# SIXTH ANNUAL REPORT

Intermountain Forest Tree
Nutrition Cooperative

April 1986

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

INTERMOUNTAIN FOREST TREE
NUTRITION COOPERATIVE

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# SUMMARY


Results based on analysis of four-year basal area, height increment, and volume growth response and mortality for 45 1981 and 4 1980 test sites indicate the following:

(a) There were significant differences in response between geographic regions.

(b) Only central Washington showed statistically significant response differences between treatments of 200 and 400 lbs of nitrogen per acre, the other regions did not.

(c) Gross basal area and volume four-year increment for both 200 and 400 lb treatments were significantly different from the controls for all geographic regions. However, this was not the case for net basal area and volume growth. Only central Idaho, central Washington, and northern Idaho showed significant net responses to both treatments.

(d) Mortality associated with the nitrogen treatments occurred primarily in the smaller size classes in more dense stands and was highest in the 400 lb nitrogen treatments. Nearly all of the mortality occurred during years 3 and 4 of the period. On a per-acre basis, the mortality was often high enough to offset growth gains due to the nitrogen treatments.

(e) Application of nitrogen has significantly altered stand development after only four years. Additional analysis is required to quantify the distribution of added increment due to nitrogen treatments across size classes within a stand.

(f) We have empirical evidence that the nitrogen treatments may have resulted in potassium deficiencies on some soil parent materials.

## INTRODUCTION:

In the 1985 annual report of the Cooperative, the results of a predictive model of 2-year basal area response to nitrogen fertilization were reported. Three factors were found to be important in predicting response: (1) stand density at the time of treatment, (2) soil parent material, and (3) pretreatment rate of soil nitrogen mineralization (Min N). Although 2-year basal area response to treatment varied widely between stands in the Intermountain Northwest, much of the variation could be explained by these three factors! These results are still "valid" and should be kept in mind when thinking about the new results contained in this report.

The predictive model developed and reported last year was based on the analysis of 2-year basal area growth for 90 IFTNC Douglas-fir installations (i.e., those established in both 1981 and 1982). This year's report includes estimates of four-year height, basal area, and volume growth response to nitrogen treatments as well as mortality estimates for the forty-five 1981 installations and the four 1980 installations. Basal area growth response estimates are also provided for each two-year period (i.e., years 1 and 2 and years 3 and 4).

## FOUR-YEAR GROWTH RESPONSE OF THE 1980 and 1981 TEST SITES:

### General description of the analysis:

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

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

### Experimental design models:

The design models took the form:

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

where INC = the growth occurring in 4 years;

Region = the geographic region of the cooperative;

Treatment = the level of nitrogen fertilizer applied;

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

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

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 Tables 1 through 5 of the Technical Documentation Report.

<u>Basal area growth response</u>:

Means (adjusted to a common initial basal area of 125 $ft^2/A$) for both gross and net basal area increment are given in Table 1. The four-year gross basal area per acre (GBA/A) increment for both the 200 and 400 lb treatments were statistically different from the controls across all geographic regions. Except for central Washington, there was no significant difference between the 200 and 400 lb nitrogen treatments. These results are the same as for the two-year basal area response results (1984 Annual Report of the Cooperative). However, the situation is different for net basal area increment (NBA/A). This is clearly shown in Figure 1. There is no statistical difference in net basal area increment between either fertilizer treatment and the controls for the Montana, northeast Oregon, and northeast Washington geographic regions. The reason for the different results for gross and net basal area response is, of course, mortality. Fertilized plots had significantly higher mortality rates during years 3 and 4 than the control plots. Analysis of mortality by treatment and region will be presented in detail in a later section of this report.

Several important points are clearly evident in Figure 1 and Table 1. The 400 lb nitrogen treatment in central Washington continues to show a

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

| | | Net Basal Area Increment | | | Gross Basal Area Increment | | |
|---|---|---|---|---|---|---|---|
| | | Total | Increase over control | | Total | Decrease over control | |
| Region | Treatment | $ft^2$/acre | $ft^2$/acre | percent | $ft^2$/acre | $ft^2$/acre | percent |
| Central Idaho | Control | 15.2 | | | 15.7 | | |
| | 200 # N | 18.9 | 3.7 | 24.2 | 19.2 | 3.6 | 22.8 |
| | 400 # N | 19.3 | 4.1 | 26.6 | 19.8 | 4.1 | 26.2 |
| Central Washington | Control | 15.2 | | | 15.3 | | |
| | 200 # N | 19.1 | 3.9 | 25.6 | 19.6 | 4.4 | 28.7 |
| | 400 # N | 22.7 | 7.4 | 48.9 | 23.4 | 8.1 | 53.2 |
| Montana | Control | 13.5 | | | 13.5 | | |
| | 200 # N | 15.4 | 1.9 NS | 13.9 | 15.5 | 2.1 | 15.4 |
| | 400 # N | 14.2 | 0.7 NS | 5.5 | 15.3 | 1.8 | 13.6 |
| Northern Idaho | Control | 17.5 | | | 19.1 | | |
| | 200 # N | 24.2 | 6.7 | 37.9 | 25.0 | 5.9 | 31.0 |
| | 400 # N | 24.4 | 6.9 | 39.2 | 25.4 | 6.3 | 33.0 |
| Northeast Oregon | Control | 10.6 | | | 13.2 | | |
| | 200 # N | 13.4 | 2.8 NS | 26.1 | 16.0 | 2.8 | 21.6 |
| | 400 # N | 12.9 | 2.3 NS | 21.3 | 15.9 | 2.7 | 20.7 |
| Northeast Washington | Control | 17.2 | | | 18.9 | | |
| | 200 # N | 19.6 | 2.4 NS | 14.2 | 22.2 | 3.3 | 17.2 |
| | 400 # N | 17.3 | 0.1 NS | 0.7 | 22.8 | 3.9 | 20.4 |
| Overall | Control | 14.9 | | | 15.9 | | |
| | 200 # N | 18.3 | 3.3 | 22.4 | 19.5 | 3.6 | 22.4 |
| | 400 # N | 18.4 | 3.4 | 23.0 | 20.4 | 4.5 | 28.5 |

[1]Averages are adjusted to a common initial basal area of 125 $ft^2$/A.

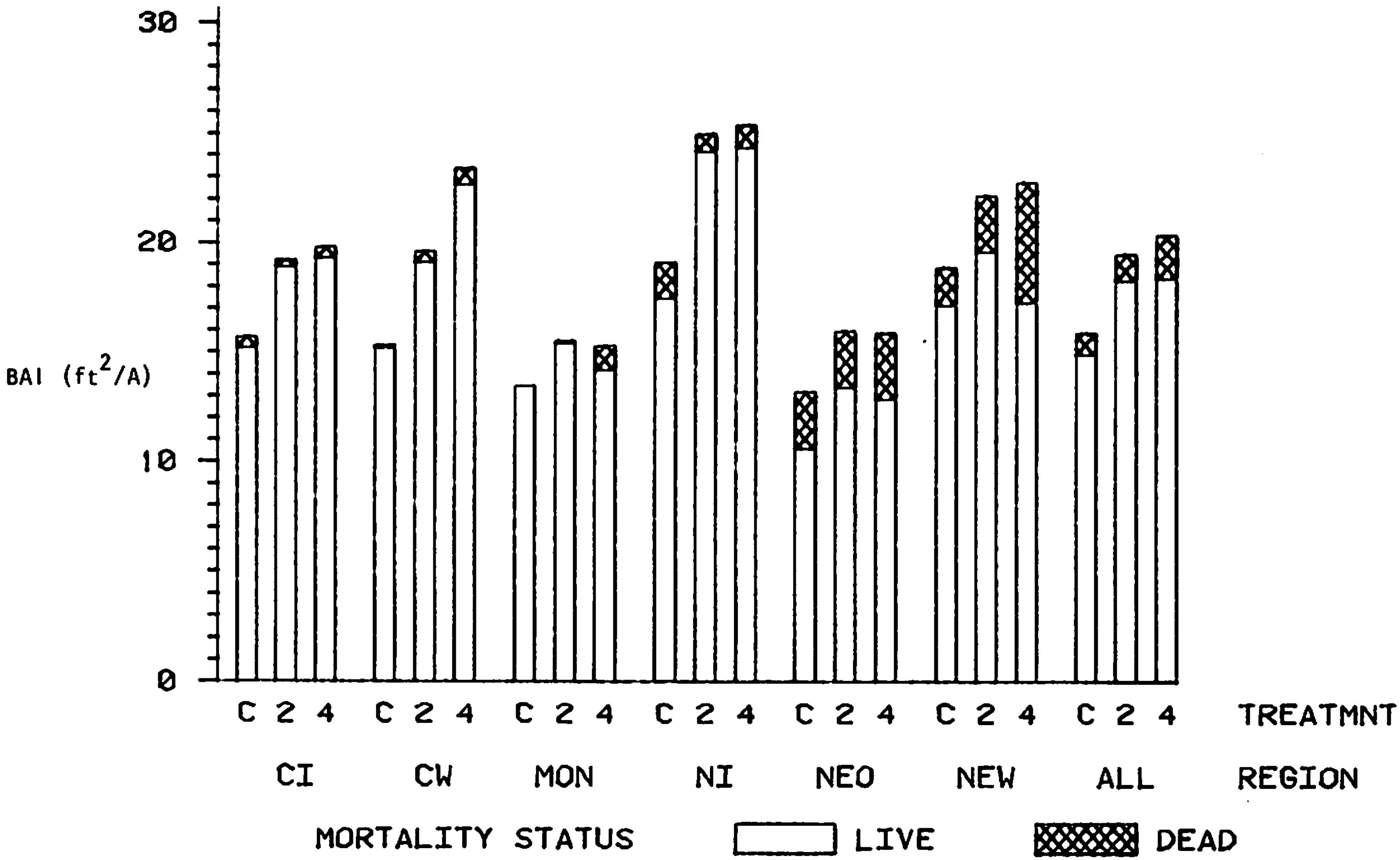


Figure 1. Four-year gross basal area increment per region and treatment type partitioned into live (net) and dead components.

significant growth response over both the control (7.4 $ft^2$ NBA/A; 48.9%) and the 200 lb nitrogen treatments. The north Idaho region showed the largest net basal area response to the 200 lb treatment (6.7 $ft^2$ in 4 years, 39.2%). Notice the large decrease from gross to net basal area response for the 400 lb treatment in Montana, northeast Oregon, and particularly northeast Washington.

Stand density (basal area) at the time of treatment has significant effect on both gross and net basal area increment. The relationship is parabolic, as shown in Figure 2. Initially as basal area per acre increases, periodic net basal area increment also increases up to a point (maximum net BAI occurs at 177 $ft^2$/A) and then decreases as initial stand density continues to increase. The relationship between gross basal area increment and initial basal area has the same curve shape but the maximum increment point is shifted to a higher initial basal area of 222 $ft^2$/A. The shift in the maximum increment point for gross versus net basal area increment is the result of higher mortality in more dense stands.

<u>Height increment response</u>:

This analysis is based on average four-year height increment per tree. All fertilization treatments in all regions, except the 400 lb treatment in central Idaho and the 200 lb treatment in northeast Oregon, showed significantly greater height growth than the untreated control plots. There was no difference in height increment between the 200 and 400 lb treatments, except for central Washington. These results are provided in Table 2 and shown in Figure 3.

