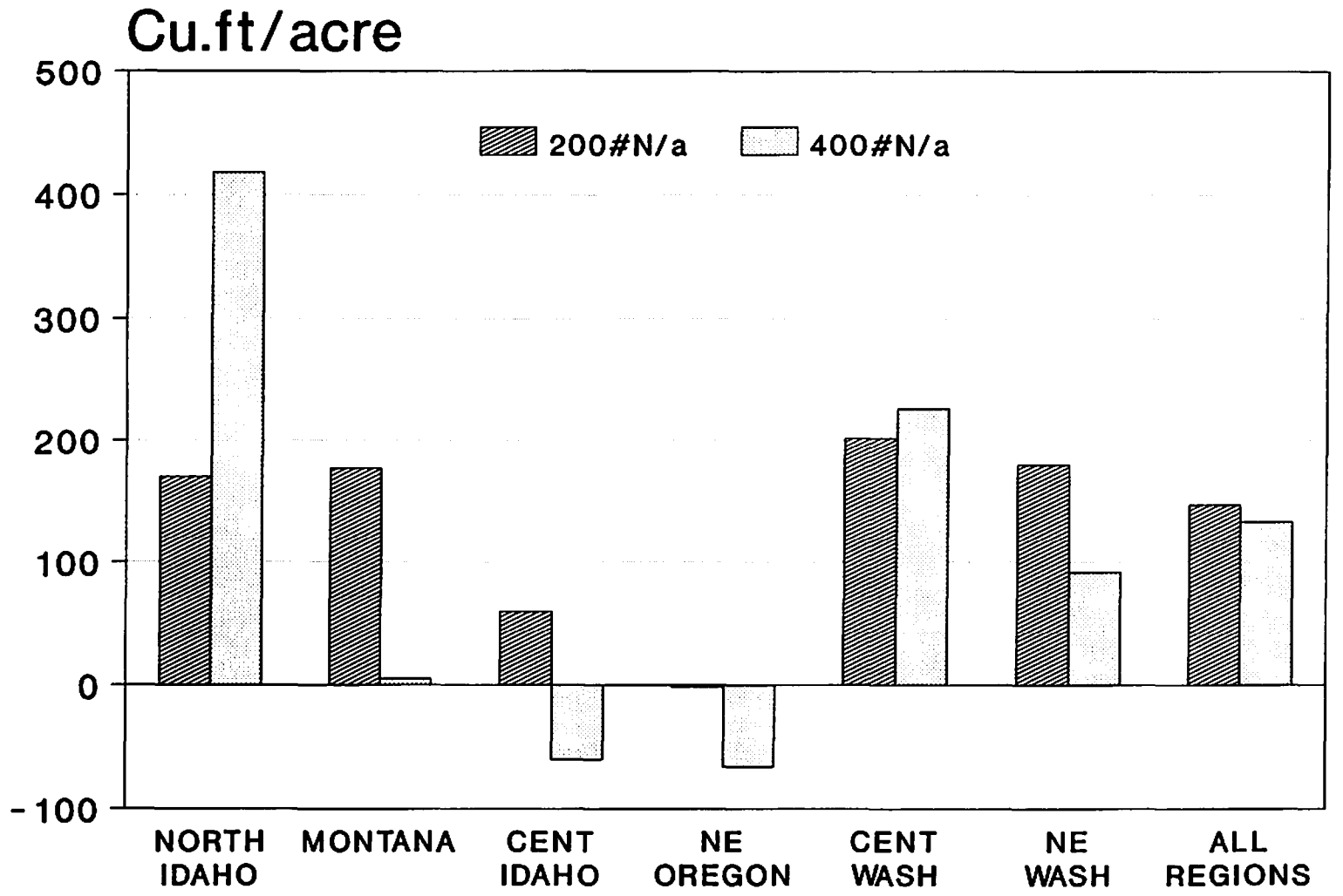

Figure 2b. Average eight-year net volume response by region and treatment for the Douglas-fir installations.

Eight-year height increment response:

Both nitrogen treatments produced significant height growth response in all regions except central Idaho and northeast Oregon (Table 3). There was no significant difference between the two nitrogen treatments for any geographic region. Relative height increment response to fertilization tends to be less than radial growth response. This confirms separate work by Shafii et al 1989. However, the slight differences in relative diameter and height response are unlikely to have any significant impact on stem profiles for most regions.

Average Stand Diameter Response

A 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 in northern Idaho and central Washington. The 200 lb N treatment significantly increased mean tree diameter increment in central Idaho. The 400 lb N treatment produced a significant increase in average stand diameter for Montana and northeast Washington. Neither treatment produced a significant effect on average stand diameter in northeastern Oregon. This response variable is one way to quantify the within-stand effects of N fertilization. In some regions where average net stand level response is not significant, the average stand diameter response is significant.

Duration of Response:

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

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

			Height Increment Response	
Region	Treatment	Total ft/tree	ft/acre	percent
Northern Idaho	Control	9.0	1.2 (.000)	13.6
	200 # N	10.2	1.2 (.000)	13.0
	400 # N	10.2	-0.0 (.892)	-0.5
Montana	Control	5.2	0.8 (.017)	14.6
	200 # N	6.0	0.8 (.019)	15.6
	400 # N	6.1	0.1 (.889)	0.9
Central Idaho	Control	5.8	0.5 (.200)	8.0
	200 # N	6.3	0.4 (.200)	7.6
	400 # N	6.3	-0.0 (953)	-0.4
Northeast Oregon	Control	6.0	0.3 (.570)	4.6
	200 # N	6.3	0.0 (.998)	0.0
	400 # N	6.0	-0.3 (.619)	-4.4
Central Washington	Control	6.3	1.4 (.000)	22.9
	200 # N	7.7	1.7 (.000)	27.5
	400 # N	8.0	0.3 (.377)	3.8
Northeast Washington	Control	7.6	0.6 (.078)	7.9
	200 # N	8.2	0.6 (.038)	8.4
	400 # N	8.3	0.0 (.906)	0.5
Overall	Control	6.8	0.9 (.000)	12.8
	200 # N	7.7	0.9 (.000)	13.3
	400 # N	7.7	0.0 (.860)	0.5

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

[2] Numbers in parentheses are significance levels.

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

		Change in Average Stand Diameter		
Region	Treatment	Growth (inches)	Response (inches)	percent
Northern Idaho	Control	1.4	0.4 (.001)	24.5
	200 # N	1.8	0.4 (.000)	26.2
	400 # N	1.8	0.0 (.836)	1.3
Montana	Control	0.8	0.1 (.496)	9.0
	200 # N	0.9	0.2 (.034)	30.8
	400 # N	1.0	0.2 (.161)	19.9
Central Idaho	Control	1.0	0.2 (.063)	22.2
	200 # N	1.2	0.2 (.133)	17.0
	400 # N	1.2	-0.1 (.687)	-4.3
Northeast Oregon	Control	1.3	0.1 (.487)	8.8
	200 # N	1.4	-0.1 (.500)	-8.5
	400 # N	1.2	-0.2 (.231)	-15.8
Central Washington	Control	1.2	0.3 (.010)	21.9
	200 # N	1.4	0.3 (.001)	29.2
	400 # N	1.5	0.1 (.419)	6.0
Northeast Washington	Control	1.1	0.2 (.139)	14.7
	200 # N	1.3	0.4 (.000)	32.1
	400 # N	1.5	0.2 (.091)	15.3
Overall	Control	1.1	0.2 (.001)	18.4
	200 # N	1.3	0.3 (.000)	23.5
	400 # N	1.4	0.1 (.370)	4.3

[1] Numbers in parentheses are significance levels.

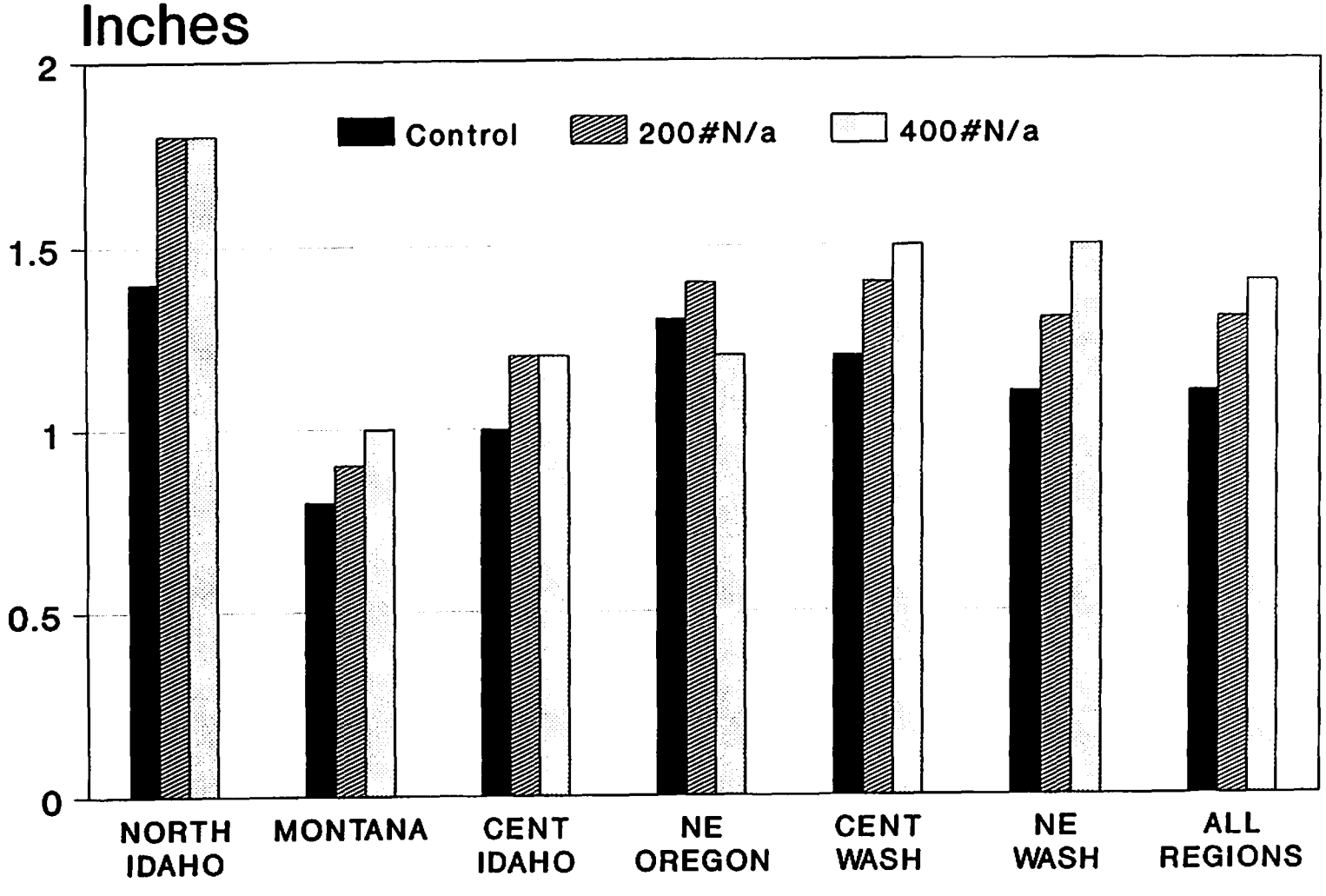

Figure 3. Average eight-year change in average stand diameter by region and treatment for the Douglas-fir installations.

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.[1]

		Basal area increment in the first two years			
		Net Response		Gross Response	
Region	Treatment	ft²/A/yr	percent	ft²/A/yr	percent
Northern Idaho	200 # N	1.4 (.002)	23.0	1.9 (.000)	33.1
	400 # N	2.2 (.000)	37.0	2.2 (.000)	38.7
	400 # vs 200 #	0.8 (.074)	11.4	0.3 (.338)	4.2
Montana	200 # N	0.8 (.040)	25.7	0.6 (.040)	17.3
	400 # N	0.8 (.067)	24.2	0.7 (.027)	19.6
	400 # vs 200 #	-0.1 (.947)	-1.2	0.1 (.803)	2.0
Central Idaho	200 # N	1.2 (.012)	28.1	1.0 (.006)	22.6
	400 # N	1.2 (.007)	29.0	1.1 (.001)	25.9
	400 # vs 200 #	0.0 (.947)	0.6	0.1 (.710)	2.7
Northeast Oregon	200 # N	1.2 (.055)	35.2	1.1 (.022)	31.2
	400 # N	1.3 (.045)	36.4	1.1 (.018)	32.0
	400 # vs 200 #	0.0 (.951)	0.9	.027 (.959)	0.6
Central Washington	200 # N	1.8 (.000)	40.0	1.6 (.000)	36.7
	400 # N	1.8 (.000)	40.1	2.1 (.000)	46.8
	400 # vs 200 #	0.0 (.994)	0.0	0.4 (.161)	7.4
Northeast Washington	200 # N	1.0 (.024)	21.4	1.1 (.001)	22.9
	400 # N	1.7 (.000)	35.3	1.7 (.000)	37.1
	400 # vs 200 #	0.7 (.158)	11.5	0.7 (.056)	11.5
Overall	200 # N	1.2 (.000)	28.1	1.3 (.000)	28.1
	400 # N	1.5 (.000)	34.5	1.6 (.000)	35.1
	400 # vs 200 #	0.3 (.265)	5.0	0.3 (.102)	5.4

Table 5. (cont.)

		Basal area increment in the second two years			
		Net Response		Gross Response	
Region	Treatment	ft^2/A/yr	percent	ft^2/A/yr	percent
Northern Idaho	200 # N	-0.4 (.720)	-9.0	1.2 (.000)	22.2
	400 # N	0.4 (.681)	10.0	1.7 (.000)	31.9
	400 # vs 200 #	0.8 (.486)	20.8	0.5 (.075)	7.9
Montana	200 # N	0.3 (.789)	13.0	0.3 (.254)	9.5
	400 # N	-0.5 (.654)	-23.0	0.2 (.437)	6.9
	400 # vs 200 #	-0.8 (.511)	-31.9	-0.1 (.777)	-2.4
Central Idaho	200 # N	0.1 (.929)	2.3	0.5 (.128)	9.8
	400 # N	-0.4 (.731)	-8.3	0.4 (.135)	9.1
	400 # vs 200 #	-0.5 (.702)	-10.4	-0.0 (.926)	-0.6
Northeast Oregon	200 # N	-2.5 (.123)	-112.1	0.7 (.107)	18.0
	400 # N	-1.5 (.366)	-64.8	0.2 (.630)	5.3
	400 # vs 200 #	1.1 (.565)	-392.2	-0.5 (.316)	-10.7
Central Washington	200 # N	0.9 (.386)	22.4	1.2 (.000)	30.2
	400 # N	1.3 (.208)	32.3	1.7 (.000)	41.8
	400 # vs 200 #	0.4 (.719)	8.1	0.5 (.078)	8.9
Northeast Washington	200 # N	-0.1 (.947)	-2.5	0.5 (.062)	11.7
	400 # N	-0.7 (.523)	-21.2	0.9 (.000)	20.6
	400 # vs 200 #	-0.6 (.623)	-19.2	0.4 (.170)	8.0
Overall	200 # N	-0.1 (.878)	-2.6	0.8 (.000)	17.9
	400 # N	-0.1 (.924)	-1.6	1.0 (.000)	22.8
	400 # vs 200 #	0.0 (.954)	1.1	0.2 (.193)	4.2

Table 5. (cont.)

