

RESPONSE OF WESTERN HEMLOCK TO NITROGEN FERTILIZATION AND THINNING IN THE PACIFIC NORTHWEST

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ABSTRACT

In 1976, an intensive response analysis program was initiated through the Regional Forest Nutrition Research Project (RFNRP). Three mensurational techniques were developed and evaluated using data collected at two RFNRP coastal hemlock research sites. Each analysis technique utilized increment core data and was based on the premise that future growth is directly related to previous growth trends, barring major disturbance. Results show that natural stands of hemlock, in fact, respond in a highly variable manner to nitrogen fertilization. Geographical trends in response between Cascade and coastal sites are not clearly indicated. Evaluations of a combined thinning and fertilizer treatment indicate that younger thinned stands respond best to fertilizer, while older (over 25 years) respond best to thinning. Based on these results, we concluded that growing space limitations in natural stands of hemlock may only partially explain variability in fertilizer response.

INTRODUCTION

In 1976, western hemlock *Tsuga heterophylla* [Raf.] Sarg.) represented approximately 25% of the total softwood resource within the continental west coast region. Total standing growing stock was estimated at 660 billion bd. ft. (Beswick 1976). These figures, using average volumes per acre, equate to some 14 million acres (5.7 ha) of hemlock (Beswick 1976).

In 1969, the Regional Forest Nutrition Research Project (RFNRP) began fertilization research in natural stands of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and western hemlock. Twenty-six permanent research installations were established in stands predominantly occupied by hemlock in coastal Washington, coastal Oregon, and the Washington Cascades. At each installation two levels of urea fertilizer, 200 and 400 lb N/acre, were evaluated using a randomized block design.

In 1971, eight similar research installations were established in thinned stands of western hemlock (40% basal area reduction). These two types of research installations, fertilization without thinning and fertilization in thinned stands, will hereafter be referred to as phase I and phase II installations,

respectively (Figure 1). Detailed descriptions of the experimental design and past results have been published by the Regional Forest Nutrition Research Project (Univ. Washington 1972, 1974, 1976, 1979).

DeBell et al. (1975) summarized results of several N fertilization trials undertaken in western hemlock (Figure 2). This publication documented the high degree of response variability observed by several researching organizations.

Possible causes of this variability in response to N fertilization are: N limitations (N may not be limiting throughout the hemlock range); mensurational techniques (commonly used analysis techniques may not be sufficiently sensitive to assess response on an area-by-area basis or in stands of high structure variability); other (factors such as disease [e.g., *Fomitopsis annosa*], genetic variability, other limiting nutrients, stand density, toxicity to urea N or all may control magnitudes of response).

The second category, mensurational techniques, warranted further investigation for several reasons: (1) Most response analysis conducted in western hemlock has relied heavily on plot comparison techniques. Such techniques assume a homogeneous stand structure among plots within individual installations, which is rarely the case. (2) Without accurate estimates of treatment response, analyses to establish causation are meaningless. (3) Response estimates on an area-by-area basis have become increasingly important because of the need to correlate response with identifiable physical parameters that can be used to guide operational programs.

Figure 3 indicates the magnitude of within installation variability for 24 phase I installations maintained by RFNRP. In these highly variable stands, if differences in posttreatment diameter growth are used to estimate treatment effect, response is likely over- or underestimated because of differences in growth trends between plots prior to treatment. This is demonstrated in Figure 4 where estimates of both pretreatment and posttreatment average diameter growth are shown for two phase I (unthinned) installations. Though the 200 lb N/acre treatment (Inst. #4) indicates a 27% increase in growth over control during the 3-yr posttreatment period, a pretreatment

Figure 1. Phase I and II western hemlock installations (RFNRP).