Initial basal area was not a significant covariate in the height increment analysis but was included in the model to allow consistent

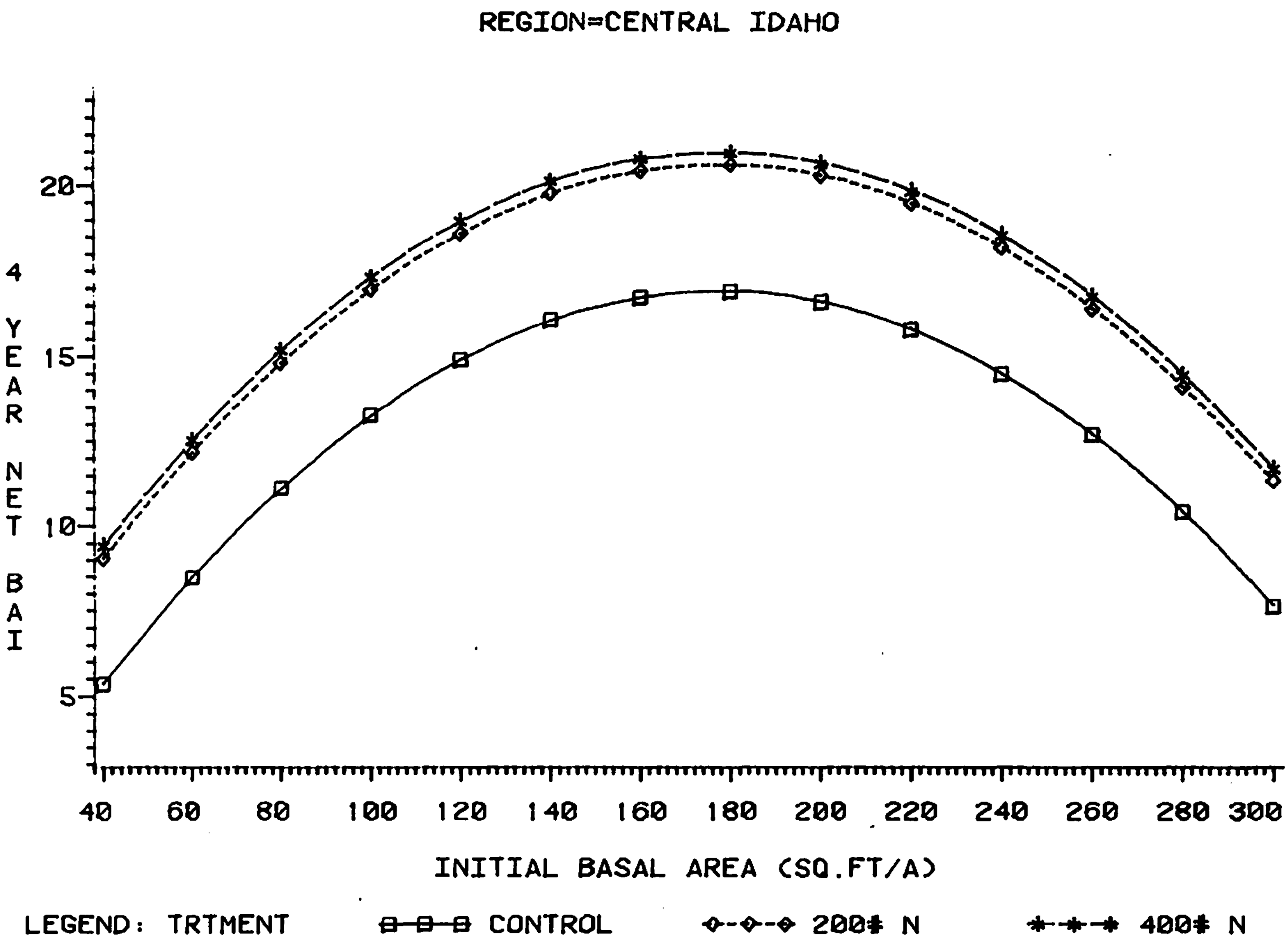


Figure 2. The relationship between four-year net basal area increment and stand basal area at the time of treatment.

Table 2. Average four-year height increment response per tree by region and treatment.[1]

| Region | Treatment | Height Increment: Total ft/tree | Increase over control: ft/tree | Increase over control: percent |
|---|---|---|---|---|
| Central Idaho | Control | 3.1 | | |
| | 200 # N | 3.7 | 0.6 | 17.9 |
| | 400 # N | 3.3 | 0.2 NS | 8.0 |
| Central Washington | Control | 3.7 | | |
| | 200 # N | 4.6 | 0.9 | 25.4 |
| | 400 # N | 5.0 | 1.4 | 36.6 |
| Montana | Control | 3.1 | | |
| | 200 # N | 3.6 | 0.5 | 16.5 |
| | 400 # N | 3.7 | 0.6 | 18.8 |
| Northern Idaho | Control | 5.5 | | |
| | 200 # N | 6.2 | 0.7 | 12.2 |
| | 400 # N | 6.2 | 0.7 | 12.6 |
| Northeast Oregon | Control | 3.8 | | |
| | 200 # N | 4.0 | 0.3 NS | 6.7 |
| | 400 # N | 4.4 | 0.6 | 16.7 |
| Northeast Washington | Control | 4.9 | | |
| | 200 # N | 5.3 | 0.4 | 7.4 |
| | 400 # N | 5.4 | 0.5 | 10.5 |
| Overall | Control | 3.9 | | |
| | 200 # N | 4.5 | 0.6 | 14.1 |
| | 400 # N | 4.6 | 0.7 | 17.4 |

[1]Averages are adjusted to a common initial basal area of 125 $ft^2/A$.

NS = Not significant.

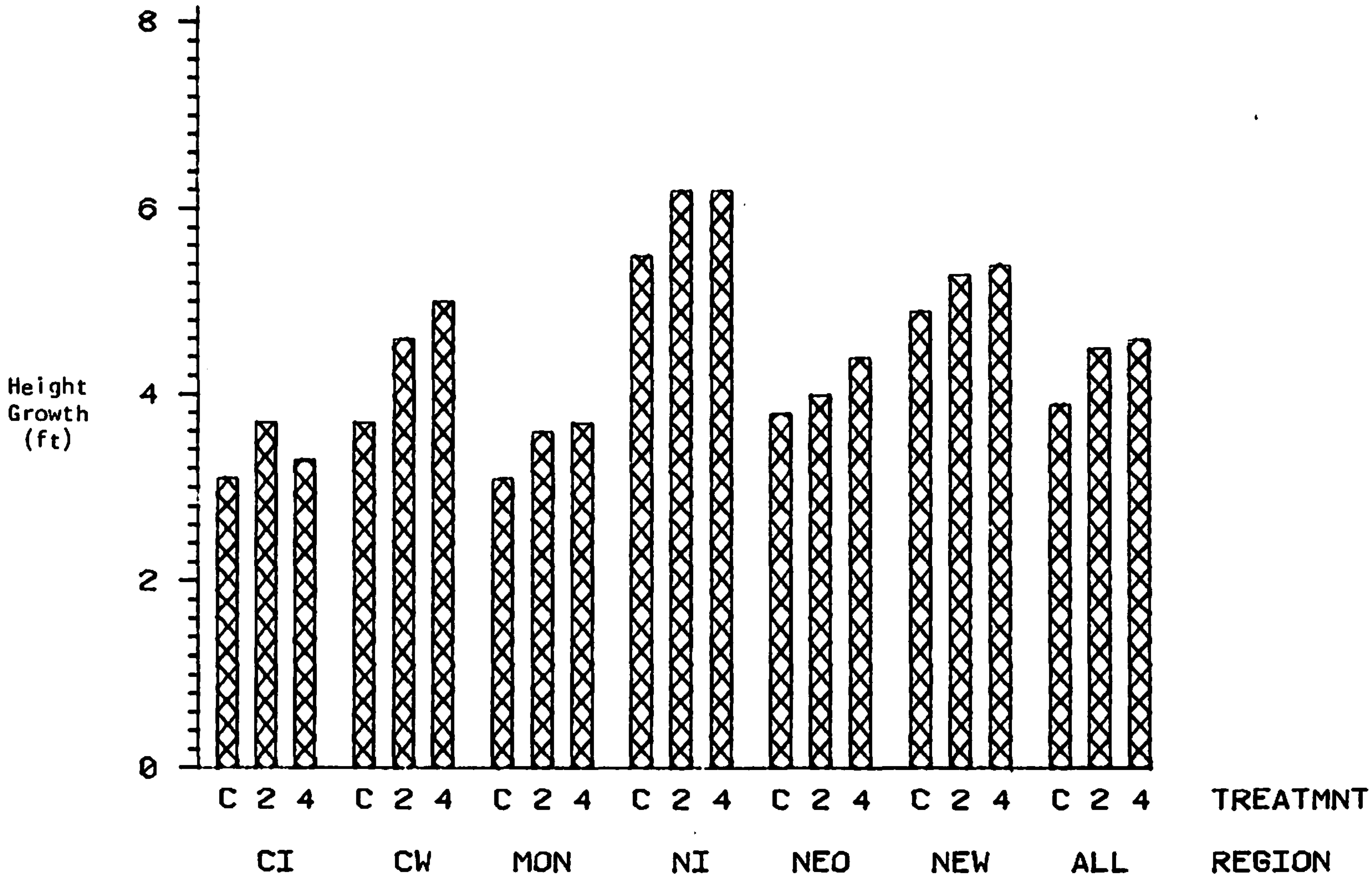


Figure 3. Average four-year height growth per tree for each region-treatment combination.

comparisons with other models. As initial basal area per acre increases four-year height increment slowly decreases.

Volume growth response:

The results for net and gross volume growth response closely parallel those for basal area growth. The net and gross volume growth estimates by region and treatment are given in Table 3 and shown in Figure 4. The gross volume per acre increments for both nitrogen treatments were significantly greater than the controls across all geographic regions. Only in central Washington was the gross volume growth for the 400 lb treatment significantly greater than the 200 lb treatment.

There is no statistical difference in net volume increment for the 400 lb treatment and the control in northeast Washington, and no difference between either fertilizer treatment and the controls in Montana and northeast Oregon. Northern Idaho showed the greatest net volume growth response to the 200 lb treatment (248 $ft^3$ in 4 years, 34.7%) while central Washington produced the largest response to the 400 lb treatment (260 $ft^3$, 43.8%).

An interesting comparison can be made with thinned Douglas-fir stands west of the Cascades. The average four-year gross and net volume responses to 200 lb nitrogen treatments were 272 and 260 $ft^3$/A, respectively. For 400 lb treatments, the four-year response for both gross and net volume was 304 $ft^3$/A. There was no mortality associated with the 400 lb treatment in the "westside" stands! (Regional Forest Nutrition Research Project, Biennial Report 1980-82; College of Forest Resources, University of Washington, Seattle.)

The relationships between gross and net volume growth and initial stand density has the same curve form as that shown for basal area

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

| Region | Treatment | Net Volume Increment: Total ft³/acre | Net Volume Increment: Increase over control ft³/acre | Net Volume Increment: Increase over control percent | Gross Volume Increment: Total ft³/acre | Gross Volume Increment: Increase over control ft³/acre | Gross Volume Increment: Increase over control percent |
|---|---|---|---|---|---|---|---|
| Central Idaho | Control | 513 | | | 520 | | |
| | 200 # N | 627 | 114 | 22.2 | 633 | 114 | 21.9 |
| | 400 # N | 629 | 116 | 22.5 | 637 | 118 | 22.7 |
| Central Washington | Control | 594 | | | 592 | | |
| | 200 # N | 747 | 154 | 25.9 | 754 | 162 | 27.3 |
| | 400 # N | 854 | 260 | 43.8 | 874 | 282 | 47.5 |
| Montana | Control | 487 | | | 478 | | |
| | 200 # N | 561 | 73 | 15.0 | 555 | 77 | 16.1 |
| | 400 # N | 524 | 36 | 7.5 | 545 | 67 | 14.0 |
| Northern Idaho | Control | 715 | | | 748 | | |
| | 200 # N | 962 | 248 | 34.7 | 962 | 214 | 28.7 |
| | 400 # N | 959 | 245 | 34.2 | 968 | 220 | 29.4 |
| Northeast Oregon | Control | 467 | | | 510 | | |
| | 200 # N | 540 | 73 | 15.7 | 583 | 73 | 14.3 |
| | 400 # N | 515 | 48 | 10.4 | 591 | 81 | 16.0 |
| Northeast Washington | Control | 635 | | | 676 | | |
| | 200 # N | 735 | 100 | 15.7 | 784 | 108 | 16.0 |
| | 400 # N | 669 | 34 | 5.3 | 796 | 120 | 17.7 |
| Overall | Control | 564 | | | 582 | | |
| | 200 # N | 684 | 120 | 21.3 | 702 | 121 | 20.8 |
| | 400 # N | 683 | 119 | 21.1 | 730 | 149 | 25.5 |

[1]Averages are adjusted to a common initial basal area of 125 $ft^2$/A.