		Basal area increment in the third two years			
		Net Response		Gross Response	
Region	Treatment	$ft^2/A/yr$	percent	$ft^2/A/yr$	percent
Northern Idaho	200 # N	0.3 (.746)	6.1	0.6 (.008)	11.0
	400 # N	1.2 (.198)	23.5	0.8 (.000)	15.0
	400 # vs 200 #	0.9 (.393)	16.4	0.2 (.370)	3.6
Montana	200 # N	0.5 (.599)	20.3	0.1 (.825)	1.7
	400 # N	-0.6 (.502)	-27.5	0.1 (.524)	5.2
	400 # vs 200 #	-1.1 (.274)	-39.7	0.0 (.689)	3.4
Central Idaho	200 # N	-0.5 (.622)	-16.57	0.1 (.771)	2.1
	400 # N	-0.7 (.462)	-23.5	0.2 (.445)	5.4
	400 # vs 200 #	-0.2 (.850)	-8.3	0.1 (.690)	3.1
Northeast Oregon	200 # N	-0.3 (.824)	-24.9	0.4 (.219)	15.8
	400 # N	-1.4 (.305)	-114.1	0.1 (.856)	2.3
	400 # vs 200 #	-1.1 (.485)	-118.9	-0.4 (.355)	-11.7
Central Washington	200 # N	0.3 (.697)	10.8	0.6 (.004)	17.3
	400 # N	-0.2 (.847)	-5.3	1.1 (.000)	29.6
	400 # vs 200 #	-0.5 (.589)	-14.5	0.4 (.053)	10.4
Northeast Washington	200 # N	1.2 (.215)	53.2	0.3 (.143)	9.7
	400 # N	0.1 (.923)	3.8	0.7 (.001)	20.6
	400 # vs 200 #	-1.1 (.269)	-32.2	0.4 (.113)	10.0
Overall	200 # N	0.3 (.535)	10.6	0.4 (.004)	10.0
	400 # N	-0.1 (.788)	-4.4	0.6 (.000)	15.4
	400 # vs 200 #	-0.5 (.422)	-13.6	0.2 (.139)	5.0

Table 5. (cont.)

		Basal area increment in the fourth two years			
		Net Response		Gross Response	
Region	Treatment	$ft^2/A/yr$	percent	$ft^2/A/yr$	percent
Northern	200 # N	0.7 (.447)	14.7	0.8 (.000)	15.4
Idaho	400 # N	1.7 (.066)	34.6	0.8 (.000)	15.8
	400 # vs 200 #	1.0 (.342)	17.4	0.0 (.935)	0.3
Montana	200 # N	0.3 (.727)	12.6	0.1 (.679)	2.7
	400 # N	-0.8 (.412)	-32.1	0.1 (.526)	4.4
	400 # vs 200 #	-1.2 (.289)	-39.7	0.1 (.814)	1.7
Central	200 # N	-0.6 (.582)	-18.9	0.2 (.345)	6.1
Idaho	400 # N	-1.3 (.217)	-40.3	0.1 (.605)	3.2
	400 # vs 200 #	-0.7 (.567)	-26.4	-0.1 (.676)	-2.8
Northeast	200 # N	1.7 (.232)	-855.1	0.4 (.157)	18.2
Oregon	400 # N	2.6 (.065)	-1313.4	0.2 (.430)	10.0
	400 # vs 200 #	0.9 (.573)	60.7	-0.2 (.575)	-6.9
Central	200 # N	-0.6 (.526)	-20.7	0.4 (.019)	13.0
Washington	400 # N	-0.1 (.959)	-1.7	0.7 (.000)	20.5
	400 # vs 200 #	0.5 (.587)	24.0	0.2 (.208)	6.6
Northeast	200 # N	0.2 (.856)	6.8	0.1 (.616)	3.3
Washington	400 # N	0.3 (.727)	11.8	0.6 (.002)	18.1
	400 # vs 200 #	0.1 (.897)	4.7	0.5 (.022)	14.6
Overall	200 # N	0.2 (.711)	6.8	0.4 (.001)	10.0
	400 # N	0.3 (.534)	10.9	0.5 (.000)	13.3
	400 # vs 200 #	0.1 (.836)	3.9	0.1 (.322)	3.0

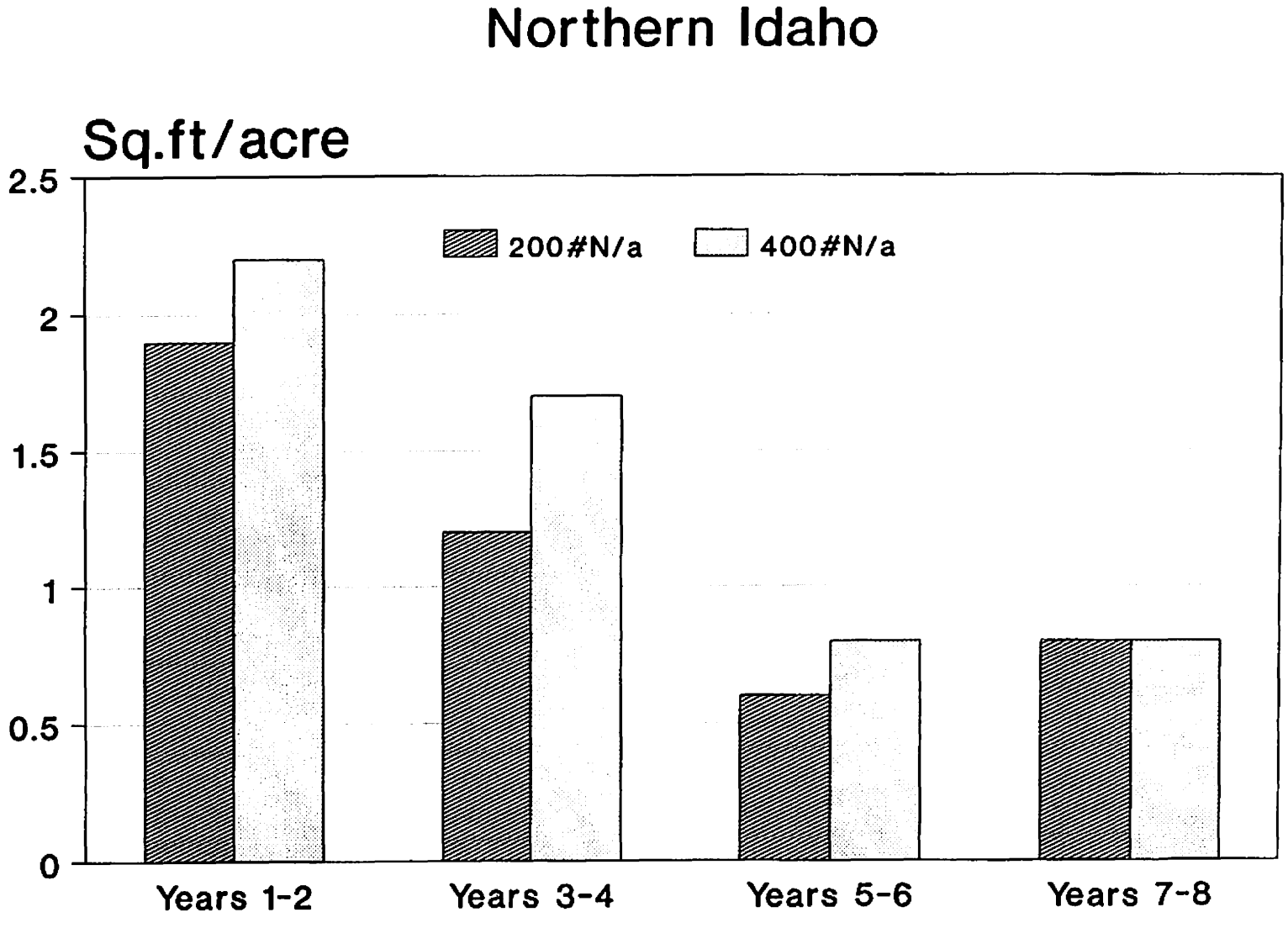

Figure 4a. Average periodic gross basal area response by treatment for the northern Idaho Douglas-fir installations.

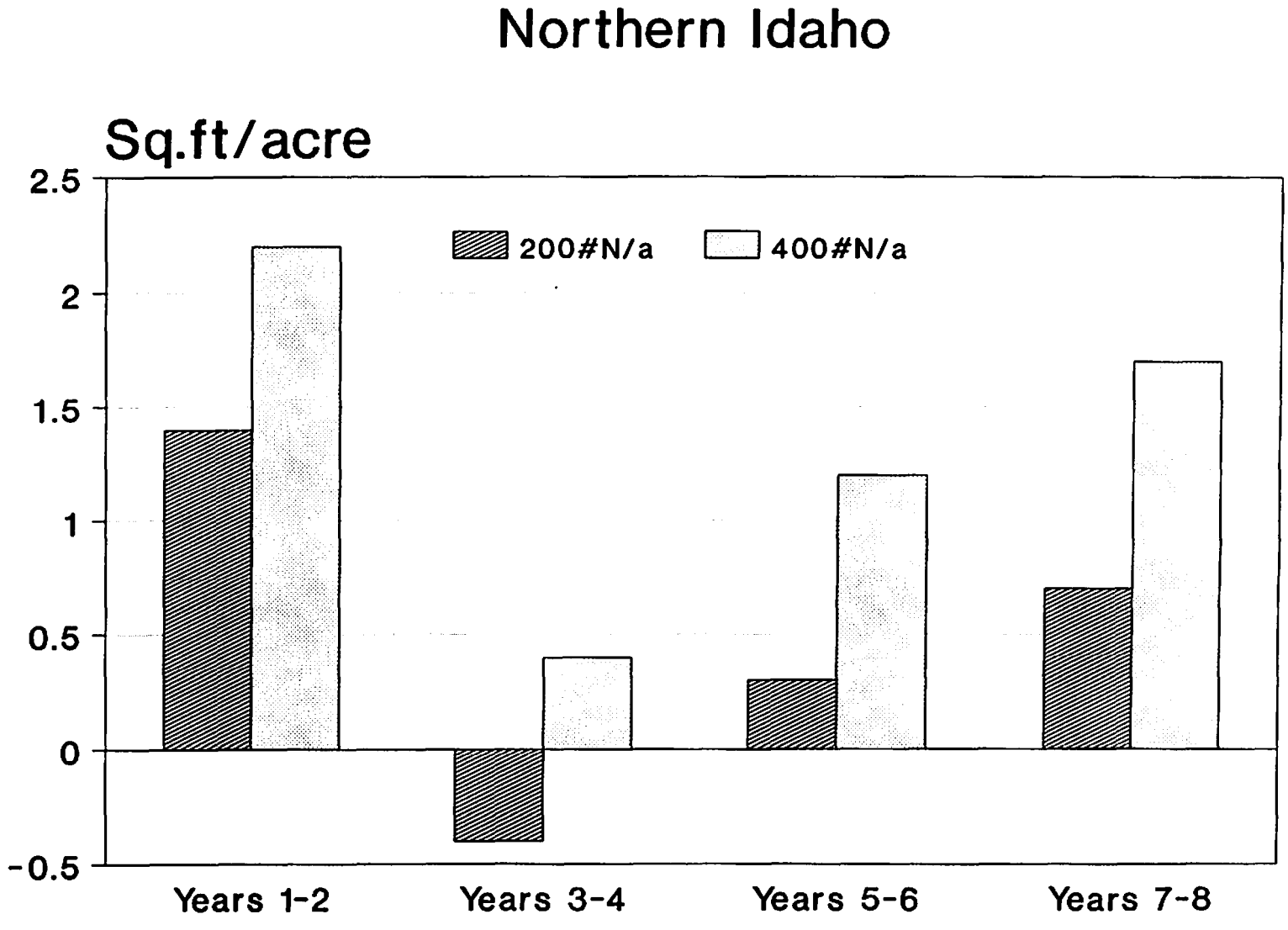

Figure 4b. Average periodic net basal area response by treatment for the northern Idaho Douglas-fir installations.

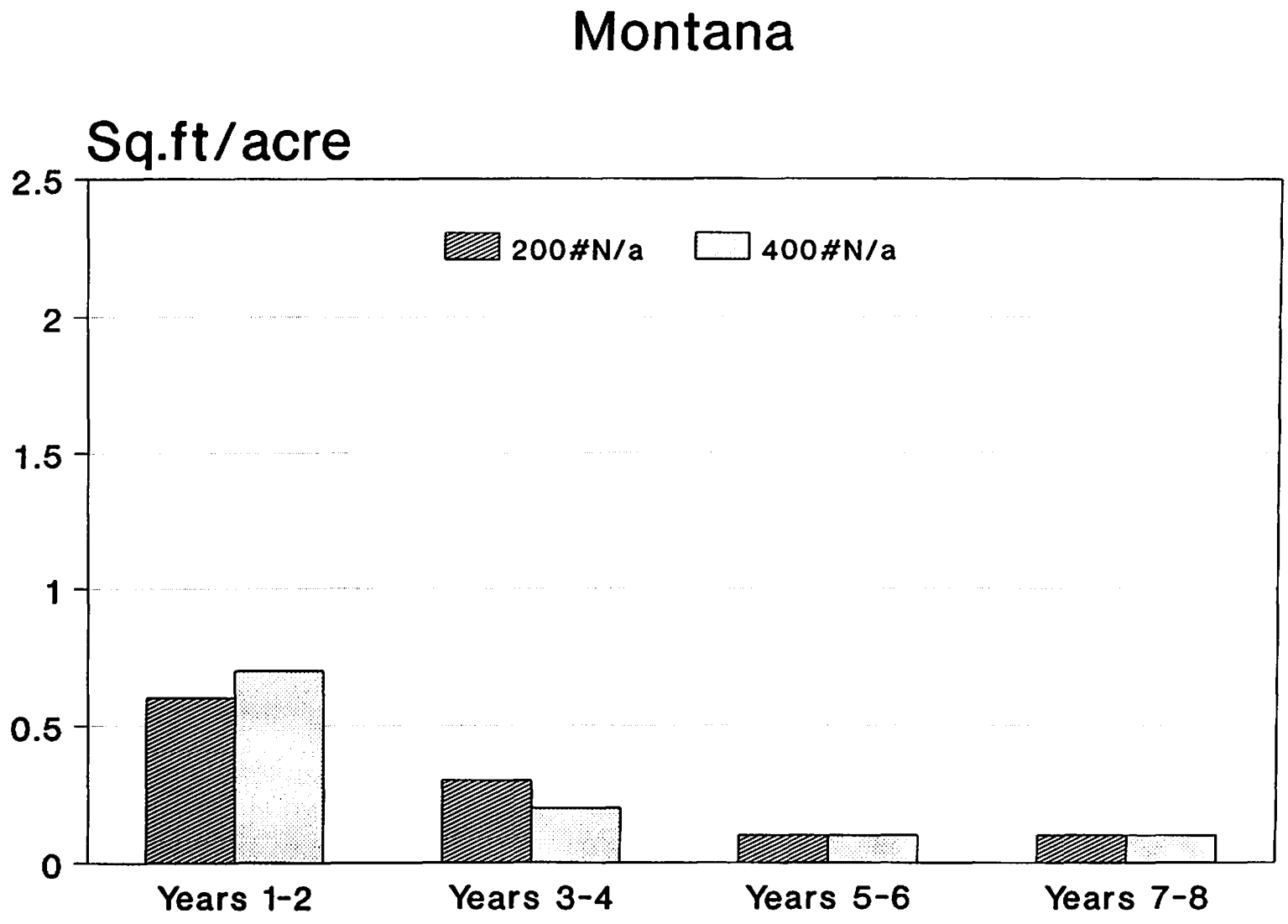

Figure 5a. Average periodic gross basal area response by treatment for the Montana Douglas-fir installations.