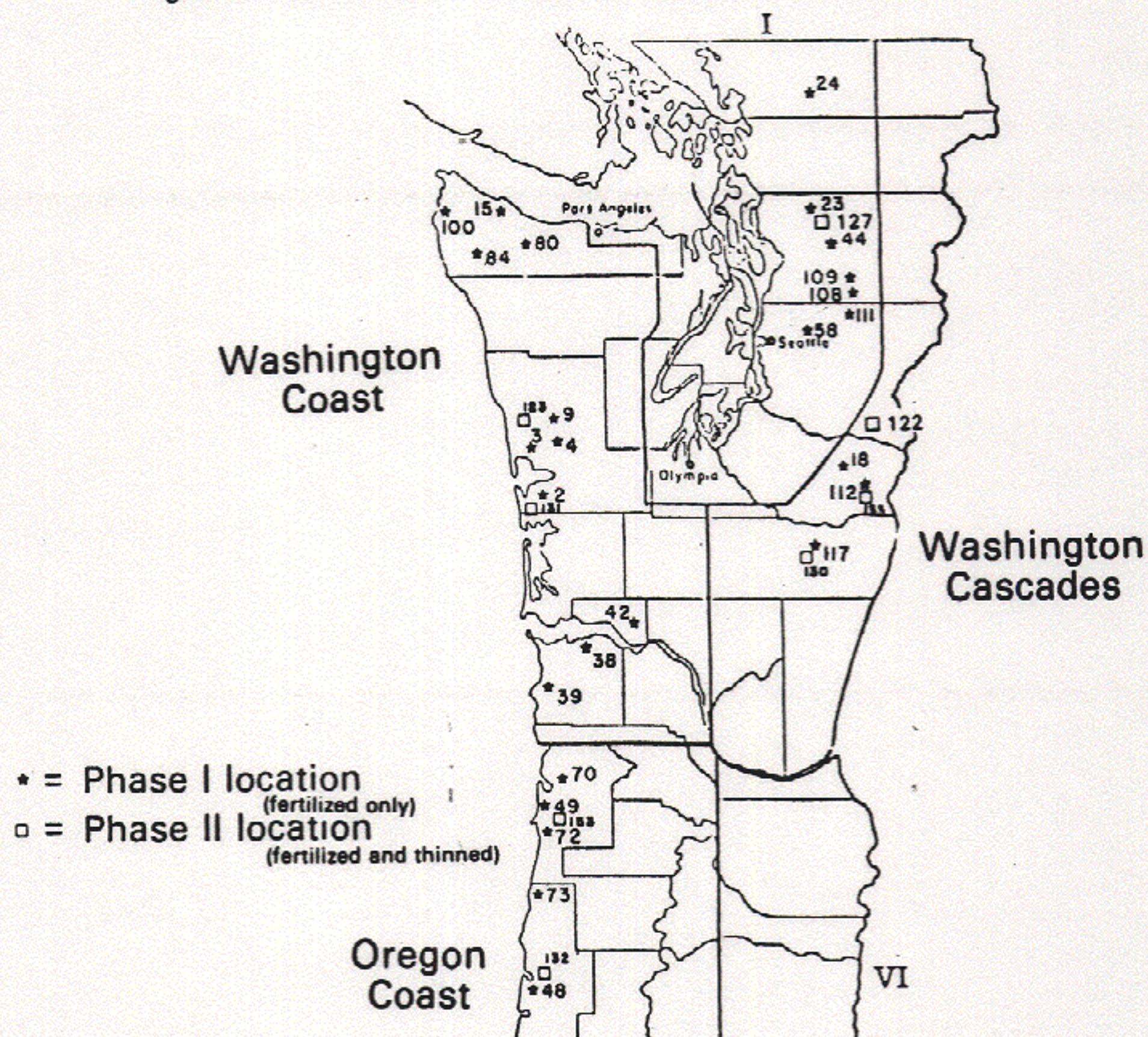