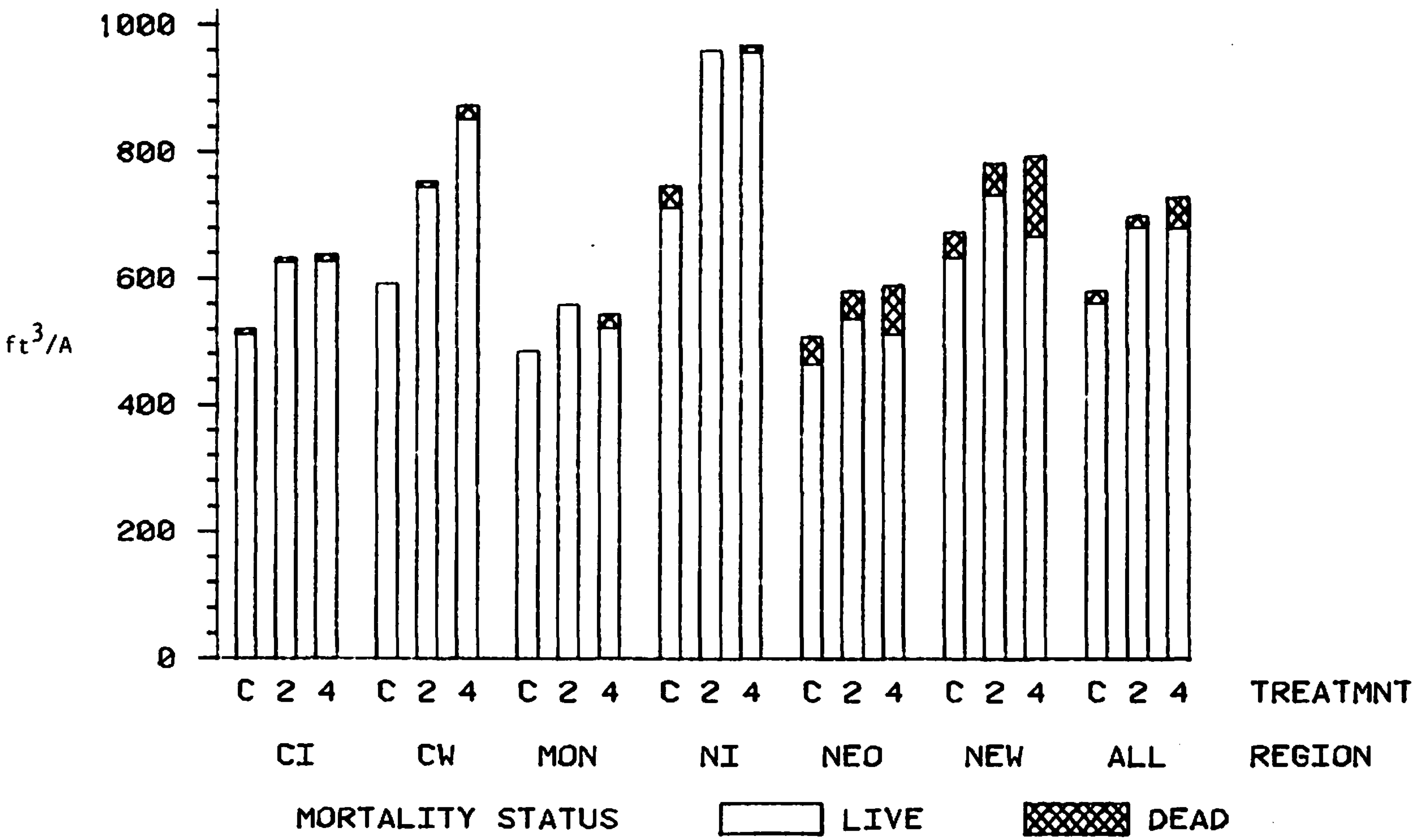


Figure 4. Four-year volume increment by region and treatment type partitioned into live (net) and dead components.

increment in Figure 2. Net volume increment is maximum at an initial basal area of 206 $ft^2/A$, while gross volume increment peaks at 294 $ft^2/A$.

Differences in mortality rates by treatment:

Mortality rates differed significantly among treatments. Basal area and volume per acre mortality estimates by treatment and geographic region are given in Table 4. Although not significant, mortality rates for the 400 lb treatments tended to be higher in most regions. The mortality rates for the 200 lb treatments also tended to be higher than the controls. This was not the case in northern Idaho, where the controls sustained the highest mortality.

Almost all of the mortality occurred during the second two-year period (i.e., years 3 and 4). The most common mortality cause recorded was "competition." Some trees on treated plots were also damaged or downed by snow and/or wind damage. The competition-caused mortality occurred mainly in the smaller size classes. This is illustrated in Figure 5, which shows mortality rates by diameter class and treatment for all the trees on the 1980 and 1981 installations. The difference in mortality rates is most noticeable in the 6-inch diameter class, where 7.8% of the trees died versus 1.7% in the control plots. The diameter distribution for all trees in this population is provided in Figure 6 to contrast with the mortality distribution in Figure 5. It is clear that the mortality is concentrated in the smaller size classes. This is not unexpected as previous research has shown that forest fertilization accelerates stand differentiation. What is surprising is how rapidly it seems to be happening in these thinned stands. However, mortality was lower in less dense stands. The relationship between stand density and mortality is shown in Figure 7.

Table 4. Average four-year basal area and volume mortality rates by region and treatments.[1]

| | | Basal Area | | Volume | |
|---|---|---|---|---|---|
| Region | Treatment | Total $ft^2/A$ | | Total $ft^3/A$ | |
| Central Idaho | Control | 0.4 | | 6 | |
| | 200 # N | 0.3 | | 6 | |
| | 400 # N | 0.5 | | 9 | |
| Central Washington | Control | 0.1 | | 0 | |
| | 200 # N | 0.5 | | 6 | |
| | 400 # N | 0.7 | | 19 | |
| Montana | Control | 0.0 | | 0 | |
| | 200 # N | 0.2 | | 0 | |
| | 400 # N | 1.0 | | 21 | |
| Northern Idaho | Control | 1.6 | | 33 | |
| | 200 # N | 0.8 | | 0 | |
| | 400 # N | 1.0 | | 9 | |
| Northeast Oregon | Control | 2.6 | | 43 | |
| | 200 # N | 2.7 | | 43 | |
| | 400 # N | 3.0 | | 75 | |
| Northeast Washington | Control | 1.8 | | 41 | |
| | 200 # N | 2.6 | | 49 | |
| | 400 # N | 5.5 | .006 | 127 | .02 |
| Overall | Control | 1.0 | | 17 | |
| | 200 # N | 1.2 | | 18 | |
| | 400 # N | 2.1 | .08 | 47 | .09 |

[1]Averages are adjusted to a common initial basal area of 125 $ft^2/A$.

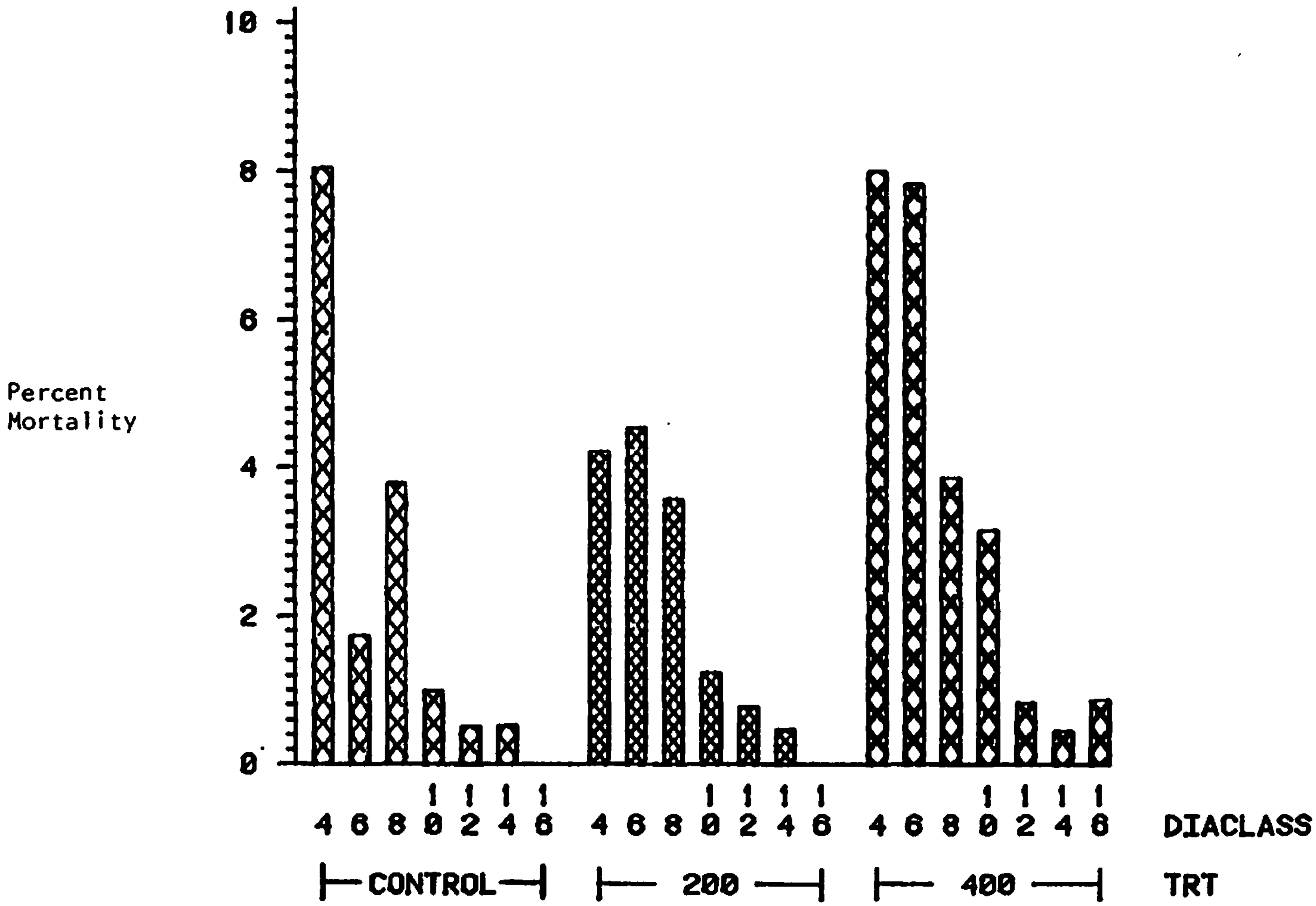


Figure 5. Percentage of total trees dead after four years by diameter class and treatment.