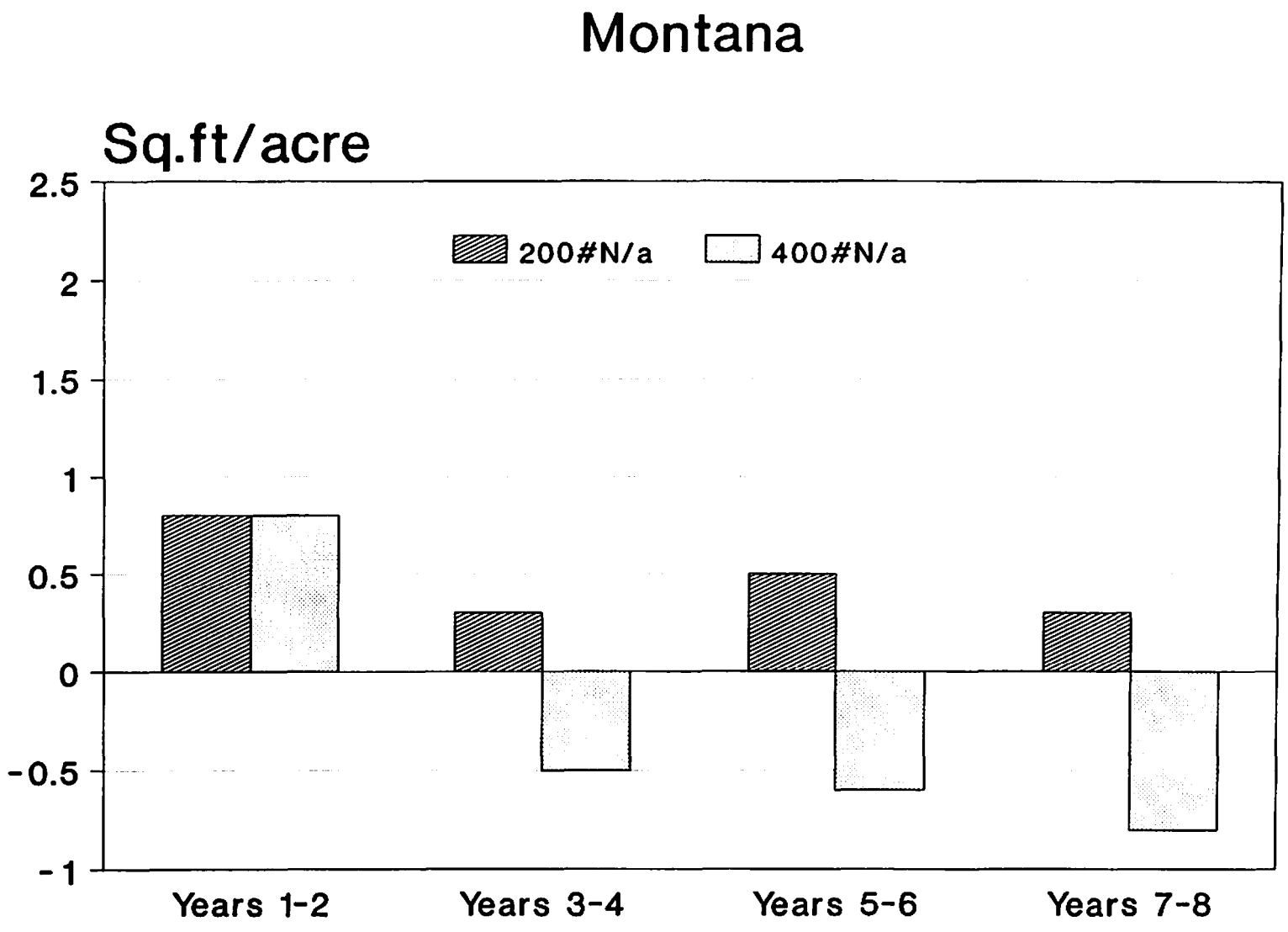

Figure 5b. Average periodic net basal area response by treatment for the Montana Douglas-fir installations.

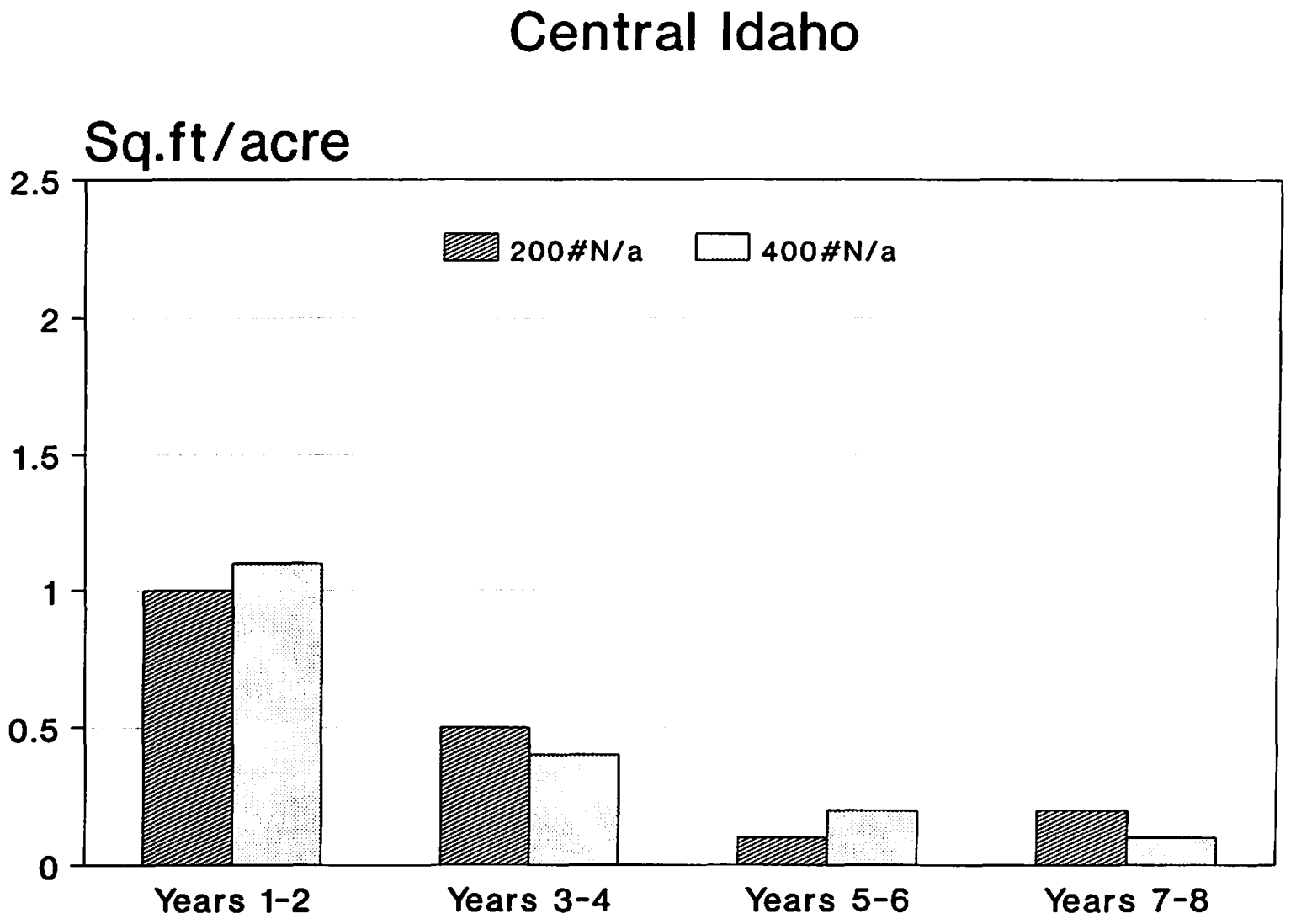

Figure 6a. Average periodic gross basal area response by treatment for the central Idaho Douglas-fir installations.

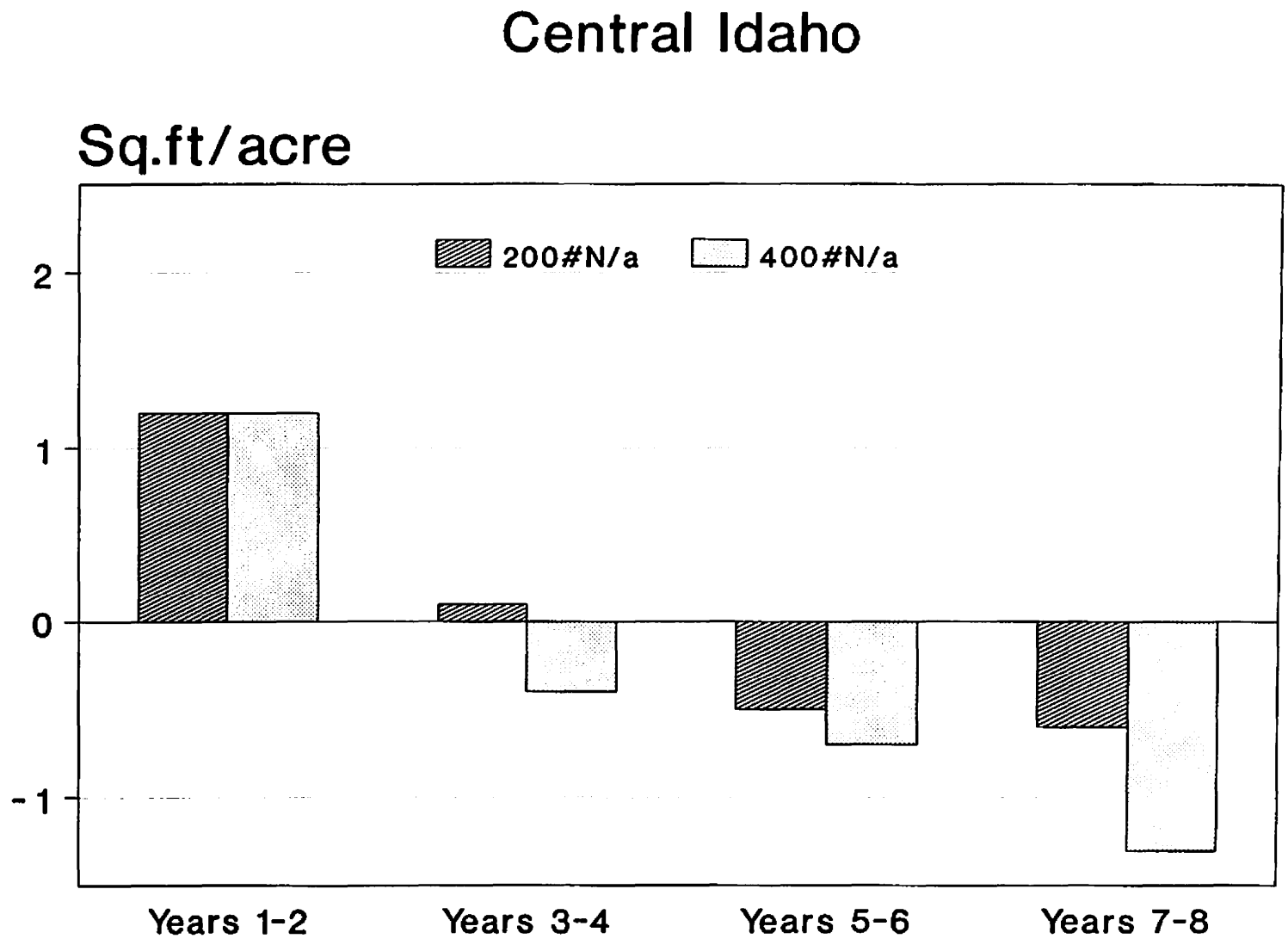

Figure 6b. Average periodic net basal area response by treatment for the central Idaho Douglas-fir installations.

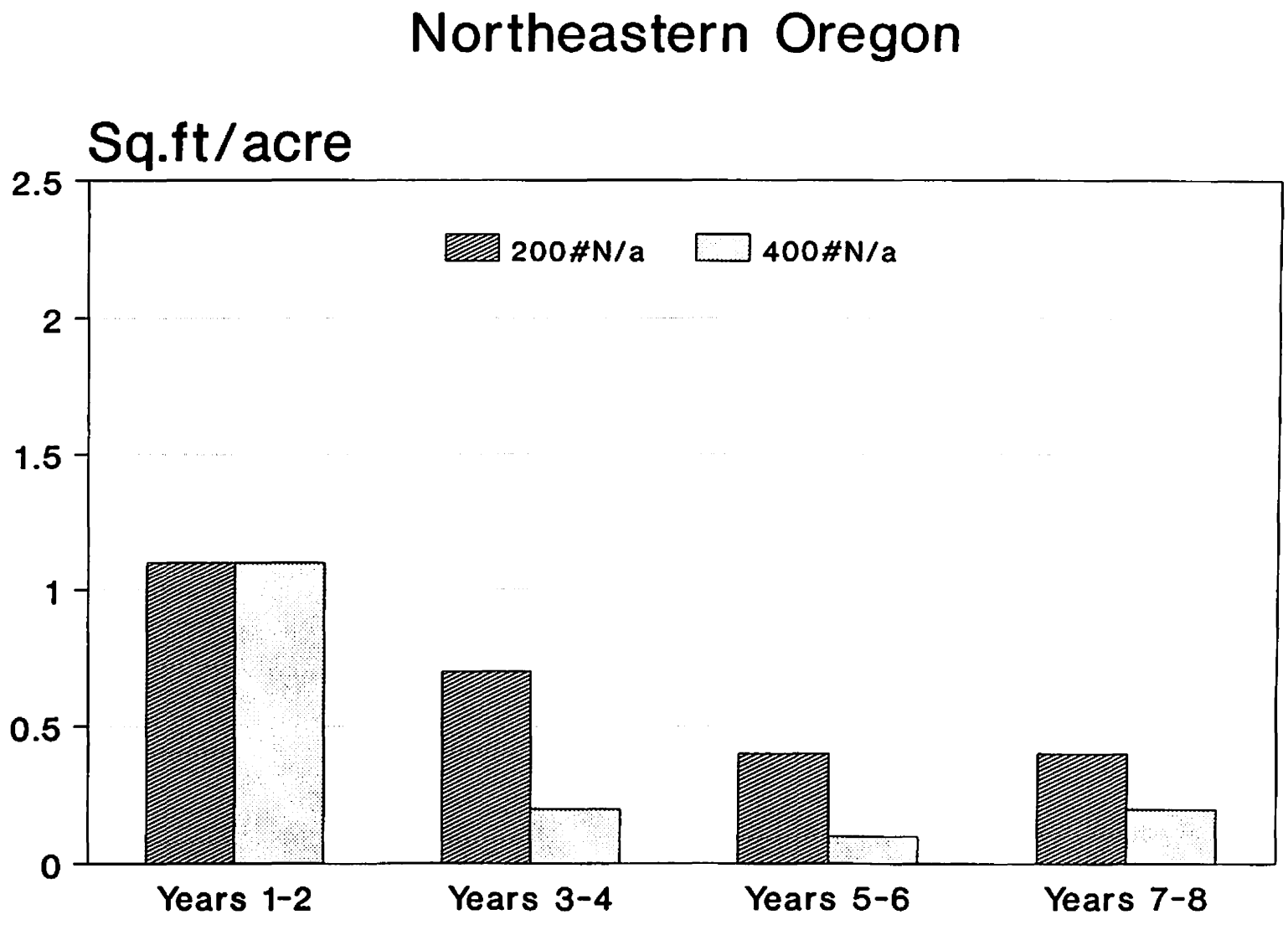

Figure 7a. Average periodic gross basal area response by treatment for the northeast Oregon Douglas-fir installations.