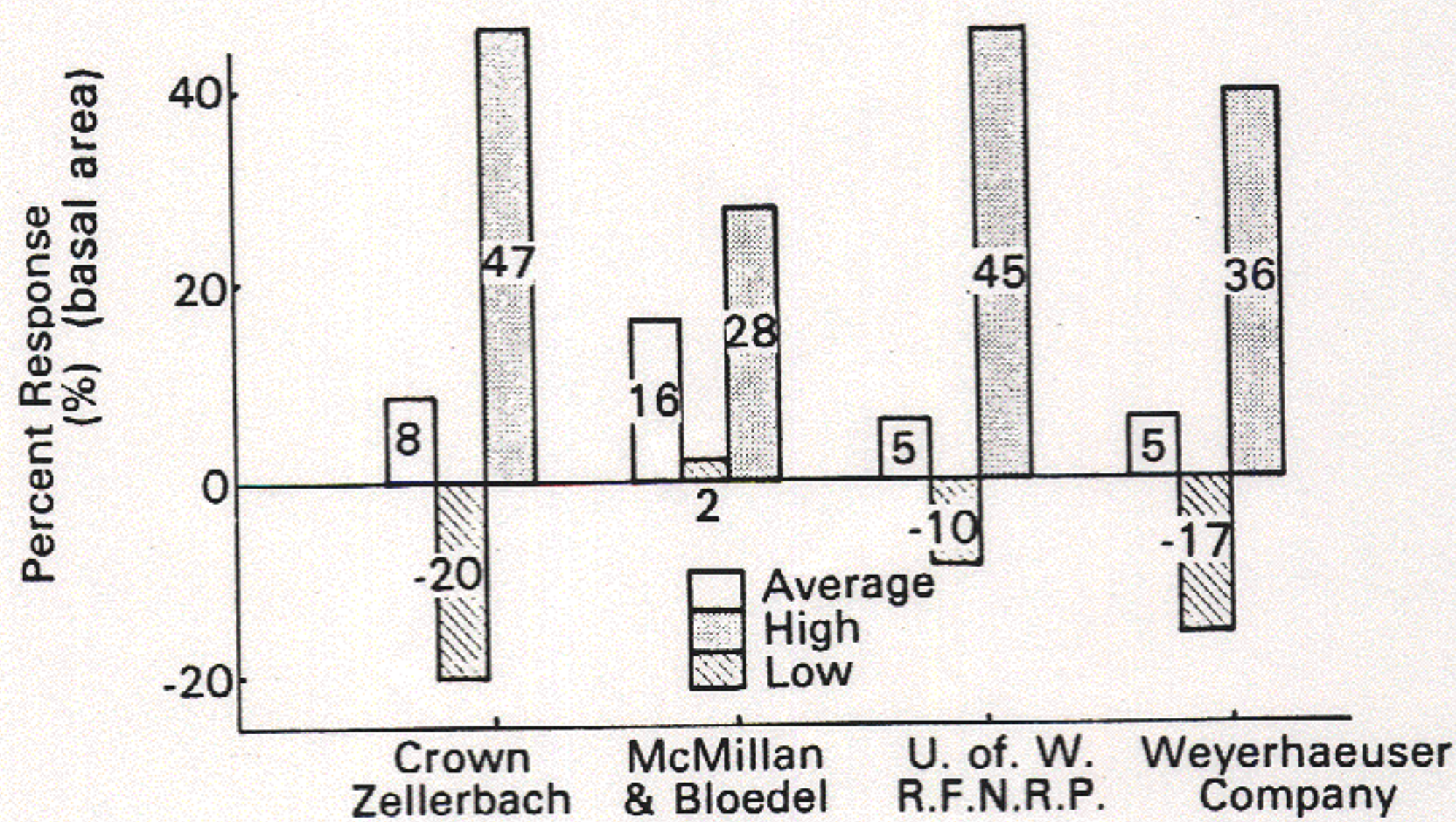