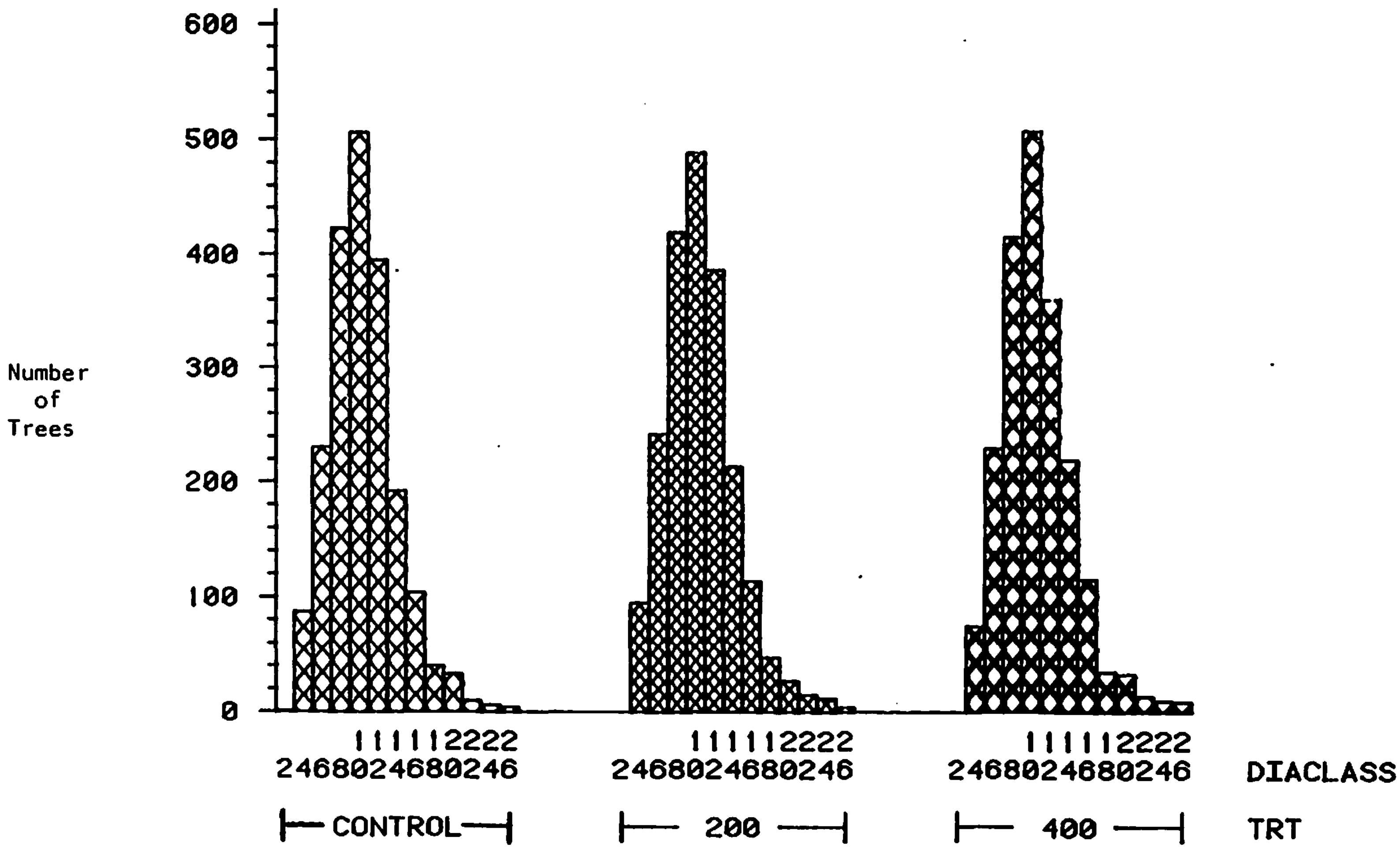


Figure 6. Number of trees by diameter class and treatment for the 1981 installations.

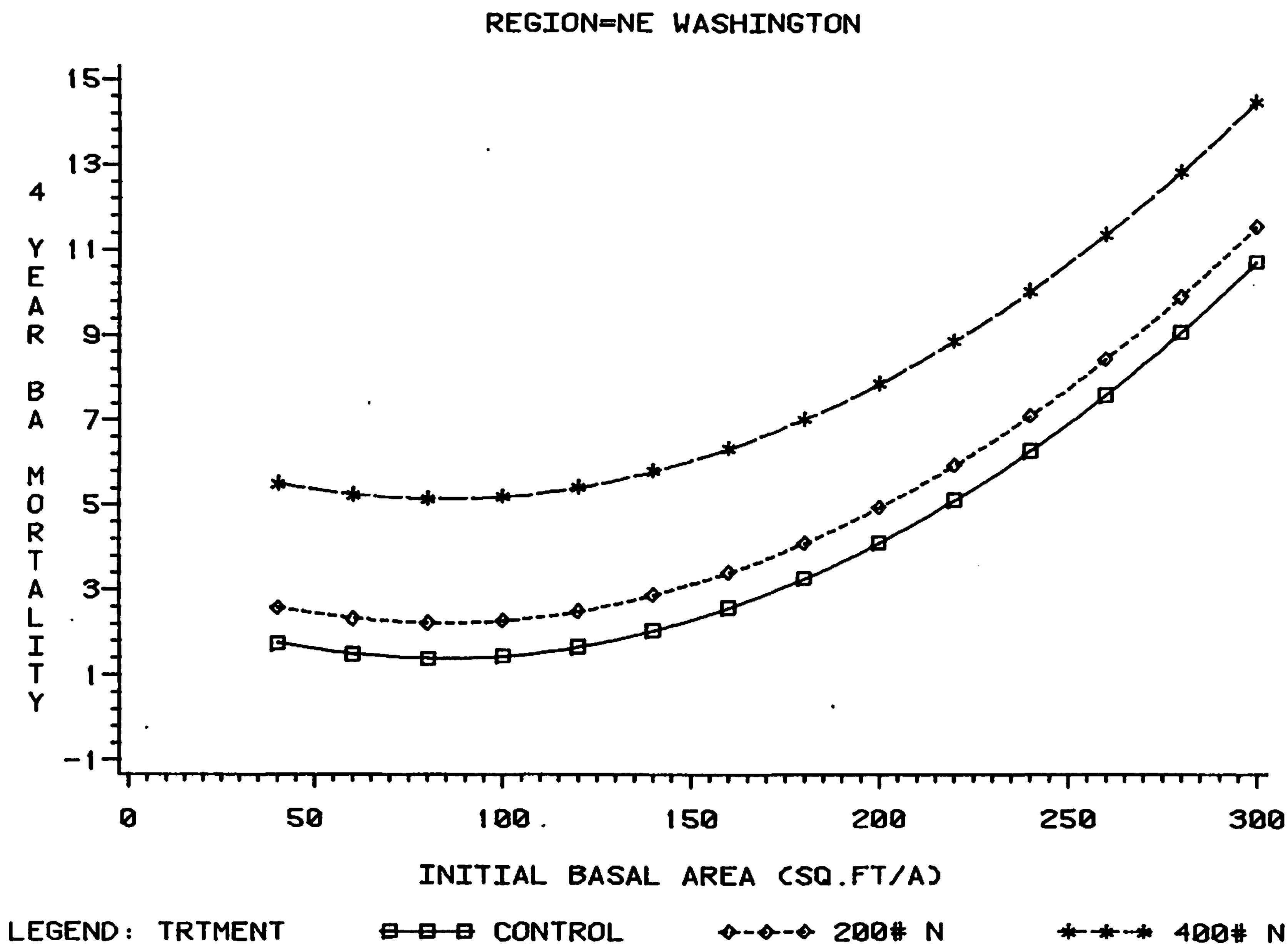


Figure 7. The relationship between four-year mortality and stand basal area at the time of treatment.

Accelerating stand differentiation implies that the larger trees are responding more to fertilization than the smaller trees. We have circumstantial evidence that this is occurring. We need further analysis to quantify the distribution of fertilization response by size classes within a stand. This analysis will be conducted, but not in time for the annual meeting of the cooperative. However, the results of this analysis will be provided in a separate report to cooperators when it is completed.

Duration of response:

The data collected this year provides our first opportunity to look at duration of treatment response. Since only diameters were remeasured after the first two-year growth period, the following analysis is based only on periodic basal area growth. Basal area increments for the first and second two-year periods are compared in Table 5.

The gross and net basal area increments by treatment and region are shown in Figures 8 and 9 for the first two-year and second two-year periods, respectively.

The gross basal area responses declined during years 3 and 4 compared to years 1 and 2 in all regions except central Washington. The decline in response during the second two-year period was even more noticeable for net basal area increment. The only treatments that produced a significant response in net basal area increment for years 3 and 4 were the 200 and 400 lb treatments in north Idaho and the 400 lb treatment in central Washington. As mentioned previously, almost all mortality occurred during the second two-year period.

Something else interesting can be seen in Figure 9 and Table 5. Net basal area increment for the untreated control plots declined during years 3 and 4 in every region except central Idaho and central Washington. The

Table 5. Average net and gross basal area response for each two-year period by region and treatment.

| | | BAI in the first two years[1] | | | | | | BAI in the second two years[1] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Net | | | Gross | | | Net | | | Gross | | |
| | | Total | Increase over control | | Total | Increase over control | | Total | Increase over control | | Total | Increase over control | |
| Region | Treatment | $ft^2/A$ | $ft^2/A$ | percent | $ft^2/A$ | $ft^2/A$ | percent | $ft^2/A$ | $ft^2/A$ | percent | $ft^2/A$ | $ft^2/A$ | percent |
| Central Idaho | Control | 7.0 | | | 7.5 | | | 7.9 | | | 7.8 | | |
| | 200 # | 9.5 | 2.5 | 35.9 | 9.8 | 2.3 | 31.1 | 9.2 | 1.3 NS | 16.5 | 9.2 | 1.3 | 17.1 |
| | 400 # | 10.2 | 3.2 | 46.6 | 10.3 | 2.9 | 38.3 | 9.3 | 1.5 NS | 18.9 | 9.4 | 1.6 | 20.2 |
| Central Washington | Control | 7.0 | | | 7.3 | | | 8.3 | | | 8.2 | | |
| | 200 # | 9.3 | 2.3 | 32.2 | 9.6 | 2.3 | 32.1 | 9.8 | 1.6 NS | 19.2 | 10.2 | 2.0 | 24.9 |
| | 400 # | 11.0 | 4.0 | 56.7 | 11.3 | 4.0 | 55.6 | 12.3 | 4.0 | 48.6 | 12.2 | 4.0 | 49.1 |
| Montana | Control | 8.1 | | | 8.0 | | | 5.4 | | | 5.4 | | |
| | 200 # | 9.4 | 1.3 NS | 16.5 | 9.4 | 1.4 | 17.1 | 5.9 | 0.5 NS | 9.5 | 6.1 | 0.7 NS | 12.8 |
| | 400 # | 8.9 | 0.8 NS | 9.3 | 9.2 | 1.2 | 14.5 | 5.4 | 0.0 NS | 0.0 | 6.1 | 0.7 NS | 12.1 |
| Northern Idaho | Control | 10.1 | | | 10.0 | | | 7.5 | | | 9.2 | | |
| | 200 # | 13.2 | 3.0 | 29.9 | 13.4 | 3.4 | 34.3 | 11.1 | 3.7 | 49.0 | 11.7 | 2.5 | 27.3 |
| | 400 # | 13.3 | 3.2 | 31.8 | 13.5 | 3.5 | 35.3 | 11.1 | 3.7 | 49.4 | 11.9 | 2.8 | 30.5 |
| Northeast Oregon | Control | 4.6 | | | 5.9 | | | 4.3 | | | 5.9 | | |
| | 200 # | 7.6 | 3.0 | 64.5 | 7.7 | 1.8 | 30.6 | 4.5 | 0.2 NS | 3.7 | 7.3 | 1.4 | 23.4 |
| | 400 # | 6.8 | 2.2 | 47.3 | 7.7 | 1.8 | 30.6 | 4.4 | 0.1 NS | 2.3 | 6.9 | 0.9 NS | 15.9 |
| Northeast Washington | Control | 9.2 | | | 9.3 | | | 7.5 | | | 9.2 | | |
| | 200 # | 11.1 | 1.9 | 20.3 | 11.2 | 2.0 | 21.1 | 8.6 | 1.1 NS | 14.7 | 10.5 | 1.3 | 14.3 |
| | 400 # | 10.8 | 1.6 | 17.2 | 11.4 | 2.1 | 22.9 | 5.3 | -2.2 NS | -29.7 | 10.8 | 1.6 | 16.9 |
| Overall | Control | 7.8 | | | 7.9 | | | 6.9 | | | 7.6 | | |
| | 200 # | 9.9 | 2.2 | 29.3 | 10.1 | 2.1 | 26.9 | 8.2 | 1.3 | 18.6 | 9.1 | 1.5 | 19.6 |
| | 400 # | 10.1 | 2.5 | 32.3 | 10.5 | 2.6 | 32.4 | 8.0 | 1.0 NS | 15.0 | 9.6 | 2.0 | 25.5 |

[1]Averages are adjusted to a common initial basal area of 125 $ft^2/A$.