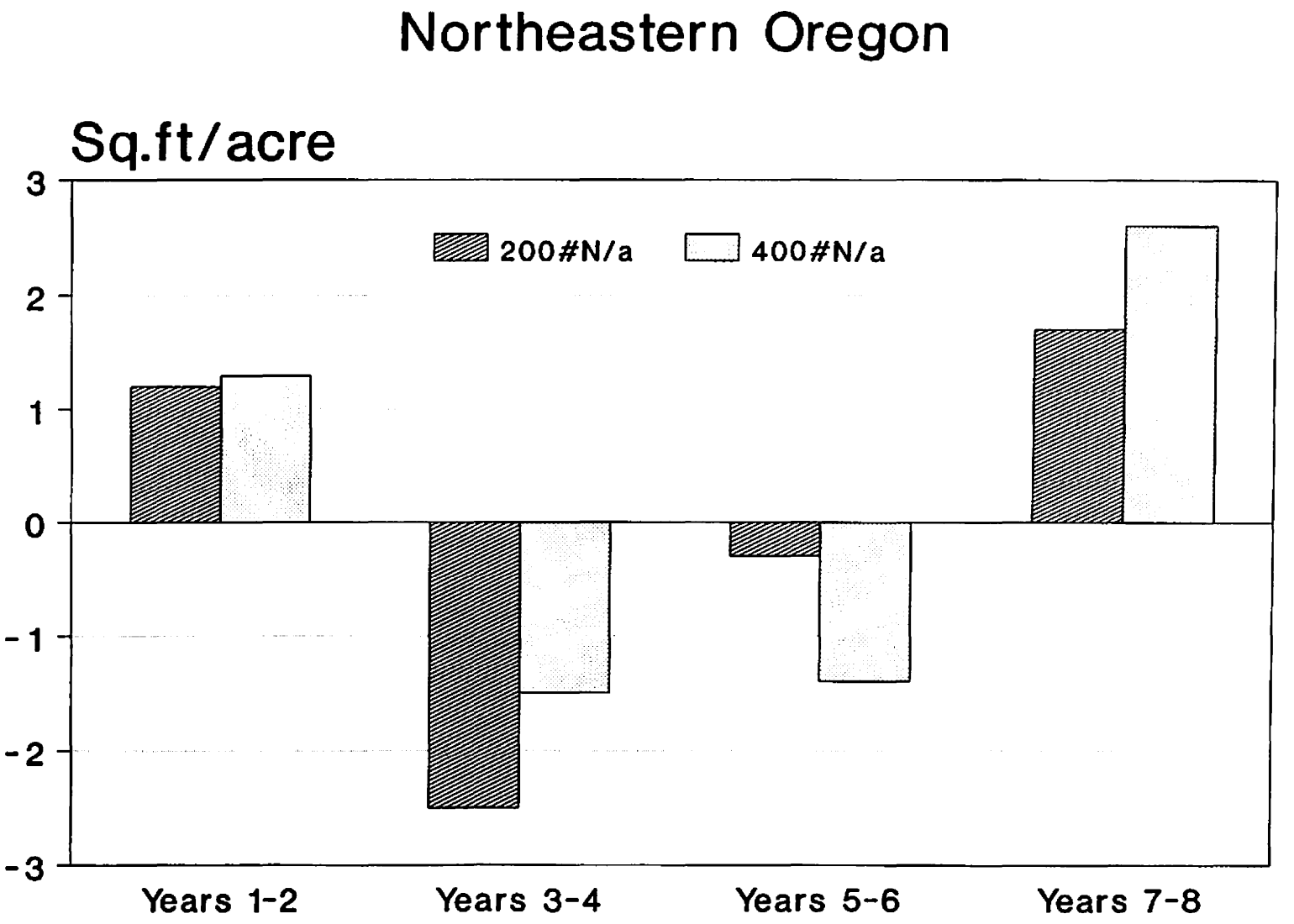

Figure 7b. Average periodic net basal area response by treatment for the northeastern Oregon Douglas-fir installations.

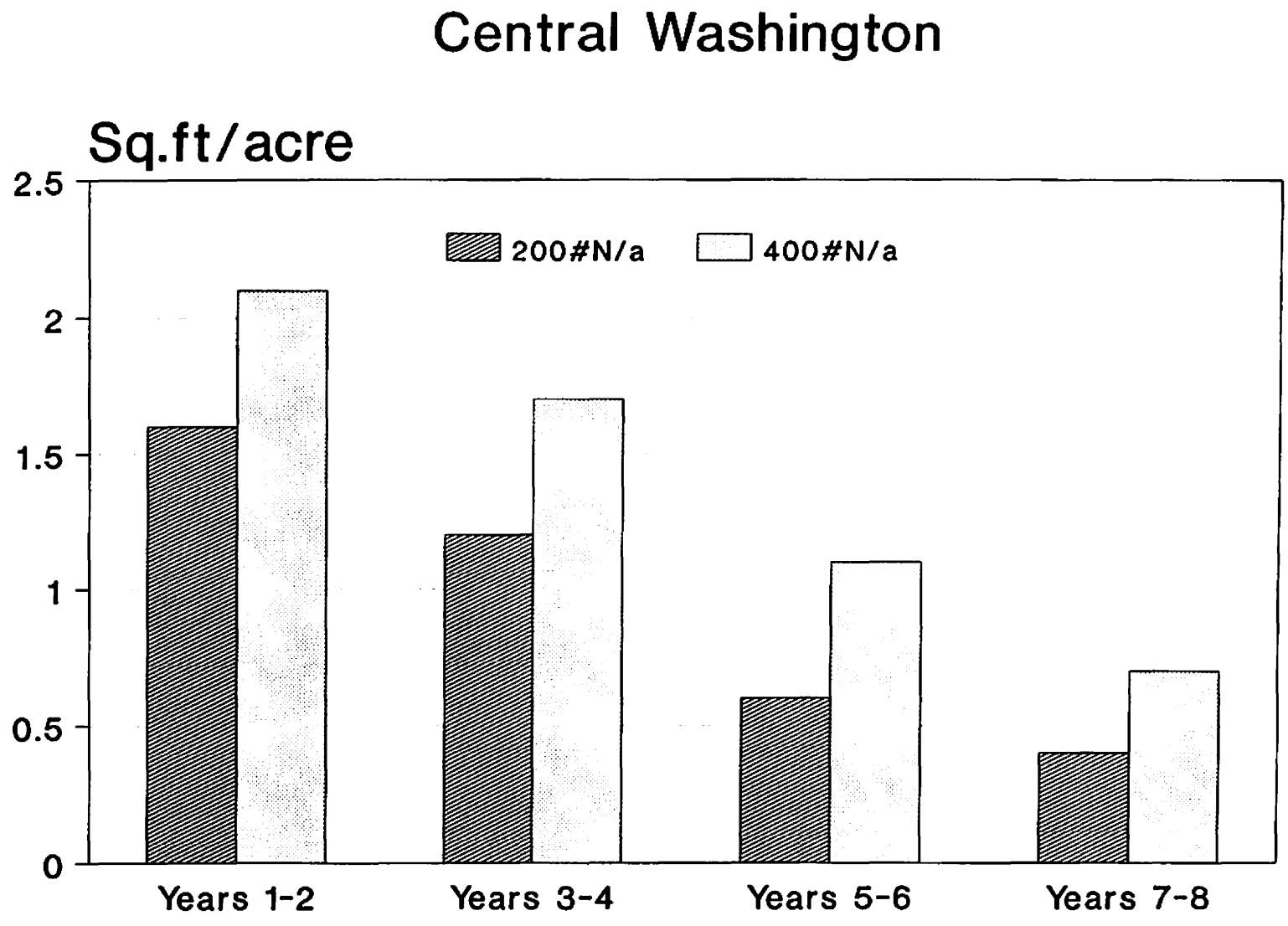

Figure 8a. Average periodic gross basal area response by treatment for the central Washington Douglas-fir installations.

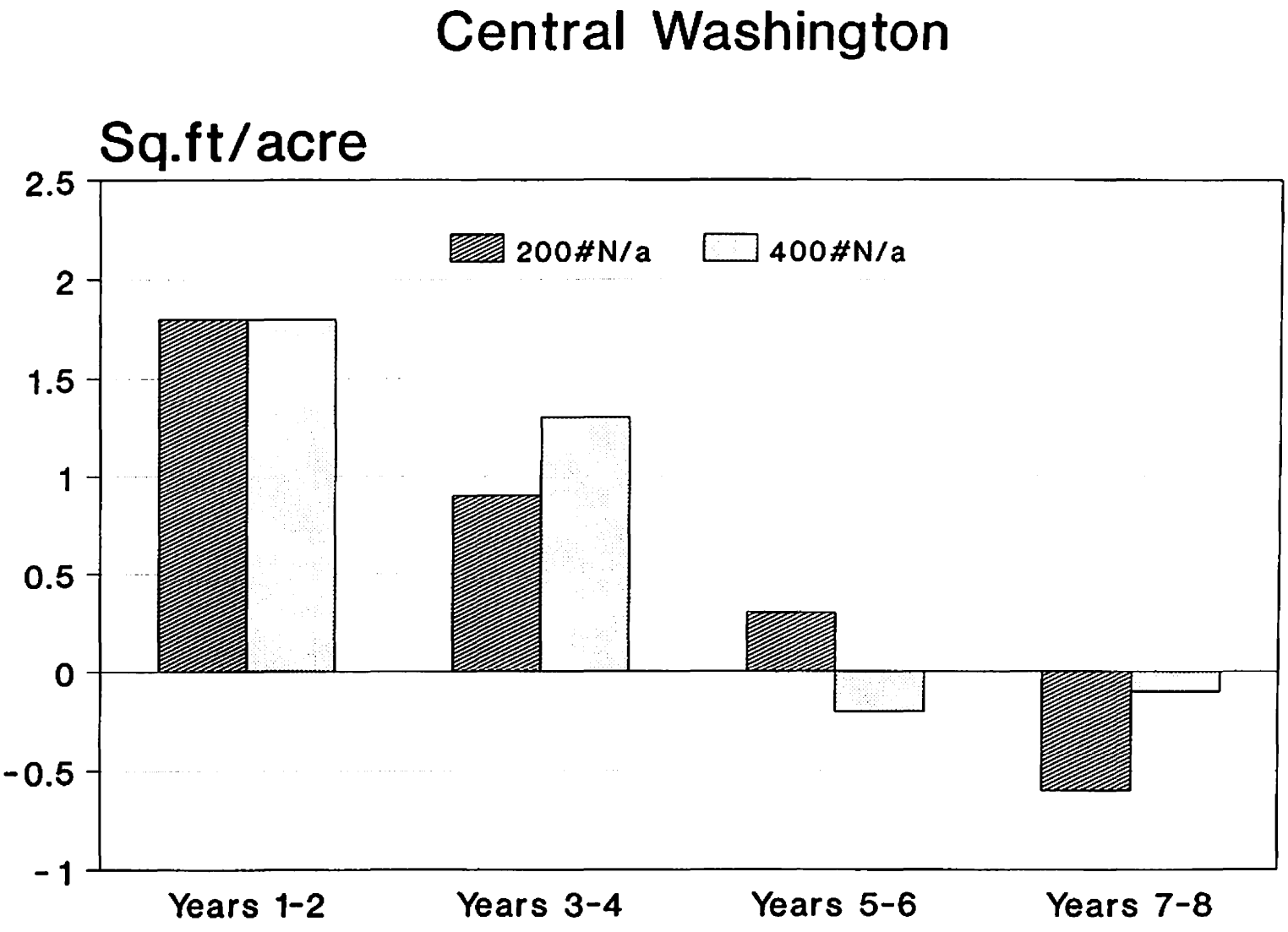

Figure 8b. Average periodic net basal area response by treatment for the central Washington Douglas-fir installations.

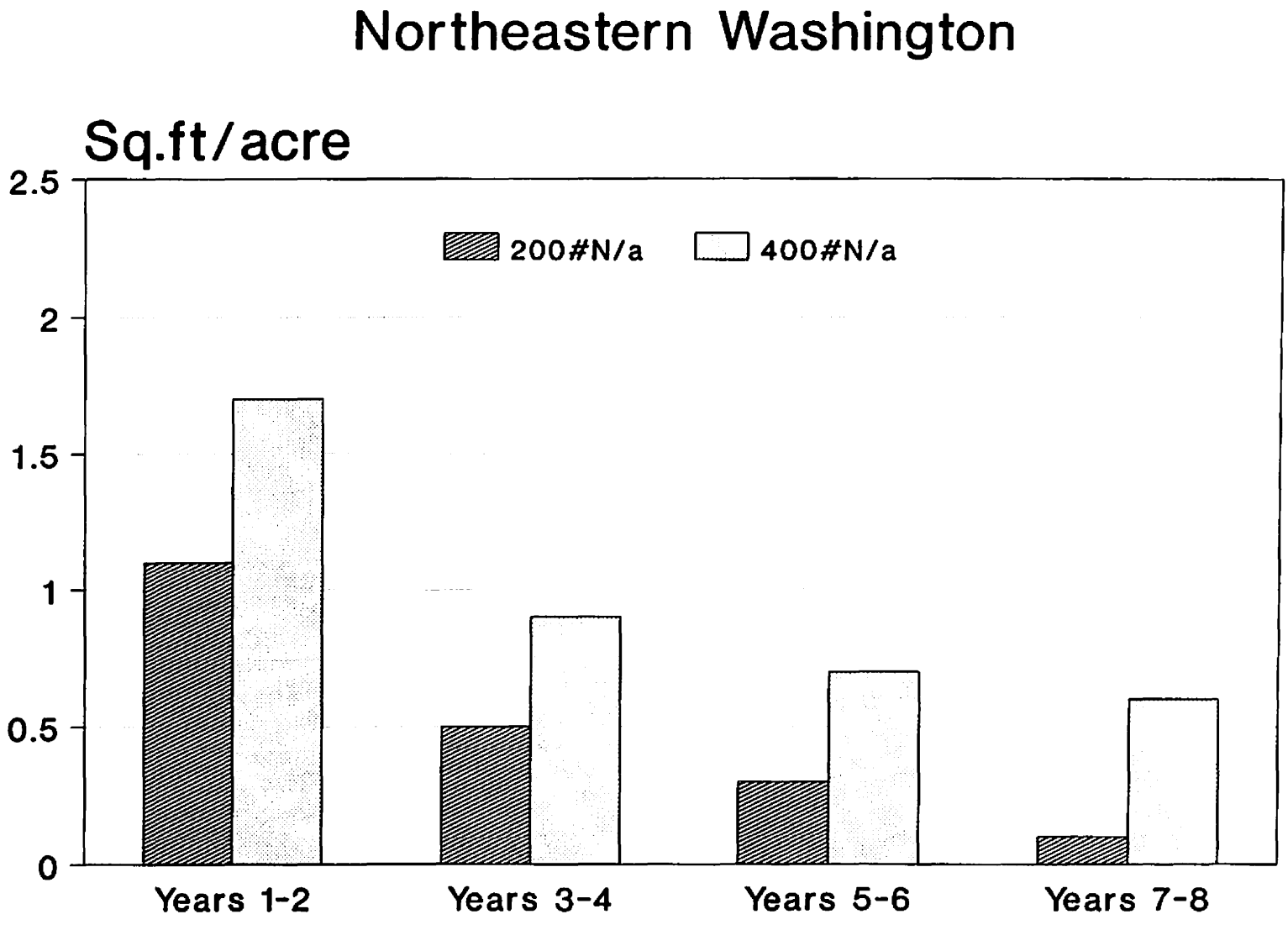

Figure 9a. Average periodic gross basal area response by treatment for the northeastern Washington Douglas-fir installations.

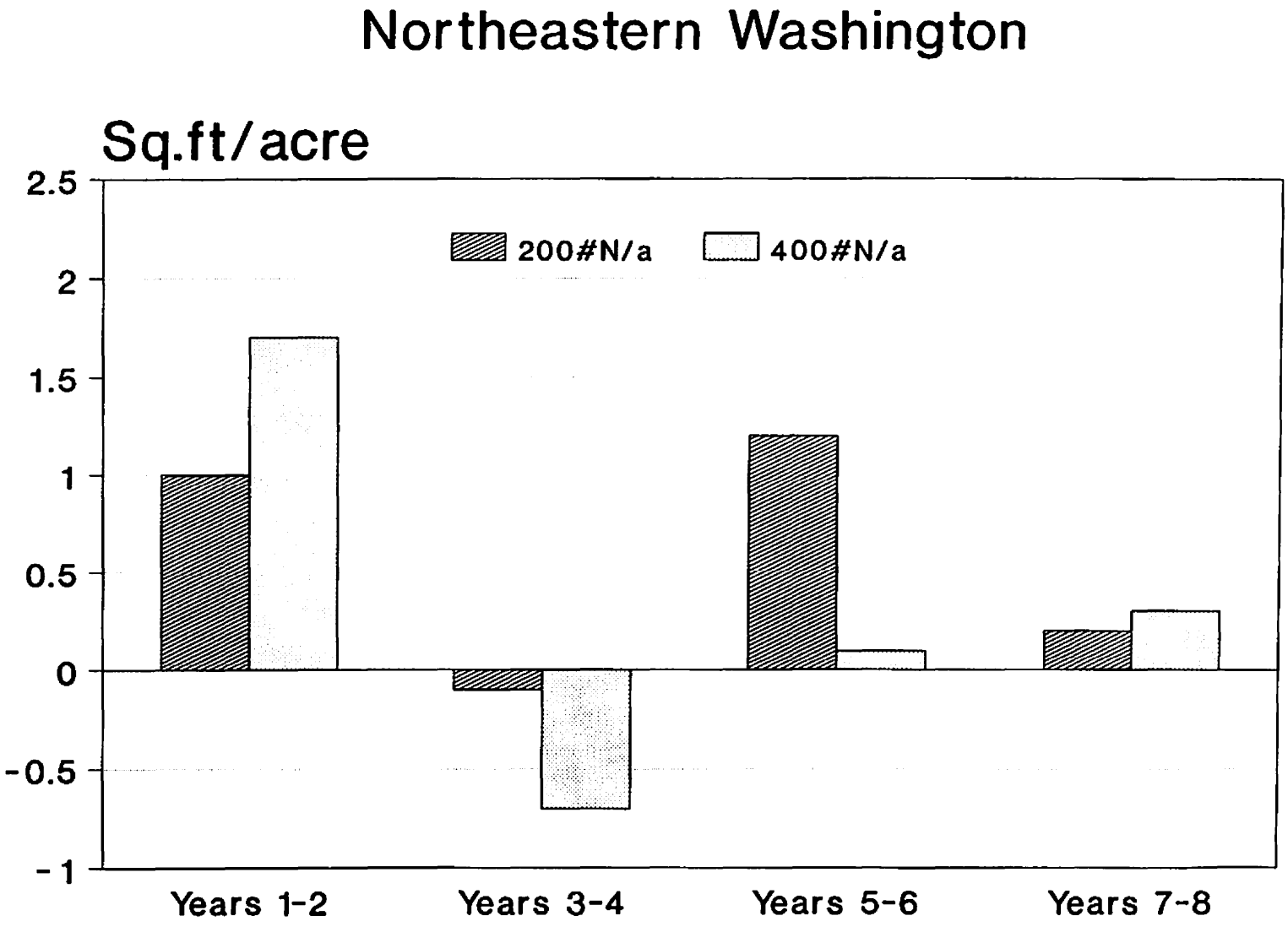

Figure 9b. Average periodic net basal area response by treatment for the northeastern Washington Douglas-fir installations.

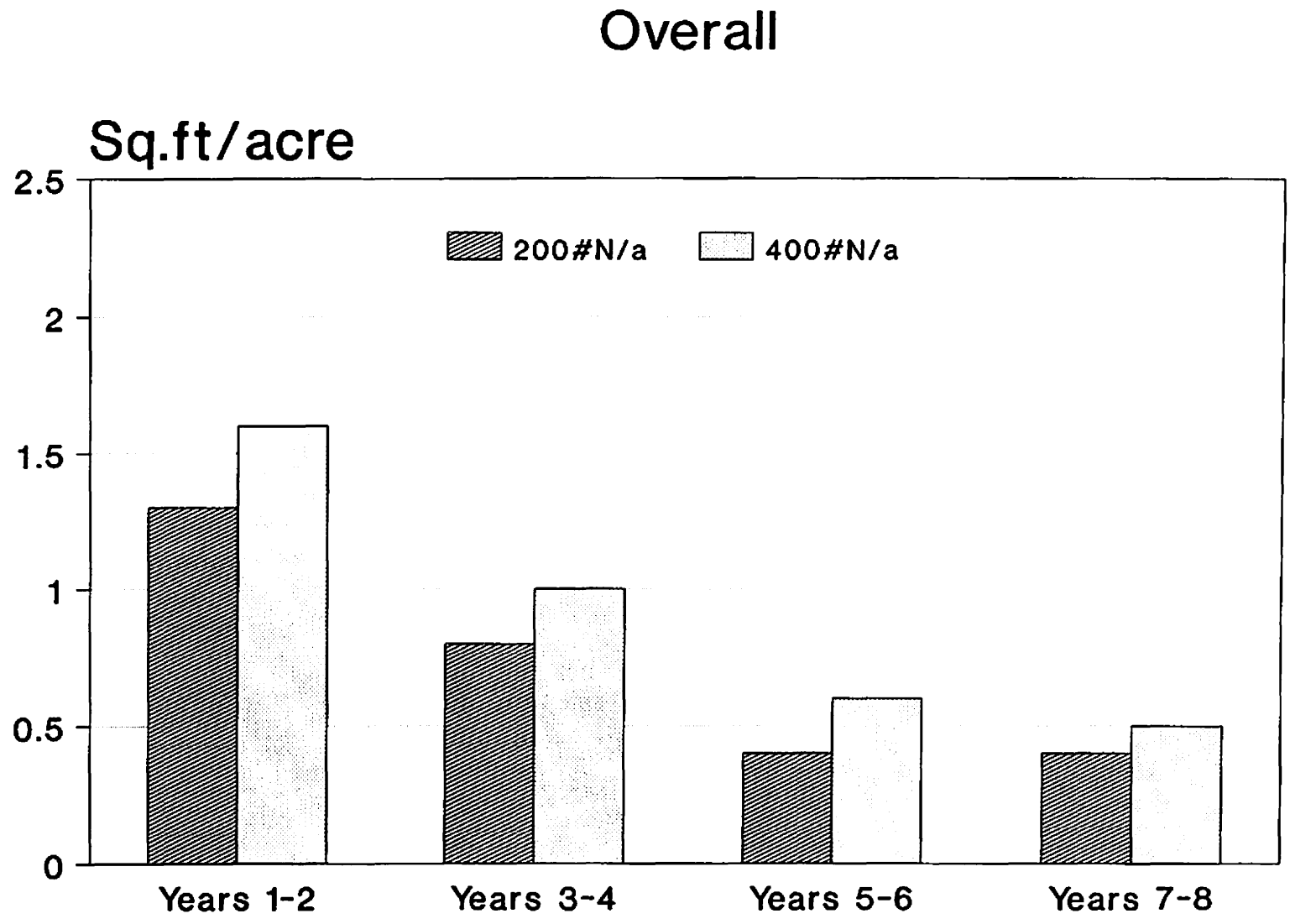

Figure 10a. Average periodic gross basal area response by treatment for all Douglas-fir installations.

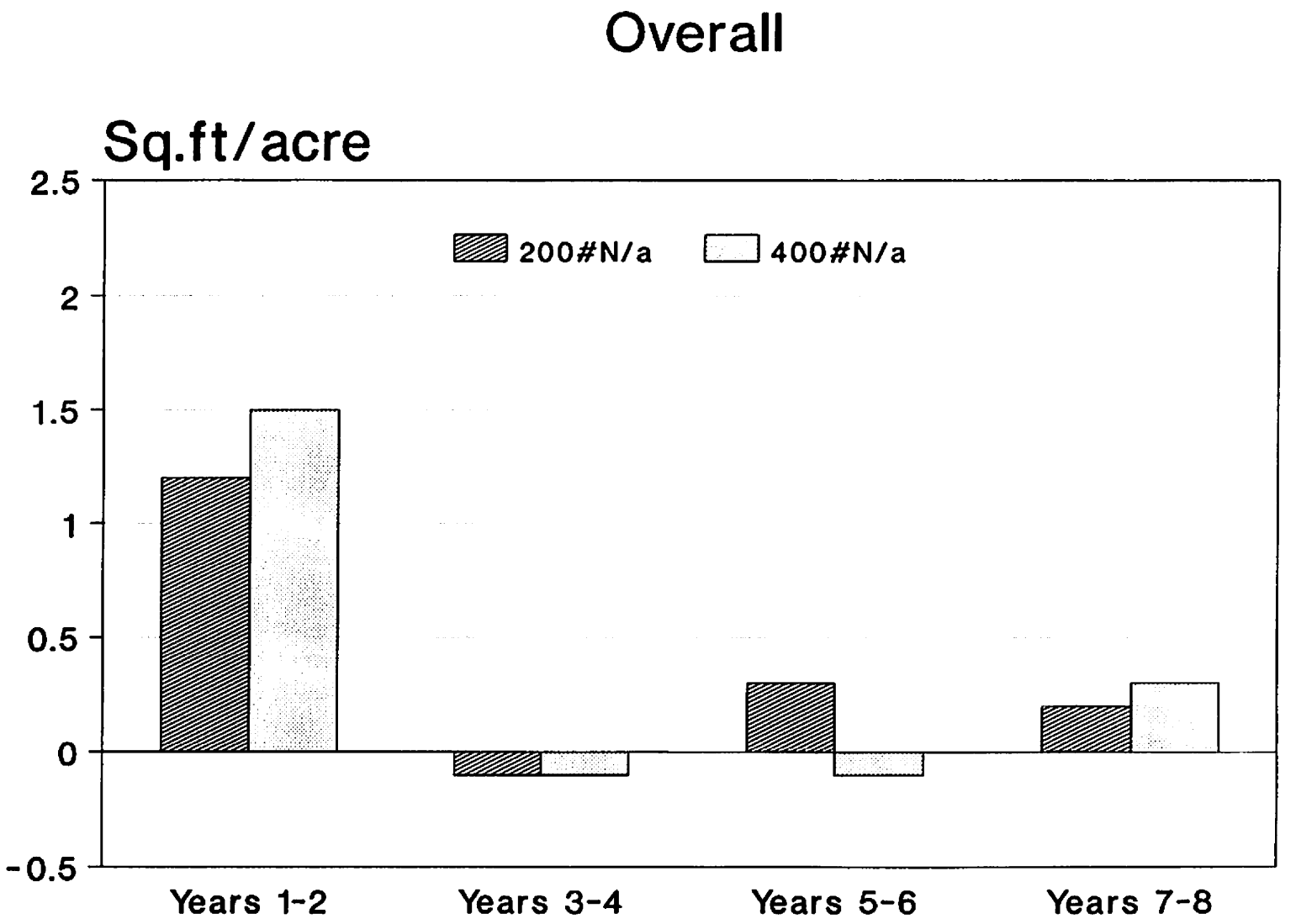

Figure 10b. Average periodic net basal area response by treatment for all Douglas-fir installations.

Relative gross basal area response declined for each successive two-year period for most regions. Both nitrogen treatments continued to produce significant gross basal area response for each of the four two-year periods in northern Idaho and central Washington. Neither nitrogen treatment produced significant average gross basal area response in central Idaho, Montana, or northeast Oregon after the first two years. For northeast Washington, the 400 lb treatment response was significant for each of the four growth period; however, average response to the 200 lb treatment was not significant after the first two growth periods. Over all regions, the average gross basal area response to both nitrogen treatments was still significant during years 7 and 8.

The decline in net basal area response to the fertilizer treatments is more pronounced than for gross basal area. The only treatments that produced a significant net basal area response for years 7 and 8 was the 400 lb nitrogen treatment in northern Idaho and northeast Oregon. Central Idaho and central Washington show negative net basal area responses to both nitrogen treatments during the last two year growth period. Montana shows negative net basal area response to the 400 lb N treatment after the initial two-year period. There is substantial period to period variation in mortality and consequently net basal area growth and response. For example, average net basal area growth for northeast Oregon control plots was negative during years 7 and 8, partially due to a spruce budworm outbreak.

The successive declines in basal area increments for untreated control plots during the first three two-year periods has been reversed during years 7 and 8 for most geographic regions. Only northeast Oregon and central Washington showed continued declines in net basal area growth. Perhaps growing conditions (precipitation) have improved somewhat in the last year or two.

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

As time since treatment increases, the variation in response to nitrogen fertilization also

increases. The distribution of eight-year gross volume response is shown in Figure 11 and net volume response in Figure 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.

One-half of all Douglas-fir installations treated with 200 lbs N produced response exceeding 136 cu. ft./Ac. after eight years, while the median 400 lb. N response was 196 cu. ft./Ac. Expressed on a relative basis, the median 200 lb N response was 13.6 percent and the median 400 lb. N response was 18.8 percent. Even though the 400 lb treatment continues to maintain higher relative response than the 200 lb treatment, after eight years this advantage is still not sufficient to justify the higher application rate.

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

Two-year average basal are a response to the nitrogen and nitrogen plus potassium retreatments are provided for each geographic region in Tables 6a through 6g and for volume response in Tables 7a through 7g. The results for all regions are illustrated in Figures 13 and 14. The cumulative effects of both the old and new treatments across all regions were significant for both gross basal area and volume. However, for net basal area and volume, none of these overall cumulative effects were significant (Tables 6g and 7g). These results, varied, however, by individual geographic region.

For example, both net basal area and volume responses to the old treatments were significant in northern Idaho but the cumulative effects of both old and new treatments were not (Tables 6a and 7a). No cumulative treatment effects were significantly positive for net basal area or volume response in Montana and northeastern Washington. For gross responses, no cumulative

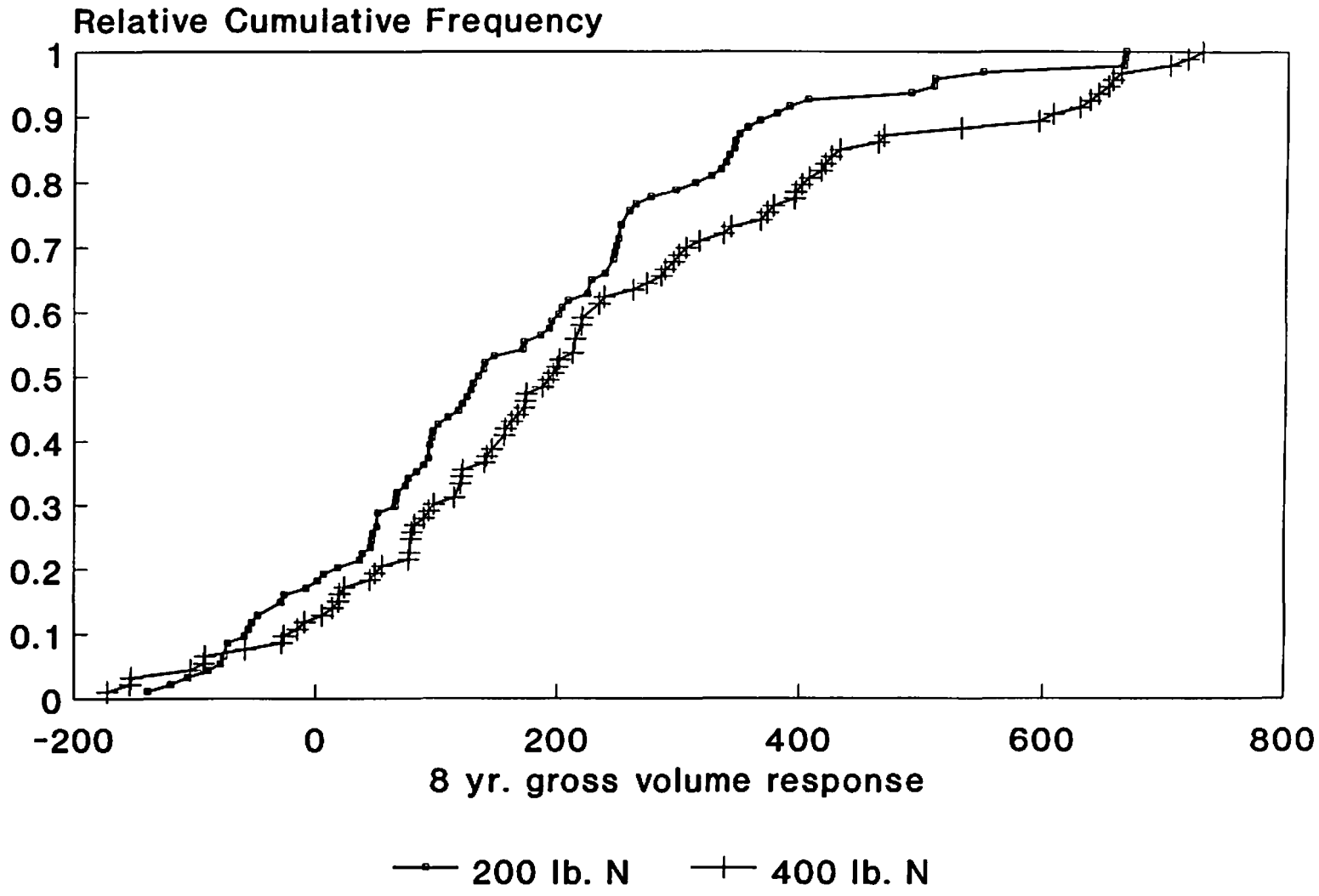

Figure 11. The cumulative distribution of gross eight-year volume growth response to the nitrogen treatments for the Douglas-fir installations.