NS = Not significant.

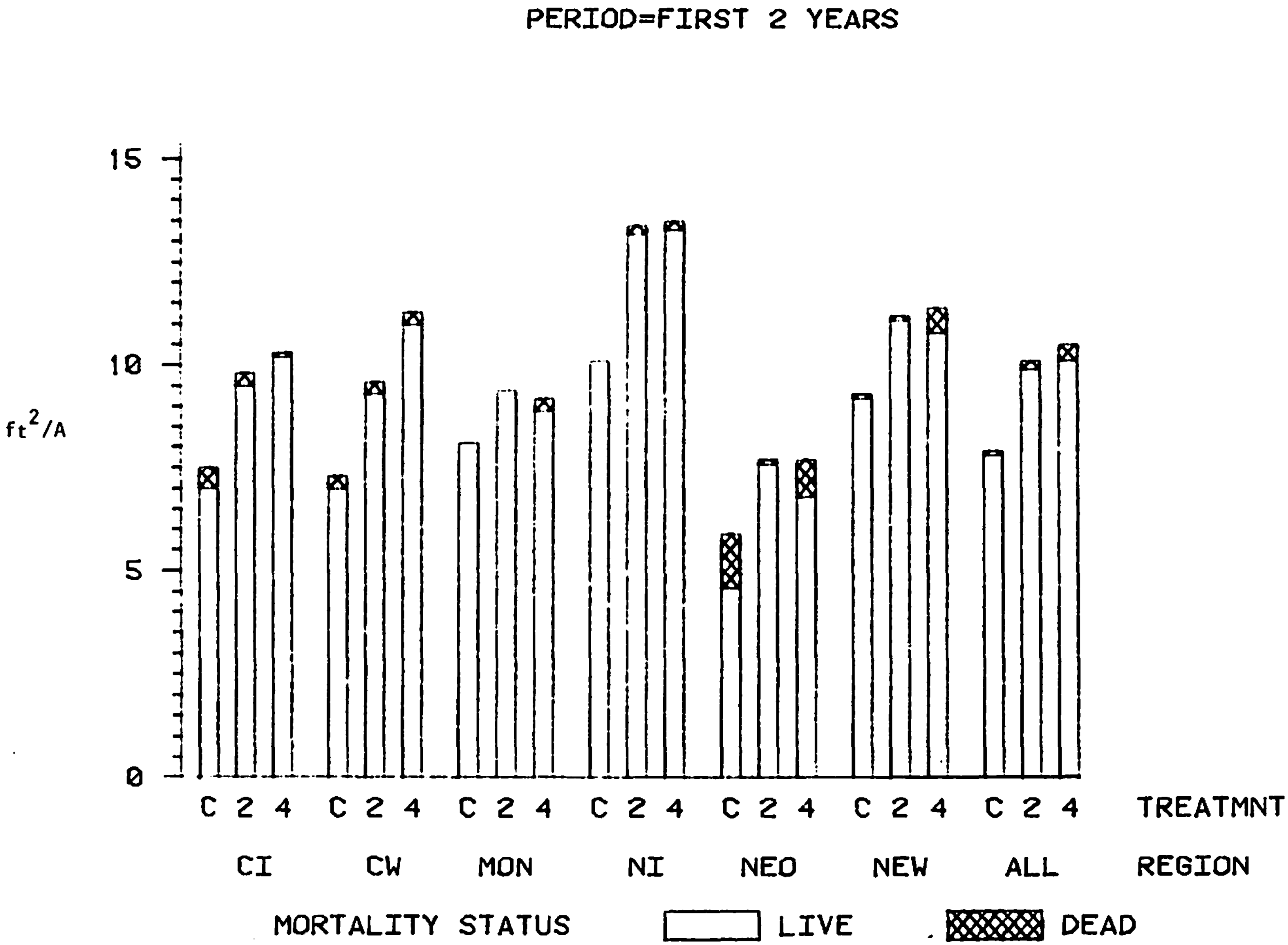


Figure 8. Average basal area increment by region and treatment for years one and two of the study.

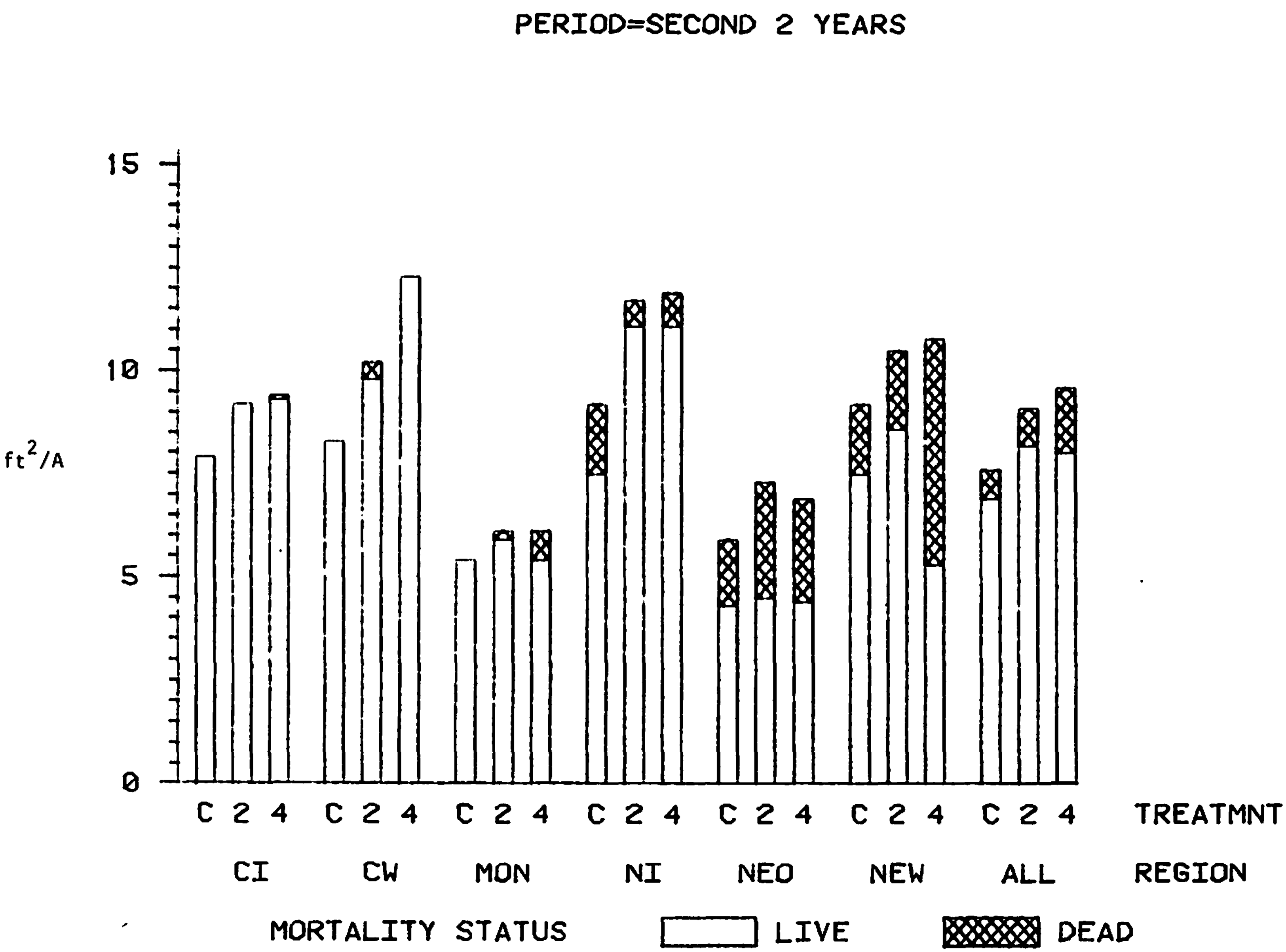


Figure 9. Average basal area increment by region and treatment for years three and four of the study.

same is true for gross basal area increment, although declines are not so great. Montana had a particularly large drop in control growth rate between the two periods, from 8.1 to 5.4 $ft^2/A$ net basal area. The reason for this drop is not clear, but it was not due to mortality in the control plots.

Four-year Growth Response of the 1980 Test Sites:

Boise Cascade Corporation supported the establishment of four test sites in thinned Douglas-fir stands on their lands 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 randomly assigned to the plots and 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 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) 200 lbs/A of nitrogen and 50 lbs/A of sulphur applied in the spring. Urea and sulphur-coated urea were the sources for nitrogen and sulphur.

The diameters and heights of all sample trees were measured before treatment and again after the 1984 growing season. Therefore, this analysis is based on basal area, height, and volume increments for four years after treatment. Response estimates for the 1980 installations are presented as smoothed estimates derived from the statistical models indicated in Tables 6 through 10 of the Technical Documentation Report. Averages are all adjusted to a common initial basal area of 105 $ft^2/A$.

Basal area response:

Average four-year net and gross basal area increments for each treatment type are given in Table 6 and shown in Figure 10. The four-year gross basal area/A increments for all the treatments were significantly different ($\alpha$=.05) from the controls but there were no significant differences between any of the fertilizer treatments. For the net four-year basal area increments, only three treatments were different from the controls: The 200 lb nitrogen plus 50 lb sulphur treatments applied in both fall and spring and 400 lbs nitrogen applied in the spring. There were no significant differences in net basal area increment between the fertilizer treatments. However, notice that the net four-year basal area increments for all the fertilizer treatments are greater than the untreated control growth, although not significantly greater for some treatments.

Height growth response:

The average untreated (control) height increment was 4.2 feet. All six of the fertilizer treatments had height growth greater than the controls, although only two treatments were statistically different. These were: 200 lbs nitrogen applied in the fall, and the spring application of 400 lbs of nitrogen. None of the differences between fertilized treatments were significant.

Volume growth response:

The four-year volume growth response results were similar (but not identical) to the basal area response results. Volume increments by treatment for the 1980 installations are shown in Figure 11 and the estimates are provided in Table 7. The gross volume increments for all treatments, except the spring application of 200 lbs of nitrogen, were significantly

Table 6. Average four-year net and gross basal area response by treatment for four 1980 installations.[1]

| Treatment | | | Net Basal Area Increment | | | Gross Basal Area Increment | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Increase over control | | Total | Increase over control | |
| Nitrogen (#/A) | Sulphur (#/A) | Time of application | $ft^2$/acre | $ft^2$/acre | percent | $ft^2$/acre | $ft^2$/acre | percent |
| 0 | 0 | -- | 16.6 | | | 18.2 | | |
| 200 | 0 | Fall | 19.2 | NS 2.5 (.20) | 15.3 | 22.6 | 4.4 (.003) | 24.0 |
| 400 | 0 | Fall | 18.6 | NS 2.0 (.30) | 12.0 | 22.5 | 4.2 (.003) | 23.2 |
| 200 | 50 | Fall | 19.8 | 3.2 (.08) | 19.4 | 21.8 | 3.5 (.007) | 19.3 |
| 200 | 0 | Spring | 17.8 | NS 1.2 (.50) | 7.1 | 21.7 | 2.4 (.05) | 13.3 |
| 400 | 0 | Spring | 21.8 | 5.2 (.01) | 31.3 | 23.1 | 4.9 (.001) | 26.6 |
| 200 | 50 | Spring | 19.9 | 3.2 (.08) | 19.5 | 21.1 | 2.8 (.025) | 15.4 |
| Overall treatment vs. control | | | | 2.9 (.025) | 17.4 | | 3.7 (.0001) | 20.3 |

[1]Averages are adjusted to a common initial basal area of 105 $ft^2$/A.