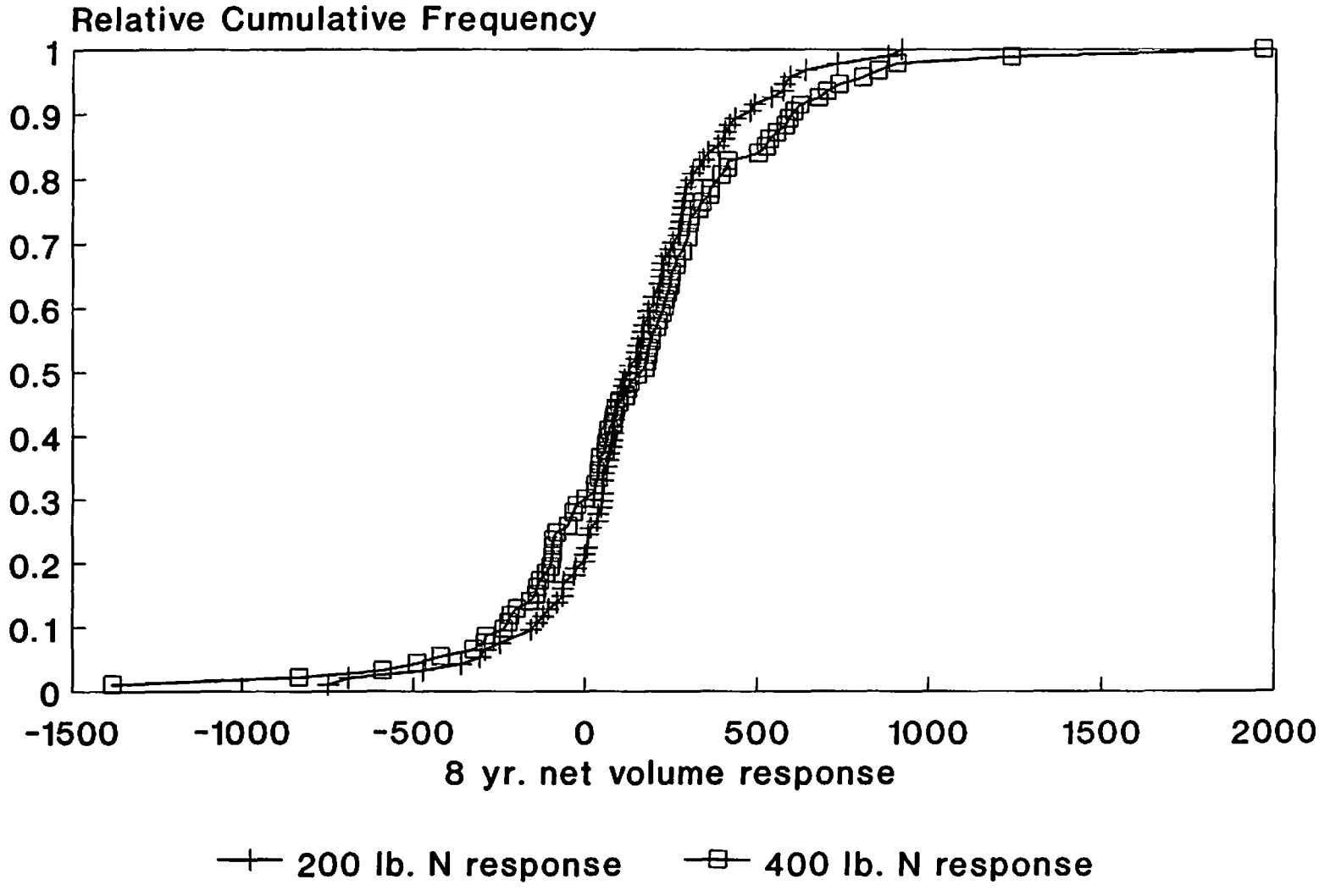

Figure 12. The cumulative distribution of net eight-year volume growth response to the nitrogen treatments for the Douglas-fir installations.

Table 6a. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northern Idaho.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area				
200 # N	None	3.2 (.118)	35.6				
400 # N	None	4.4 (.041)	48.9				
200 # N	200 # N	4.1 (.076)	45.6	0.9 (.740)	7.4		
400 # N	200 # N	1.7 (.464)	18.9	-2.7 (.299)	-20.1		
0 # N	N + K	1.9 (.334)	21.1				
200 # N	N + K	1.7 (.466)	18.9			-2.4 (.740)	-18.3
400 # N	N + K	3.5 (.133)	38.9			1.7 (.534)	15.9
			Gross Basal Area				
200 # N	None	1.5 (.001)	15.2				
400 # N	None	1.6 (.001)	16.2				
200 # N	200 # N	3.4 (.000)	34.3	1.9 (.001)	16.5		
400 # N	200 # N	4.1 (.000)	41.4	2.4 (.000)	20.7		
0 # N	N + K	2.2 (.000)	22.2				
200 # N	N + K	1.4 (.001)	14.1			-2.1 (.000)	-15.8
400 # N	N + K	3.7 (.000)	37.4			-0.4 (.536)	-2.9

Table 6b. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in Montana.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft²/A	Percent	ft²/A	Percent	ft²/A	Percent
			Net Basal Area				
200 # N	None	1.0 (.615)	19.6				
400 # N	None	-1.3 (.532)	-25.5				
200 # N	200 # N	0.7 (.769)	13.7	-0.3 (.908)	-4.9		
400 # N	200 # N	-0.3 (.909)	-5.6	1.O (.663)	26.3		
0 # N	N + K	0.3 (.861)	5.6				
200 # N	N + K	-0.4 (.854)	-7.8			-1.1 (.689)	-19.0
400 # N	N + K	1.1 (.641)	21.6			1.4 (.610)	29.2
			Gross Basal Area				
200 # N	None	0.3 (.608)	5.2				
400 # N	None	0.4 (.452)	6.9				
200 # N	200 # N	0.5 (.415)	8.6	0.2 (.708)	3.3		
400 # N	200 # N	0.9 (.050)	15.5	0.5 (.360)	8.1		
0 # N	N + K	0.9 (.088)	15.5				
200 # N	N + K	1.5 (.004)	25.9			1.1 (.082)	17.5
400 # N	N + K	0.9 (.090)	15.5			0.1 (.888)	1.5

Table 6c. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in central Idaho.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft²/A	Percent	ft²/A	Percent	ft²/A	Percent
			Net Basal Area				
200 # N	None	-0.7 (.767)	-11.3				
400 # N	None	-2.4 (.279)	-38.7				
200 # N	200 # N	-1.6 (.504)	-25.8	-0.9 (.716)	-17.1		
400 # N	200 # N	-6.0 (.019)	-96.8	-3.7 (.165)	-97.4		
0 # N	N + K	-1.3 (.536)	-21.0				
200 # N	N + K	0.3 (.889)	4.8			2.0 (.492)	43.5
400 # N	N + K	-1.2 (.619)	-19.4			4.8 (.107)	2400.0
			Gross Basal Area				
200 # N	None	0.4 (.382)	6.2				
400 # N	None	0.4 (.401)	6.2				
200 # N	200 # N	1.1 (.037)	16.9	0.7 (.238)	10.1		
400 # N	200 # N	1.0 (.068)	15.4	0.6 (.282)	8.7		
0 # N	N + K	1.5 (.002)	23.1				
200 # N	N + K	1.4 (.014)	21.5			0.3 (.688)	3.9
400 # N	N + K	1.9 (.094)	13.9			-0.1 (.861)	-1.3

Table 6d. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northeastern Oregon.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft²/A	Percent	ft²/A	Percent	ft²/A	Percent
			Net Basal Area				
200 # N	None	4.8 (.125)	208.7				
400 # N	None	7.8 (.014)	339.1				
200 # N	200 # N	0.7 (.844)	30.4	-4.2 (.275)	-168.0		
400 # N	200 # N	1.8 (.597)	78.3	-6.0 (.117)	-109.1		
0 # N	N + K	1.6 (.544)	69.6				
200 # N	N + K	0.3 (.898)	13.0			-0.3 (.940)	-17.6
400 # N	N + K	2.5 (.457)	108.7			0.7 (.870)	140.0
			Gross Basal Area				
200 # N	None	0.9 (.210)	22.0				
400 # N	None	0.5 (.450)	12.2				
200 # N	200 # N	0.7 (.395)	17.1	-0.2 (.790)	-4.0		
400 # N	200 # N	1.1 (.154)	26.8	0.6 (.500)	12.8		
0 # N	N + K	0.3 (.611)	7.3				
200 # N	N + K	0.3 (.633)	7.3			-0.3 (.699)	-6.2
400 # N	N + K	0.8 (.274)	19.5			-0.3 (.746)	-5.8

Table 6e. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in central Washington.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area				
200 # N	None	-0.7 (.714)	-14.6				
400 # N	None	1.2 (.530)	25.0				
200 # N	200 # N	1.0 (.645)	20.8	1.7 (.453)	41.5		
400 # N	200 # N	2.2 (.308)	45.8	-6.0 (.117)	-100.0		
0 # N	N + K	-2.0 (.264)	-41.7				
200 # N	N + K	0.0 (.973	0.0			-1.0 (.664)	-17.2
400 # N	N + K	2.9 (.167)	60.4			0.7 (.789)	9.9
			Gross Basal Area				
200 # N	None	0.6 (.146)	9.5				
400 # N	None	1.2 (.006)	19.0				
200 # N	200 # N	1.4 (.002)	22.2	0.8 (.109)	11.6		
400 # N	200 # N	1.8 (.000)	28.6	0.6 (.500)	8.1		
0 # N	N + K	1.7 (.000)	27.0				
200 # N	N + K	1.4 (.004)	22.2			-0.1 (.911)	-1.3
400 # N	N + K	1.2 (.008)	19.0			-0.6 (.300)	-7.4

Table 6f. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northeastern Washington.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area				
200 # N	None	1.4 (.510)	28.6				
400 # N	None	0.6 (.765)	12.2				
200 # N	200 # N	0.7 (.761)	14.3	-0.7 (.783)	-11.1		
400 # N	200 # N	0.7 (.757)	14.3	0.1 (.962)	1.8		
0 # N	N + K	1.9 (.316)	38.8				
200 # N	N + K	2.6 (.220)	53.1			2.0 (.442)	36.4
400 # N	N + K	0.0 (.999)	0.0			-0.7 (.791)	-12.5
			Gross Basal Area				
200 # N	None	0.2 (.608)	3.2				
400 # N	None	1.0 (.018)	16.1				
200 # N	200 # N	1.6 (.000)	25.8	1.4 (.009)	21.9		
400 # N	200 # N	1.8 (.000)	29.0	0.8 (.119)	11.1		
0 # N	N + K	1.9 (.000)	30.6				
200 # N	N + K	2.1 (.000)	33.9			0.5 (.393)	6.4
400 # N	N + K	1.2 (.015)	19.4			-0.6 (.277)	-7.5

Table 6g. Average two-year net and gross basal area response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in all regions.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^2/A	Percent	ft^2/A	Percent	ft^2/A	Percent
			Net Basal Area				
200 # N	None	1.3 (.192)	24.5				
400 # N	None	1.4 (.158)	26.4				
200 # N	200 # N	1.1 (.318)	20.8	-0.2 (.890)	-3.0		
400 # N	200 # N	0.2 (.870)	3.8	-1.2 (.312)	-17.9		
0 # N	N + K	0.4 (.704)	7.5				
200 # N	N + K	0.8 (.425)	15.0			-0.3 (.805)	-4.7
400 # N	N + K	1.6 (.167)	30.2			1.4 (.309)	25.5
			Gross Basal Area				
200 # N	None	0.7 (.002)	10.3				
400 # N	None	0.9 (.000)	13.2				
200 # N	200 # N	1.6 (.000)	23.5	0.9 (.000)	12.0		
400 # N	200 # N	1.9 (.000)	27.9	1.0 (.000)	13.0		
0 # N	N + K	1.5 (.000)	22.1				
200 # N	N + K	1.4 (.000)	20.6			-0.2 (.522)	-2.4
400 # N	N + K	1.6 (.000)	23.5			0.3 (.261)	-3.4

Table 7a. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northern Idaho.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft³/A	Percent	ft³/A	Percent	ft³/A	Percent
			Net Volume				
200 # N	None	116 (.086)	30.4				
400 # N	None	137 (.049)	35.9				
200 # N	200 # N	133 (.074)	34.8	17 (.832)	3.4		
400 # N	200 # N	78 (.331)	20.4	-59 (.478)	-11.4		
0 # N	N + K	76 (.234)	19.9				
200 # N	N + K	82 (.272)	21.5			-51 (.554)	-9.9
400 # N	N + K	115 (.124)	30.1			36 (.683)	7.8
			Gross Volume				
200 # N	None	49 (.007)	12.3				
400 # N	None	62 (.001)	15.6				
200 # N	200 # N	116 (.000)	29.2	67 (.002)	15.0		
400 # N	200 # N	153 (.000)	38.5	91 (.000)	19.8		
0 # N	N + K	83 (.000)	20.9				
200 # N	N + K	67 (.001)	16.9			-49 (.034)	-9.6
400 # N	N + K	136 (.000)	34.2			-17 (.482)	-3.1

Table 7b. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in Montana.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume				
200 # N	None	36 (.568)	18.2				
400 # N	None	-29 (.656)	-14.2				
200 # N	200 # N	33 (.656)	16.7	-2 (.980)	-0.9		
400 # N	200 # N	2 (.977)	1.0	31 (.681)	18.3		
0 # N	N + K	23 (.711)	11.6				
200 # N	N + K	-11 (.881)	-5.6			-45 (.619)	-19.5
400 # N	N + K	38 (.626)	19.2			36 (.678)	18.0
			Gross Volume				
200 # N	None	14 (.397)	6.6				
400 # N	None	6 (.744)	2.8				
200 # N	200 # N	26 (.200)	12.2	12 (.577)	5.3		
400 # N	200 # N	33 (.079)	15.5	27 (.183)	12.3		
0 # N	N + K	36 (.030)	16.9				
200 # N	N + K	48 (.019)	22.5			22 (.368)	9.2
400 # N	N + K	36 (.084)	16.9			3 (.898)	1.2

Table 7c. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in central Idaho.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume				
200 # N	None	-13 (.856)	-5.4				
400 # N	None	-78 (.261)	-32.6				
200 # N	200 # N	-40 (.632)	-16.7	-27 (.746)	-11.9		
400 # N	200 # N	-158 (.055)	-66.1	-80 (.349)	-49.7		
0 # N	N + K	-30 (.651)	-12.6				
200 # N	N + K	5 (.950)	2.1			45 (.621)	22.6
400 # N	N + K	-21 (.788)	-8.8			137 (.153)	169.1
			Gross Volume				
200 # N	None	11 (.592)	4.5				
400 # N	None	-3 (.862)	-1.2				
200 # N	200 # N	40 (.056)	16.5	29 (.188)	11.5		
400 # N	200 # N	22 (.317)	9.1	25 (.270)	10.5		
0 # N	N + K	42 (.020)	17.4				
200 # N	N + K	38 (.078)	15.7			-2 (.946)	-0.7
400 # N	N + K	37 (.085)	15.3			15 (.566)	5.7

Table 7d. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northeastern Oregon.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft³/A	Percent	ft³/A	Percent	ft³/A	Percent
			Net Volume				
200 # N	None	184 (.071)	1150.0				
400 # N	None	213 (.037)	1331.3				
200 # N	200 # N	-7 (.947)	-43.8	-192 (.120)	-96.0		
400 # N	200 # N	57 (.611)	356.6	-156 (.205)	-68.1		
0 # N	N + K	30 (.737)	187.5				
200 # N	N + K	10 (.919)	62.5			17 (.887)	188.9
400 # N	N + K	84 (.438)	525.0			27.(.840)	37.0
			Gross Volume				
200 # N	None	15 (.586)	8.0				
400 # N	None	8 (.783)	4.3				
200 # N	200 # N	-1 (.966)	-0.5	-16 (.624)	-7.9		
400 # N	200 # N	31 (.292)	16.5	23 (.478)	11.7		
0 # N	N + K	12 (.599)	6.4				
200 # N	N + K	9 (.741)	4.8			10 (.758)	5.4
400 # N	N + K	11 (.700)	5.9			-20 (.552)	-9.1

Table 7e. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in central Washington.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume				
200 # N	None	-31 (.622)	-15.0				
400 # N	None	37 (.553)	18.0				
200 # N	200 # N	45 (.500)	21.8	76 (.289)	43.4		
400 # N	200 # N	78 (.269)	37.9	-156 (.205)	-64.2		
0 # N	N + K	-51 (.386)	-24.8				
200 # N	N + K	-1 (.987)	-0.5			-46 (.545)	-18.3
400 # N	N + K	79 (.244)	38.3			1 (.992)	0.4
			Gross Volume				
200 # N	None	24 (.152)	9.6				
400 # N	None	40 (.016)	16.0				
200 # N	200 # N	41 (.022)	16.4	17 (.379)	6.2		
400 # N	200 # N	61 (.001)	24.4	23 (.478)	7.9		
0 # N	N + K	63 (.000)	25.2				
200 # N	N + K	56 (.002)	22.4			15 (.458)	5.2
400 # N	N + K	25 (.168)	10.0			-36 (.095)	-11.6

Table 7f. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in northeastern Washington.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume				
200 # N	None	42 (.525)	18.3				
400 # N	None	5 (.937)	2.2				
200 # N	200 # N	28 (.697)	12.2	-14 (.858)	-5.2		
400 # N	200 # N	20 (.787)	8.7	14 (.847)	6.0		
0 # N	N + K	61 (.310)	26.6				
200 # N	N + K	87 (.212)	38.0			59 (.476)	23.0
400 # N	N + K	4 (.954)	1.7			-15 (.856)	-6.0
			Gross Volume				
200 # N	None	6 (.879)	2.4				
400 # N	None	22 (.198)	8.7				
200 # N	200 # N	57 (.003)	22.5	57 (.010)	22.0		
400 # N	200 # N	67 (.001)	26.5	45 (.026)	16.4		
0 # N	N + K	67 (.000)	26.5				
200 # N	N + K	73 (.000)	28.9			16 (.481)	5.1
400 # N	N + K	41 (.034)	16.2			45 (.026)	-8.1

Table 7g. Average two-year net and gross volume growth response to retreatment with nitrogen or nitrogen plus potassium for the Douglas-fir sites in all regions.

Treatments		Response					
		Continued or Cumulative Effect		Effect of new Nitrogen		Effect of new Potassium	
Old	New	ft^3/A	Percent	ft^3/A	Percent	ft^3/A	Percent
			Net Volume				
200 # N	None	47 (.146)	20.1				
400 # N	None	40 (.219)	17.1				
200 # N	200 # N	42 (.254)	17.9	-5 (.900)	-1.8		
400 # N	200 # N	18 (.625)	7.7	-21 (.582)	-7.7		
0 # N	N + K	19 (.524)	8.1				
200 # N	N + K	32 (.334)	13.7			-9 (.814)	-3.3
400 # N	N + K	52 (.154)	22.2			34 (.438)	13.5
			Gross Basal Area				
200 # N	None	21 (.015)	7.8				
400 # N	None	26 (.002)	9.7				
200 # N	200 # N	53 (.000)	19.8	32 (.002)	5.4		
400 # N	200 # N	68 (.000)	25.4	42 (.000)	14.2		
0 # N	N + K	56 (.000)	20.9				
200 # N	N + K	53 (.000)	19.8			0 (.998)	0.0
400 # N	N + K	54 (.000)	20.1			-14 (.211)	-4.2

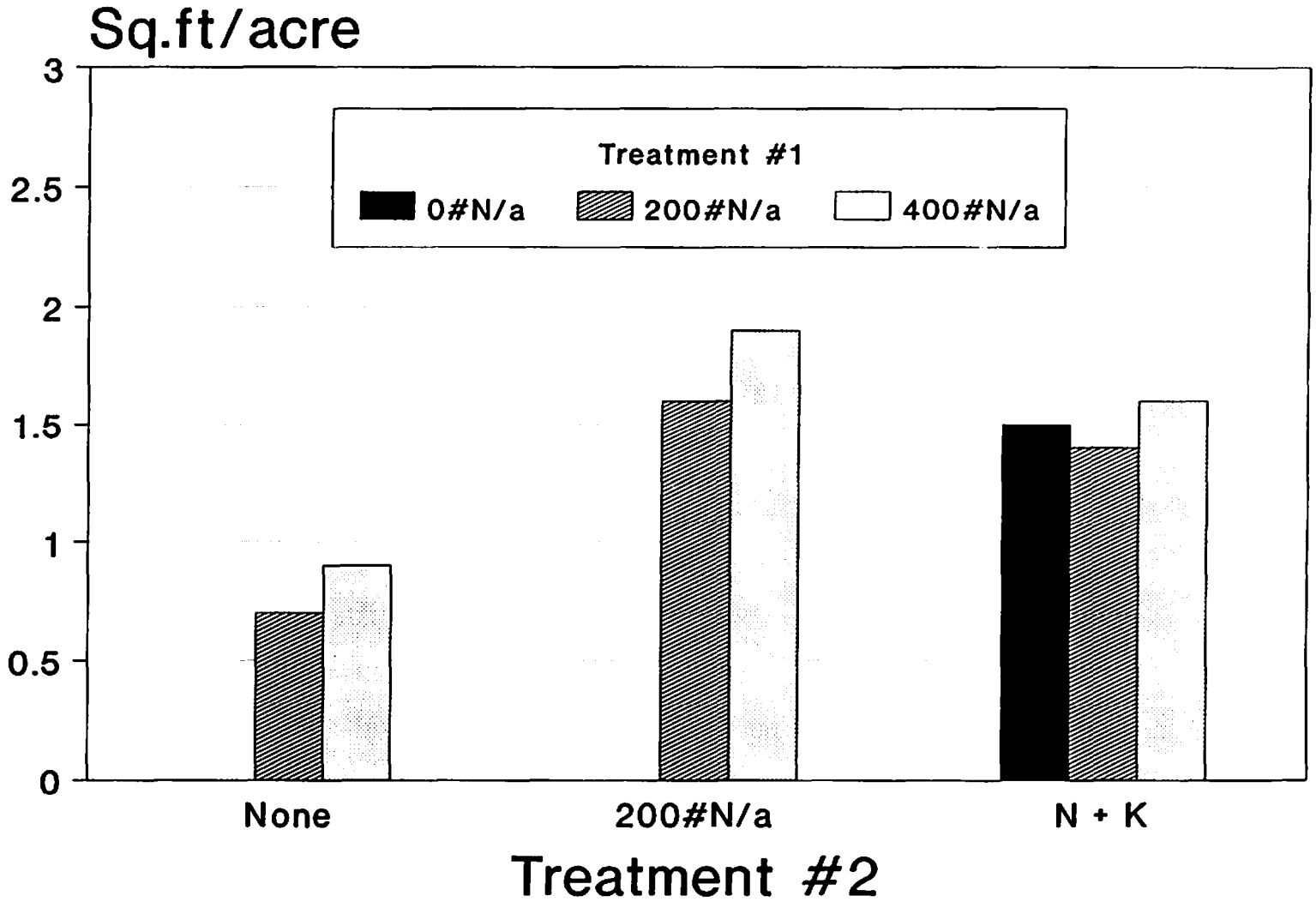

Figure 13a. Two-year average gross basal area response by previous nitrogen and new treatment with nitrogen or nitrogen plus potassium for the Douglas-fir installations.

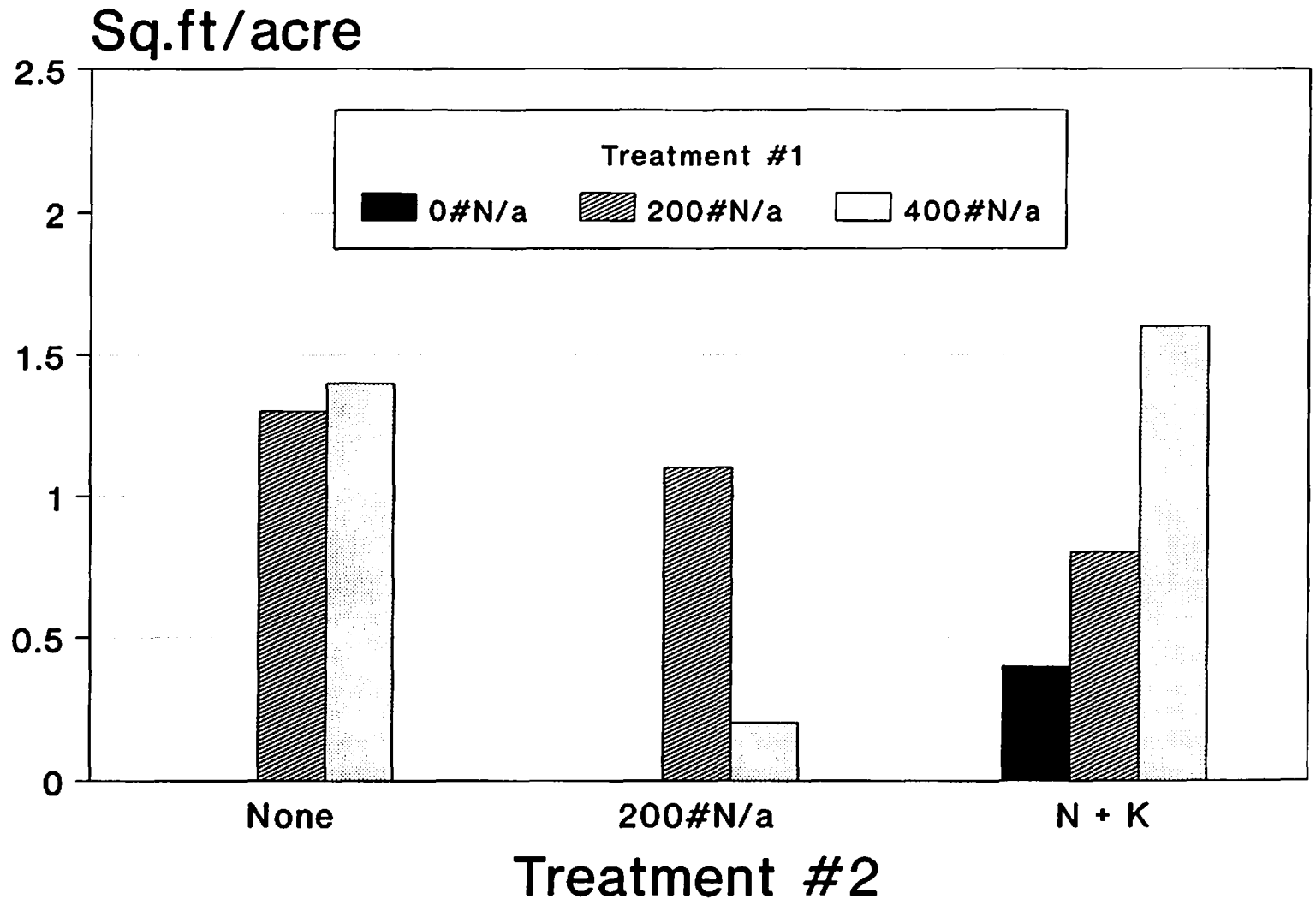

Figure 13b. Two-year average net basal area response by previous nitrogen and new treatment with nitrogen or nitrogen plus potassium for the Douglas-fir installations.

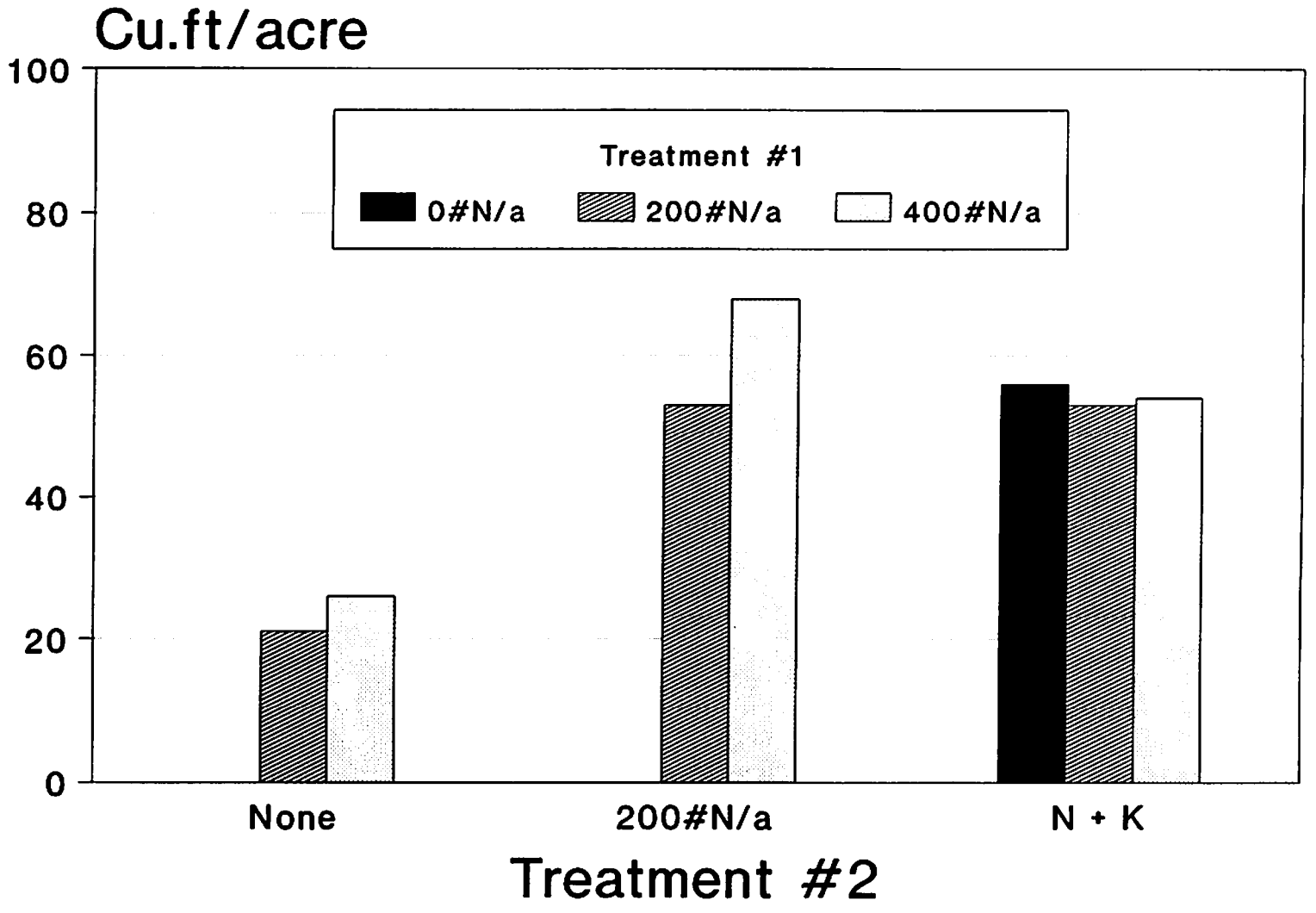

Figure 14a. Two-year average gross volume response by previous nitrogen and new treatment with nitrogen or nitrogen plus potassium for the Douglas-fir installations.