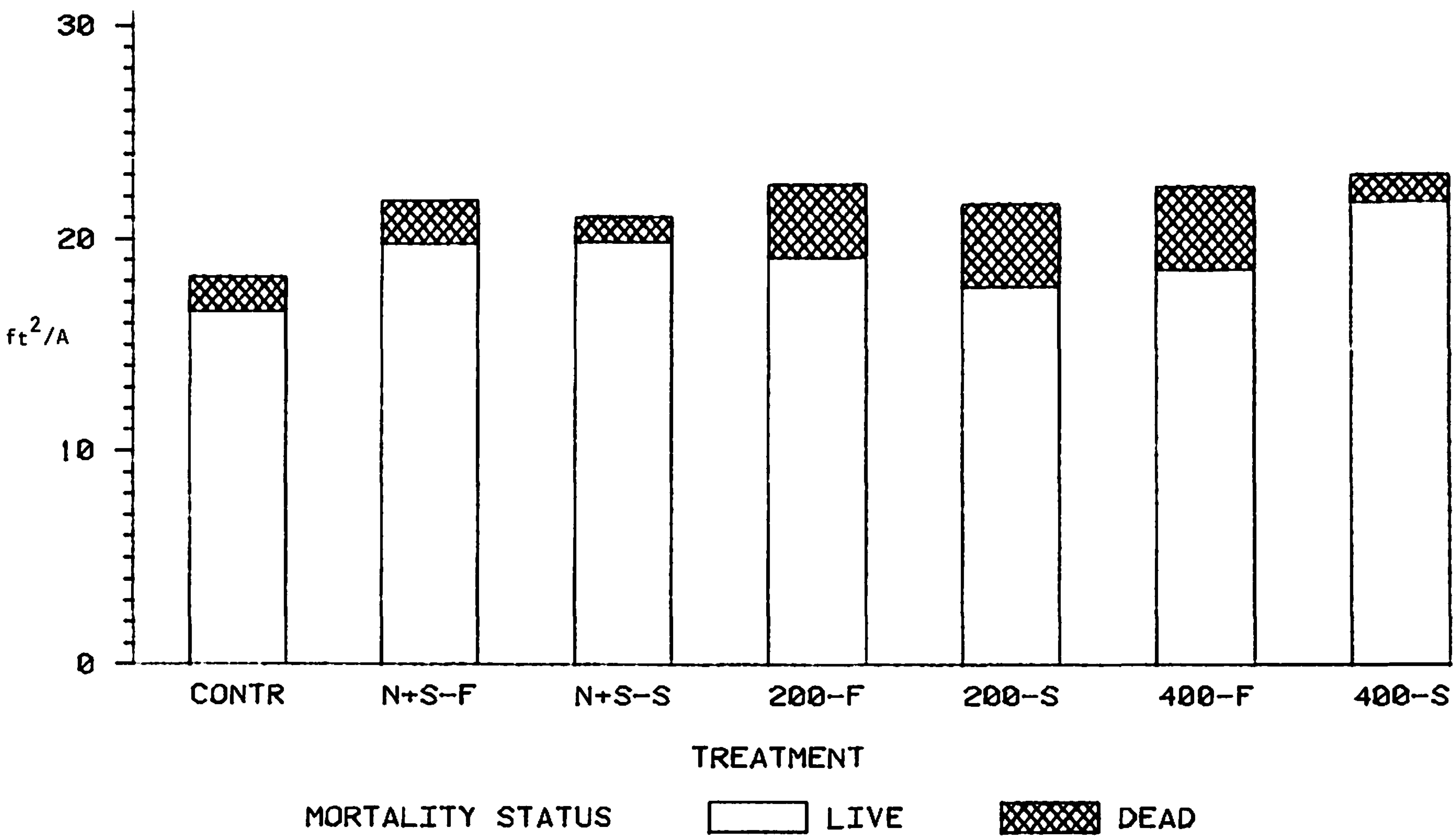


Figure 10. Average four-year basal area increment by treatment for four 1980 installations.

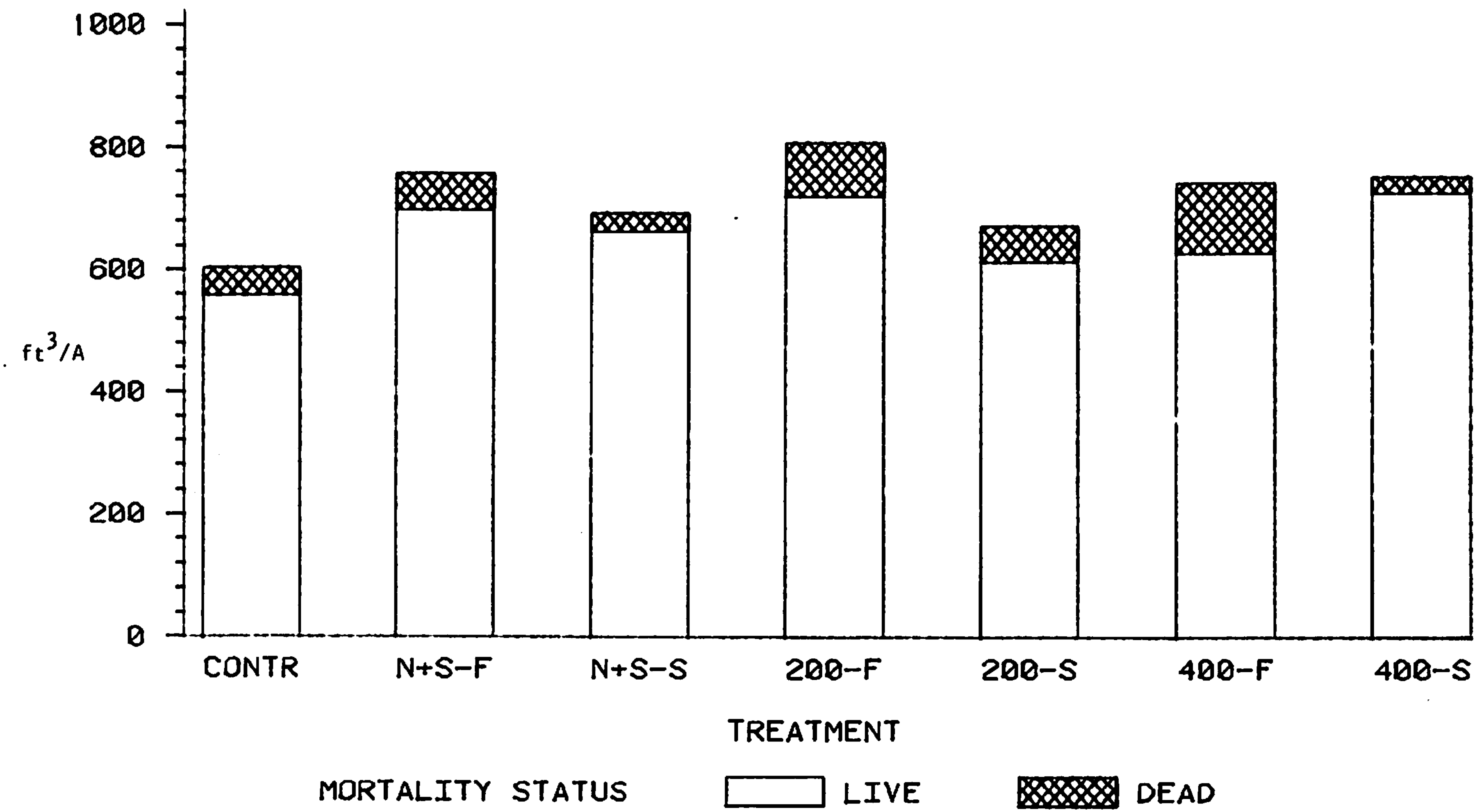


Figure 11. Average four-year total cubic foot volume increment by treatment for four 1980 installations.

Table 7. Average four-year net and gross total cubic foot volume response by treatment for four 1980 installations.[1]

| Treatment | | | Net Volume Increment | | | Gross Volume Increment | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Increase over control | | Total | Increase over control | |
| Nitrogen (#/A) | Sulphur (#/A) | Time of application | ft³/acre | ft³/acre | percent | ft³/acre | ft³/acre | percent |
| 0 | 0 | -- | 559 | | | 604 | | |
| 200 | 0 | Fall | 722 | 163 | 29.1 | 811 | 207 | 34.3 |
| 400 | 0 | Fall | 631 | 72 | 12.8 | 745 | 141 | 23.4 |
| 200 | 50 | Fall | 700 | 141 | 25.2 | 759 | 155 | 25.6 |
| 200 | 0 | Spring | 616 | 57 | 10.1 | 675 | 72 | 11.8 |
| 400 | 0 | Spring | 728 | 169 | 30.1 | 756 | 152 | 25.1 |
| 200 | 50 | Spring | 665 | 106 | 18.9 | 695 | 91 | 15.1 |

[1]Averages are adjusted to a common initial basal area of 105 $ft^2$/A.

different from the controls. The treatment of 200 lbs of nitrogen applied in the fall also produced significantly more gross volume growth than both the spring applications of 200 lbs of nitrogen and 200 lbs of nitrogen plus 50 lbs of sulphur.

Four of the six fertilization treatments produced four-year net volume responses that were significantly different from the controls. There was no statistical difference in net volume increment between the fertilization treatments, even though response ranged from 57 cu ft/A (10%) to 169 cu ft/A (30%).

The results of this limited experiment indicate that there is no difference in net volume or basal area growth response from fall or spring fertilizer applications as conducted in this study. The spring treatments were applied in early April and enough precipitation probably occurred to avoid nitrogen losses due to volatilization and nitrification. There were no differences in basal area or volume growth response between the urea and sulphur-coated urea treatments for these four installations. Since the growth responses to fall and spring applications were similar, these four installations were combined with the 45 installations established in 1981 for the overall statistical analysis. The plots treated with sulphur-coated urea were not included in the overall analysis.

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

The post-treatment foliar nitrogen levels are given by treatment and soil parent material in Table 8. These values are derived from all 90 Douglas-fir installations established in 1981 and 1982. The average foliar nitrogen concentration for the untreated control plots is only 1.1%. This is very low compared to results from studies in other regions. It has been suggested by some studies that significant response to nitrogen can be expected if foliar N levels are below 1.6%. Notice that the foliar N levels for the 200 lb nitrogen treatment, while significantly greater than the controls, do not reach 1.6%. It is only with the 400 lb treatment that we approach this level. Why then wasn't the two-year growth response to the 400 lb treatment significantly greater than the 200 lb treatment based on all 90 installations? In central Washington, and for many individual installations in other regions, the 400 lb treatment response was significantly greater than the 200 lb treatment. In the cases where additional nitrogen did not produce additional increment, it is likely that some other factor limited growth. We have empirical evidence that one of those factors was potassium.

The application of nitrogen sometimes decreased the foliar content and concentration of other mineral nutrients such as boron, iron, and copper, but particularly potassium. If the foliar concentration of potassium fell below 6000 parts per million (a published inadequate level for Douglas-fir) after treatment with 400 lbs of nitrogen, then the average increase of the 400 lb over the 200 lbs treatment was -8.4%. For the rest of the stands, where potassium remained above 6000 p.p.m., the average difference in the two treatments was +7.6%, a total difference of 16%.

Table 8. Average foliar nitrogen concentration by soil parent material and treatment.

| Parent material | Nitrogen percent | | |
|---|---|---|---|
| | Control | 200 lb | 400 lb |
| Granite (10) | 1.02 | 1.26 | 1.61 |
| Ash-loess (8) | 1.09 | 1.34 | 1.95 |
| Basalt (20) | 1.17 | 1.41 | 1.65 |
| Glacial till (22) | 1.10 | 1.38 | 1.78 |
| Ash/metasediments (12) | 1.14 | 1.38 | 1.82 |
| Valley fill (3) | 1.20 | 1.42 | 1.81 |
| Colluvium (4) | 1.06 | 1.33 | 1.74 |
| Alluvium (3) | 1.10 | 1.35 | 1.84 |
| Sandstone (3) | 1.41 | 1.41 | 1.81 |

The large shifts in foliar potassium concentrations were associated with glacial till, valley fill and loess soil parent materials. These relationships will be analyzed more completely using two-year basal area increment for all 90 Douglas-fir installations as the dependent variable. The results will be presented at the annual meeting.

Based on last year's analysis, soil parent material was an important variable in predicting two-year basal area response to treatments for all 90 installations. This new analysis may begin to explain why parent materials are important in accounting for differences in treatment response. A map showing the parent material of each Douglas-fir installation is provided in Figure 12. Montana and central Washington have the most diversity of parent materials. The glacial till soils occur primarily along the northern portion of the region.

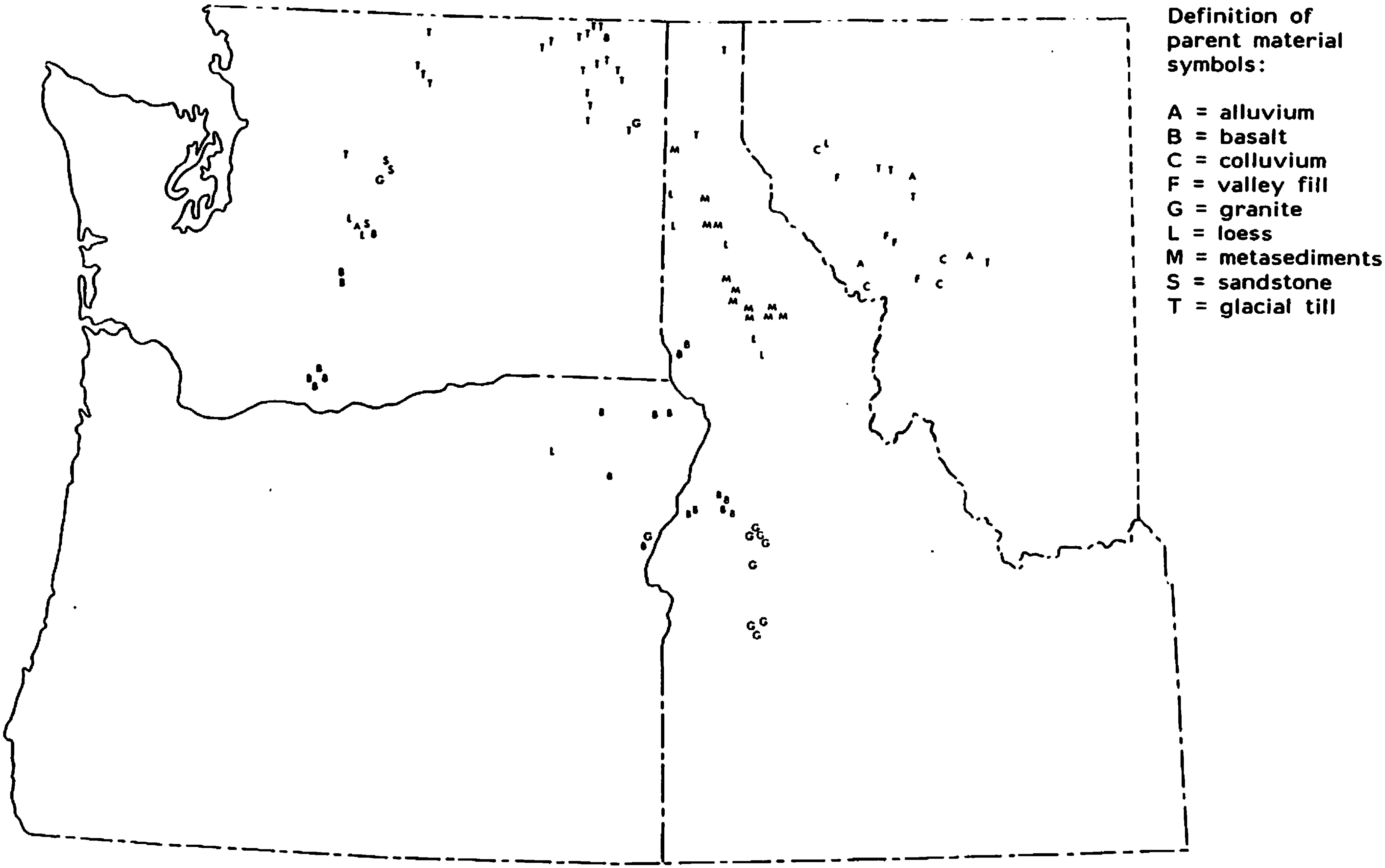


Figure 12. Soil parent material for each Douglas-fir installation of the Intermountain Forest Tree Nutrition Cooperative.

Western Larch Growth Response to Nitrogen Fertilization Six Years After Treatment:

The Colville National Forest recently shared the results of fertilization trials in three second growth western larch stands. The experiments were conducted on a contract basis by the Regional Forest Nutrition Research Project located at the College of Forest Resources, University of Washington. The experimental design is identical to our cooperative's. Treatments of 200 and 400 lbs of nitrogen per acre were evaluated versus the growth of untreated control plots. The treatments were applied in 1978, and the plots were remeasured every two years over a six-year period.

The following table contains a brief description of the initial conditions for these installations:

| Installation name | | Location S | T | R | Age | Trees/A | Basal area per acre($ft^2$) | Percent WL |
|---|---|---|---|---|---|---|---|---|
| #L223 | Timber Mountain | 15 | 35N | 42E | 47 | 1318 | 176 | 60 |
| #L224 | Bestrom Meadow | 17 | 36N | 41E | 47 | 168 | 91 | 90 |
| #L226 | Henry Creek | 24 | 39N | 32E | 50 | 204 | 56 | 91 |

Notice that the Timber Mountain stand is much more dense and has a higher proportion of other species than the other two stands.

Basal area growth response to treatment is provided for each two-year period in Table 9 and Figure 13, and volume response in Table 10 and Figure 14. The three stands each showed a different pattern of response to nitrogen treatments. The very dense stand (#L223) showed very good response to both the 200 and 400 pound treatments during the first two-year period; however, during the last two years of the measurement

Table 9. Average net basal area annual increment by two-year period for three western larch stands in northeast Washington ($ft^2/A/yr$).

| Installation | L223 | | | L224 | | | L226 | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | Years 1&2 | Years 3&4 | Years 5&6 | Years 1&2 | Years 3&4 | Years 5&6 | Years 1&2 | Years 3&4 | Years 5&6 |
| Control | 3.35 | 0.10 | 1.45 | 1.60 | 0.90 | 1.20 | 2.25 | 2.60 | 3.10 |
| 200 lbs N | 5.00 | 3.20 | 1.20 | 2.30 | 2.15 | 2.50 | 3.40 | 3.55 | 3.25 |
| 400 lbs N | 5.55 | -0.45 | -0.70 | 2.40 | -0.20 | 1.65 | 3.60 | 4.55 | 4.20 |

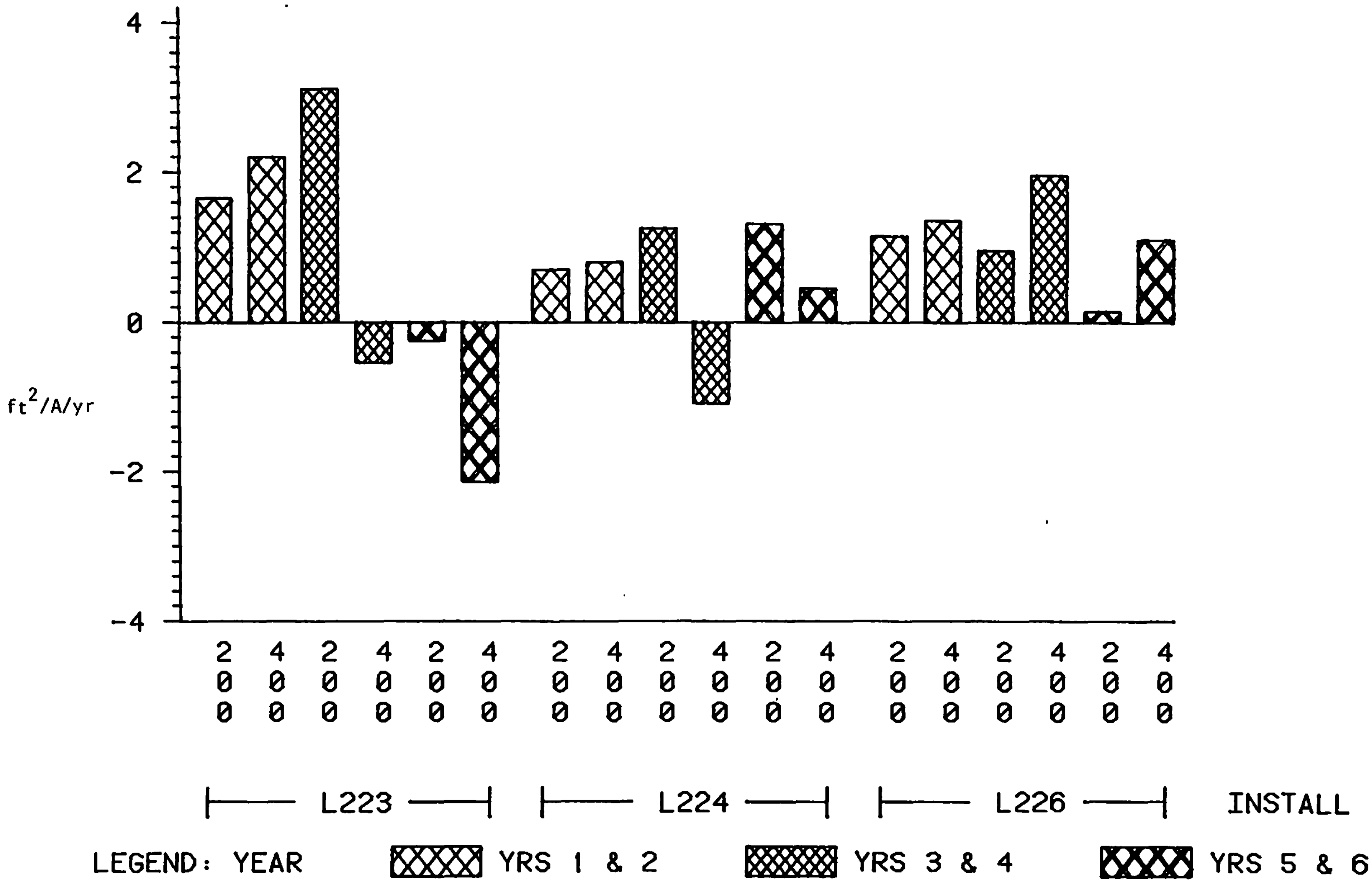


Figure 13. Average annual net basal area response by two-year period for three western larch stands in northeast Washington.