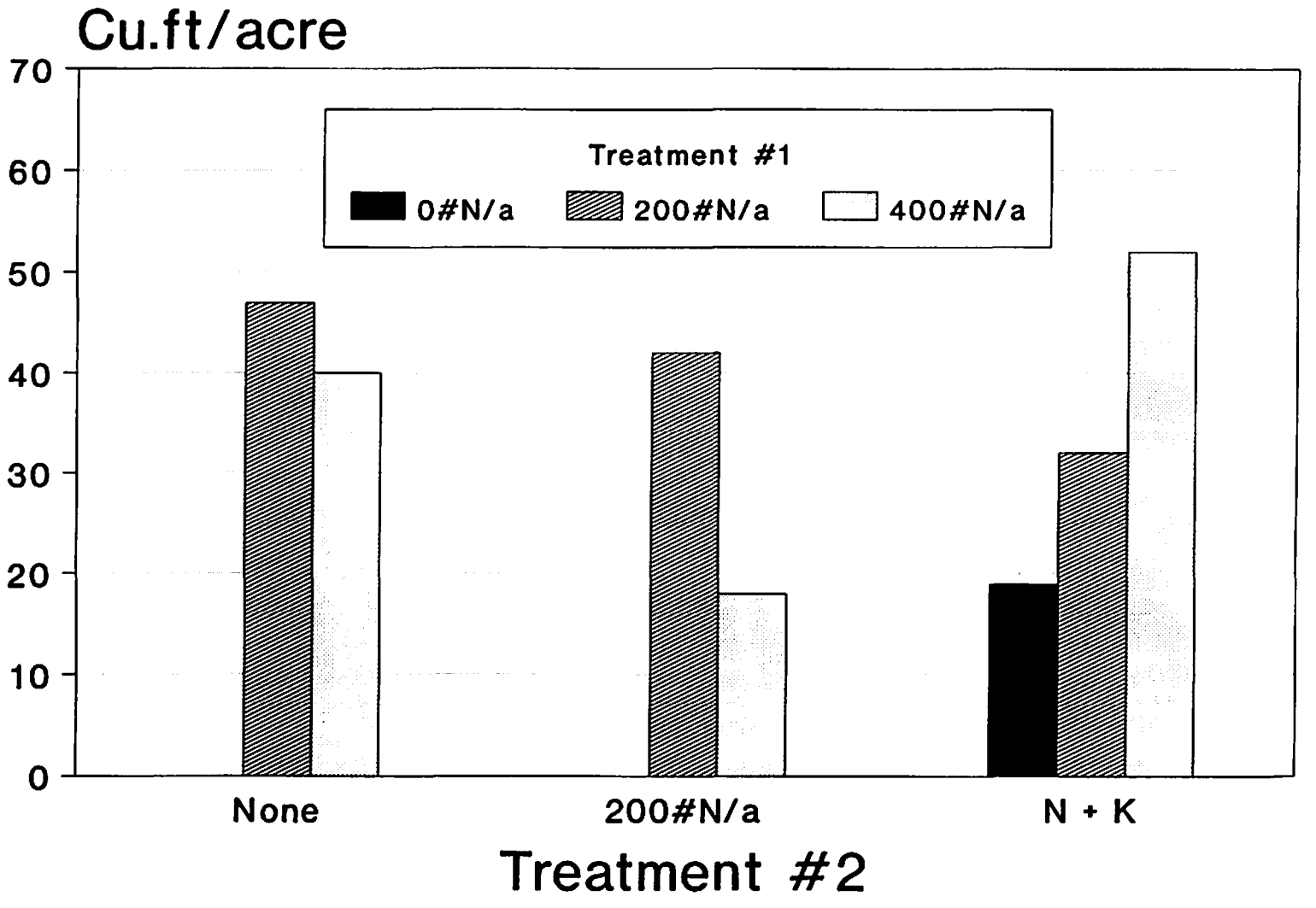

Figure 14b. Two-year average net volume response by previous nitrogen and new treatment with nitrogen or nitrogen plus potassium for the Douglas-fir installations.

effects of old treatments were significant, only cumulative effects that included new treatments produced significant response in Montana, central Idaho, and northeastern Washington. In contrast, no treatment combinations produced significant cumulative effects for gross basal area or volume response in northeastern Oregon. Only the old nitrogen treatments resulted in significant net responses for this region (Tables 6d and 7d). All treatment combinations, except the old 200 lb. N treatment, resulted in statistically significant gross basal area and volume responses for central Washington.

New Response from 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. As was the case for the first half of the installations (1991 IFTNC Annual Report), the net average effect of an additional 200 pounds of nitrogen alone on plots previously treated with nitrogen was negative although not significantly so (Tables 6g and 7g). No region produced significant net basal area or volume response to nitrogen retreatments on plots previously treated with nitrogen. There was significant gross response from retreatments with 200 lbs. of N on plots previously fertilized with both 200 and 400 lbs. of N in northern Idaho and northeastern Washington. Retreatment gross basal area response was significant in central Washington for plots previously fertilized with 200 lbs. of nitrogen.

The average two-year retreatment effects of 200 lbs of N plus 200 lbs. of K on gross basal area growth of previous control plots were less than the responses produced by the original 200 lb nitrogen treatments (Table 8). We have observed that growing conditions have declined since our original treatments were applied (average control plot growth in period one was 4.5 sq. ft. vs. 3.5 sq. ft. in period 4.); thereby reducing response to nitrogen retreatments. We attribute these response differences to overall climatic effects but we can't be certain since comparative

Table 8. Average two-year gross basal area response for Douglas-fir installations fertilized in different time periods by geographic region.

	Gross basal area response			
	Treated in 1981 and 1982		Treated in 1987 and 1988[1]	
Region	Ft.²/A.	Percent	Ft.²/A	Percent
Northern Idaho	1.9	33.1	1.1	21.9
Montana	0.6	17.3	0.4	14.4
Central Idaho	1.0	22.6	0.7	22.4
Northeastern Oregon	1.1	31.2	0.2	7.5
Central Washington	1.6	36.7	0.8	26.6
Northeastern Washington	1.7	22.9	1.0	30.7
Overall	1.3	28.1	0.8	22.3

[1] Includes only prior control plots that were treated with 200 lbs. of N plus 200 lbs. of K in 1987 and 1988.

relative response between two-year growth periods was lower for four of the geographic regions, particularly northeastern Oregon (Table 8).

New Response to Retreatments with Nitrogen plus Potassium: K Effects:

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 volume on either original nitrogen dosage (Tables 6g or 7g). Potassium effects are largest (though still not statistically significant) for net basal area and volume response on plots previously fertilized with 400 lbs. of N.

Across the entire experiment potassium fertilization does not produce a significant growth response, although perhaps there is a K effect on fertilization related mortality. However, we diagnosed K deficiency at only a minority of Douglas-fir installations so maybe we should not expect significant response from the whole population of study sites.

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

As mentioned earlier when discussing potassium fertilization response for the entire Douglas-fir experiment, we diagnosed only a subset of the population as being K "deficient".

Previous IFTNC Annual Reports describe 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%

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

We had previously shown that six-year response to the nitrogen treatments differed by potassium status category (IFTNC, Annual Report 1989). These response differences continue after eight years (Table 9). Gross volume response to both treatments is lowest for the poor K-class and highest for the good K-class. Further, net eight-year volume response to 400 lbs. N is negative for the poor K-class, indicating higher mortality rates for high nitrogen treatments on sites with poor initial potassium status.

If our hypothesis that inadequate potassium levels limited response to nitrogen fertilization is correct, then we expect that response to the new 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 10 and net and gross volume are illustrated in Figure 15 and 16. The estimates in Table 10 are for the retreatment effects of nitrogen alone or potassium alone (i.e., N + K response - N alone response).

There was no nitrogen retreatment effect on gross volume response for stands in the poor K-class, while N retreatment effects were significantly positive for the "otherwise" and good K-classes. Potassium retreatment did not produce statistically significant effects for any K-class, however, the average K effect was higher in the poor K-class. There was no significant retreatment effect on two-year net volume growth for either N or K for any potassium category. In summary, potassium status before N fertilization is still a useful diagnostic for N response, but whether we can change K nutritional status and consequently effect subsequent growth or mortality is still unresolved.

Table 9. Average eight-year gross volume per acre response to nitrogen fertilization by pre-treatment foliage potassium status.

K Status	Treatment	Gross Response Cu.Ft./A
K<6000 ppm	200 lb. N	104 (.117)
Poor	400 lb. N	128 (.054)
K/N < 50%		
K is otherwise	200 lb. N	166 (.000)
	400 lb. N	236 (.000)
K > 6000 ppm	200 lb. N	219 (.000)
Good	400 lb. N	277 (.000)
K/N > 65%		

Table 10. Average two-year gross and net volume per acre estimates of nitrogen or potassium effects by pre-treatment foliage potassium status.

K Status	New Treatment Effects	Gross Response Cu. Ft./A	Net Response Cu. Ft./A
K < 6000 ppm			
Poor	200 lb. N Effects	0 (.991)	4 (.963)
K/N < 50%	200 lb. K Effects	28 (.229)	49 (.567)
K is otherwise	200 lb. N Effects	50 (.000)	37 (.216)
	200 lb. K Effects	-9 (.291)	5 (.858)
K > 6000 ppm			
Good	200 lb. N Effects	34 (.006)	5 (.904)
K/N > 65%	200 lb. K Effects	7 (.638)	65 (.223)

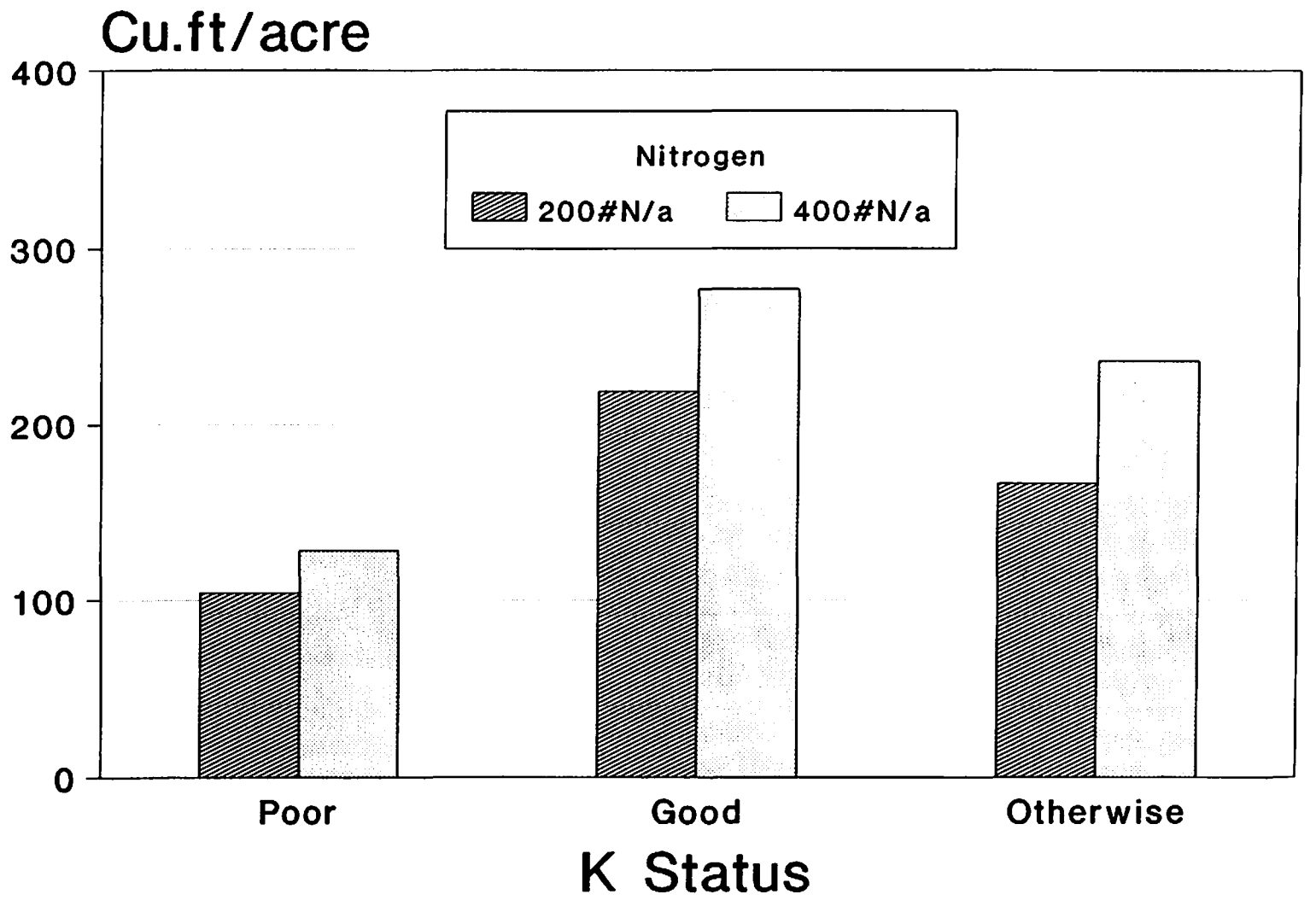

Figure 15. Average eight-year gross volume response to nitrogen fertilization by pre-treatment foliage potassium status.

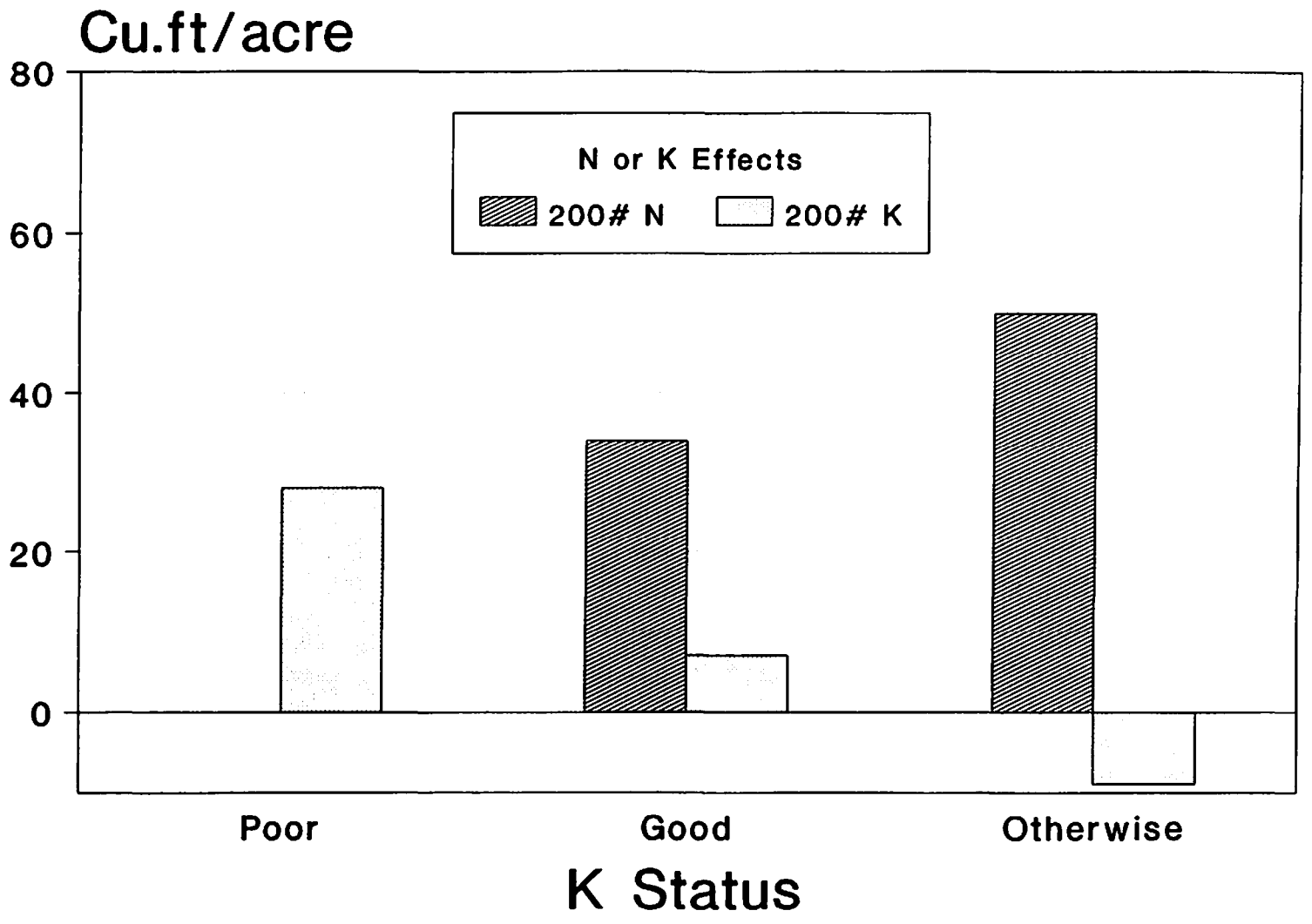

Figure 16. Average two-year gross volume response estimates of nitrogen or potassium effects by pretreatment foliage potassium status.