Table 10. Average net volume annual increment by two-year period for three western larch stands in northeast Washington ($ft^3/A/yr$).

| Installation | L223 | | | L224 | | | L226 | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | Years 1&2 | Years 3&4 | Years 5&6 | Years 1&2 | Years 3&4 | Years 5&6 | Years 1&2 | Years 3&4 | Years 5&6 |
| Control | 128 | 68 | 97 | 69 | 52 | 93 | 70 | 82 | 115 |
| 200 lbs N | 198 | 177 | 148 | 112 | 111 | 156 | 101 | 109 | 125 |
| 400 lbs N | 234 | 98 | 82 | 129 | 51 | 110 | 99 | 127 | 160 |

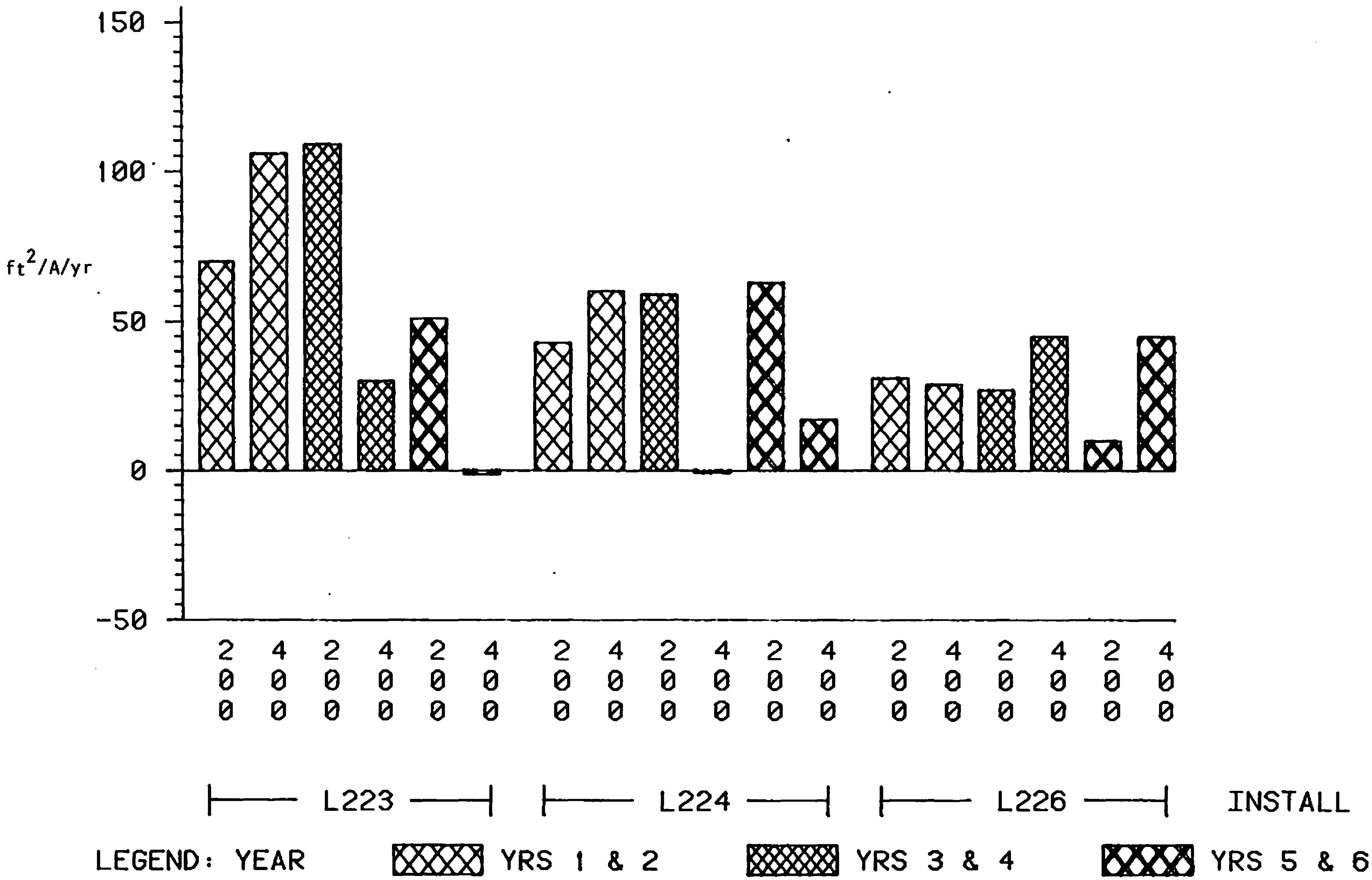


Figure 14. Average annual net total volume response by two-year period for three western larch stands in northeast Washington.

period (years 5 and 6) the net growth of the treated plots was less than the control plots. This apparently resulted from substantially higher mortality rates in the smaller size classes on the fertilized plots.

In the least dense stand (#L226), the basal area and volume response to the 200 lb treatment was greatest during the first two-year period and declined thereafter. Basal area response to the 400 lb treatment peaked during years 3 and 4, although response was still substantial in years 5 and 6. Volume response in this stand was greatest in years 3 and 4 and continued at the same level in years 5 and 6. Stand L224 was intermediate in density and also in its pattern of response to treatment.

The mortality patterns and the resultant effect on net response after the first 4 years is similar to the 1981 IFTNC Douglas-fir installations in northeast Washington. Given the general locations of these western larch stands, they are probably located on glacial till soils similar to our Douglas-fir installations.

At the annual meeting we should consider obtaining the existing data for these stands, making the 8-year field remeasurements, and including these data in future IFTNC analyses.

Ponderosa Pine Test Sites Established:

Ten installations were established in managed (thinned), second-growth ponderosa pine stands during the 1985 field season. Five of the installations were located in the central Washington region and five in northeast Oregon (Figure 15). All stands were thinned at least five years prior to our fertilizer applications. A brief mensurational description of each installation is provided in Table 11 and a more detailed description is included in the Technical Documentation Report. The same stand selection criteria and field procedures were used as for the Douglas-fir phase of the cooperative. Six 0.1 or 0.2 acre plots were established at each installation. The treatments were: control, 200 lbs and 400 lbs of nitrogen per acre. The treatments were replicated at each installation. Urea was the nitrogen source applied in the fall.

As planned, no soil or foliage sampling was conducted at the time of installation establishment. This sampling may be conducted in the future, depending on the desires of the Research Council. All other site, stand and tree attributes were collected as in the Douglas-fir phase of the cooperative.

During ponderosa pine stand selection, we wanted to sample a range of stand ages, tree sizes, densities and site conditions. Given only ten installations, we sampled a good range of conditions. For example, basal area ranges from 70 to 214 $ft^2/A$, average stand diameter ranges from 9.0 to 15.1 inches, and the stands are between 30 and 80 years old. The ponderosa pine installations were located on either Douglas-fir or grand fir habitat series. The cooperative has made a good start on the ponderosa pine phase of the project.

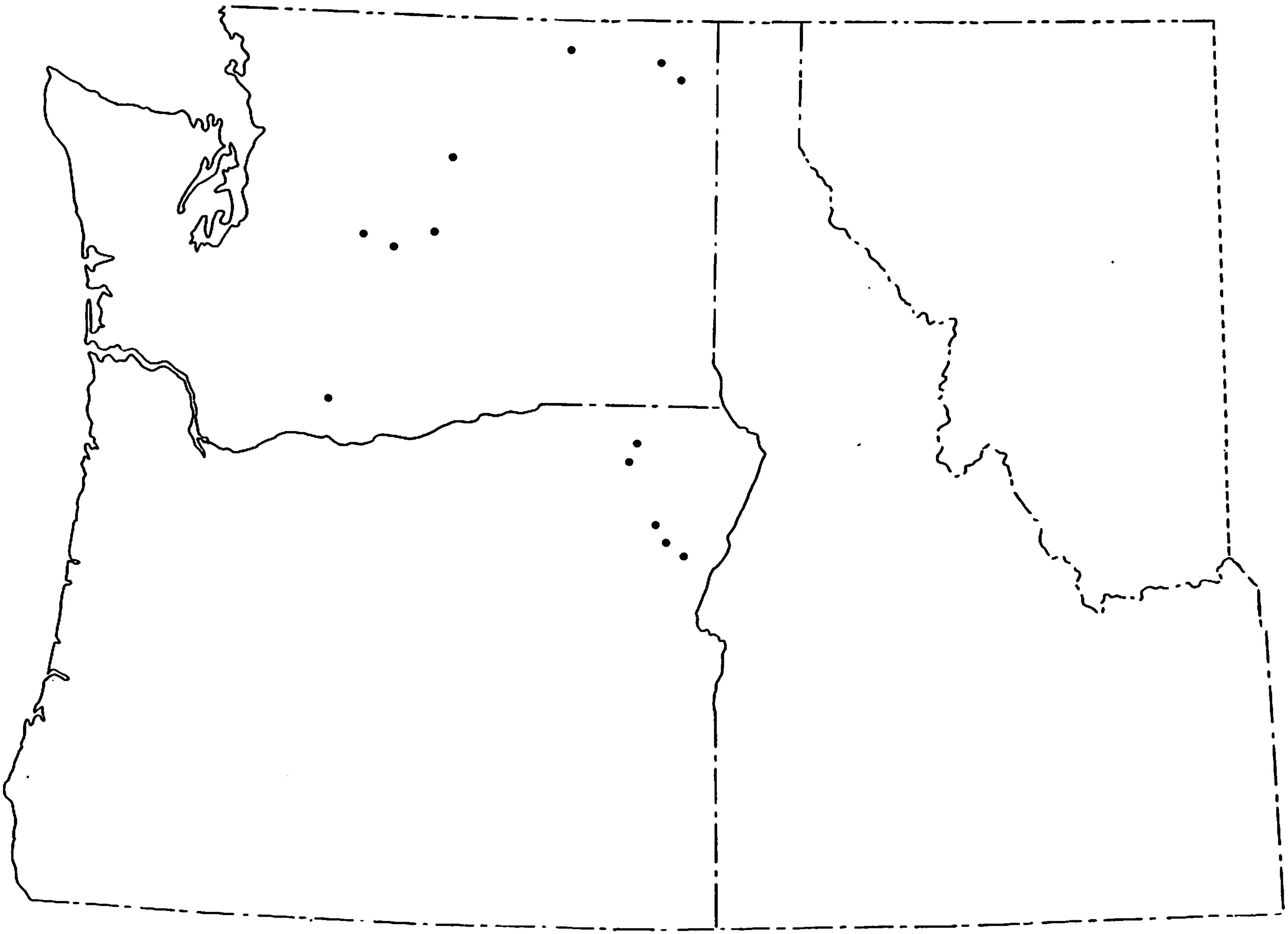

Figure 15. Locations of ten new ponderosa pine installations in northeast Oregon and central Washington; and three potential western larch test sites in northeast Washington.

Table 11. Mensurational characteristics of ponderosa pine test sites installed in 1985.

| Installation number | Age | Trees/ acre | Basal area per acre | Average DBH | Percent ponderosa pine |
|---|---|---|---|---|---|
| 291 | 80 | 71 | 77 | 13.8 | 100.0 |
| 292 | 70 | 91 | 120 | 15.1 | 94.2 |
| 293 | 35 | 177 | 88 | 9.2 | 96.0 |
| 294 | 75 | 120 | 137 | 13.6 | 93.6 |
| 295 | 30 | 245 | 120 | 9.3 | 100.0 |
| 296 | 30 | 175 | 93 | 9.6 | 100.0 |
| 297 | 45 | 155 | 70 | 9.0 | 100.0 |
| 298 | 50 | 177 | 90 | 9.5 | 100.0 |
| 299 | 70 | 237 | 167 | 11.1 | 98.2 |
| 300 | 77 | 230 | 214 | 12.6 | 100.0 |