Figure 2. Two- to six-yr fertilization results in western hemlock by researching organization (DeBell et al. 1975).



growth difference of 23% reduces response to 4%. The opposite situation is shown for the 400 lb N/acre treatment (Inst. #9), where the control plots grew in diameter more rapidly than treated areas prior to fertilization. The plot comparison analysis would indicate a 6% response when a 13% increase actually occurred. These results indicate the need for intensive analytical techniques to evaluate treatment effects in these highly variable forest stands.

In 1976 we initiated a program of intensive growth response analysis in western hemlock through RFNRP that utilized indi-

vidual tree diameter growth trend information for a 7-yr period before and after treatment. Analysis procedures developed in this study are based on the premise that short term future diameter growth can be estimated using previous growth trends (i.e., how a tree has grown in the past greatly influences future growth).

The objective of this study is to evaluate a potential for response to N in stems having a breast height diameter greater than or equal to the estimated average plot diameter using change in diameter growth trends as a measure of this potential. Response in basal area or volume will not be presented.

Figure 3. Summary of plot-to-plot variability within 24 RFNRP hemlock installations. Note: Range represents one standard deviation.

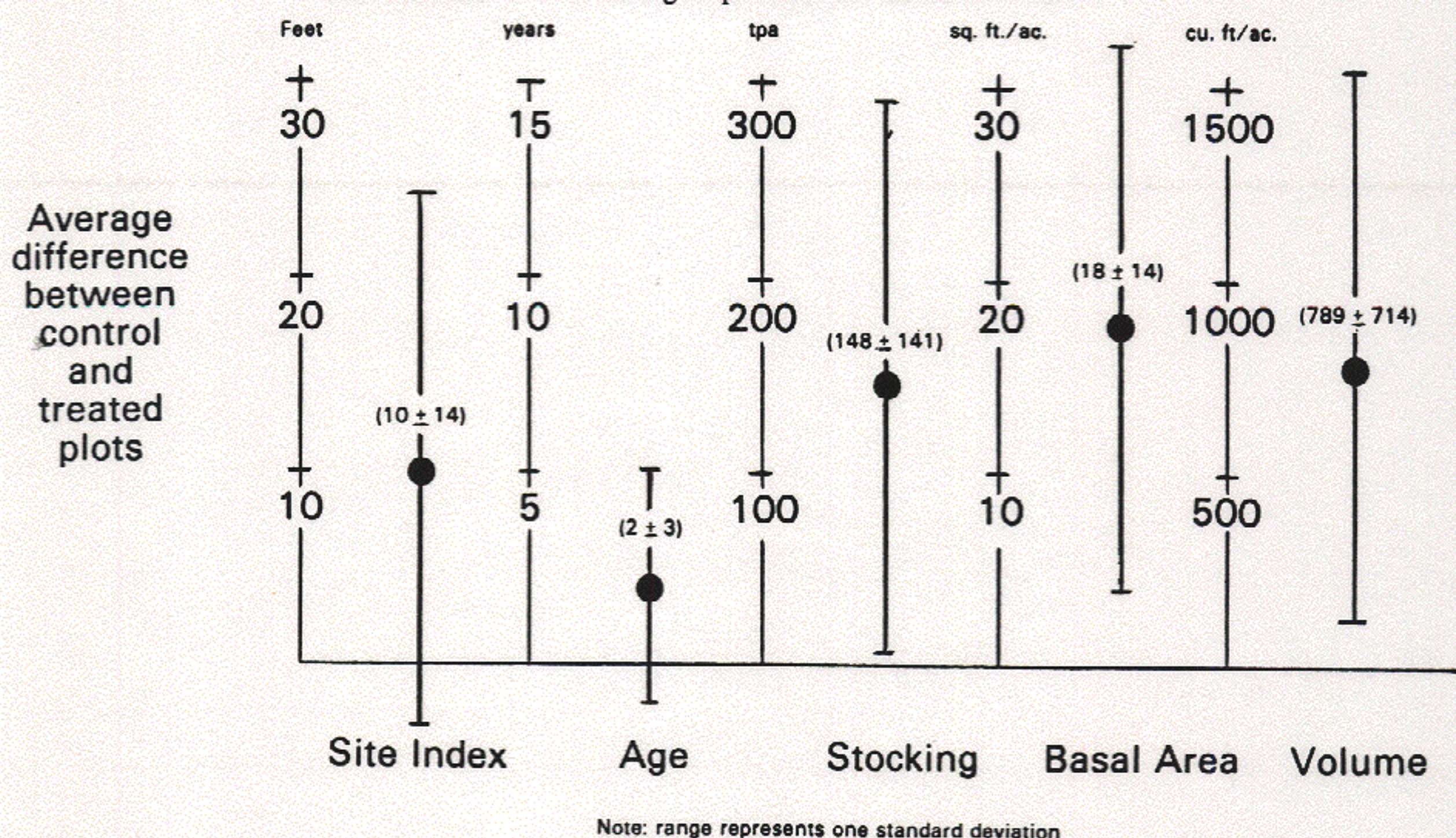
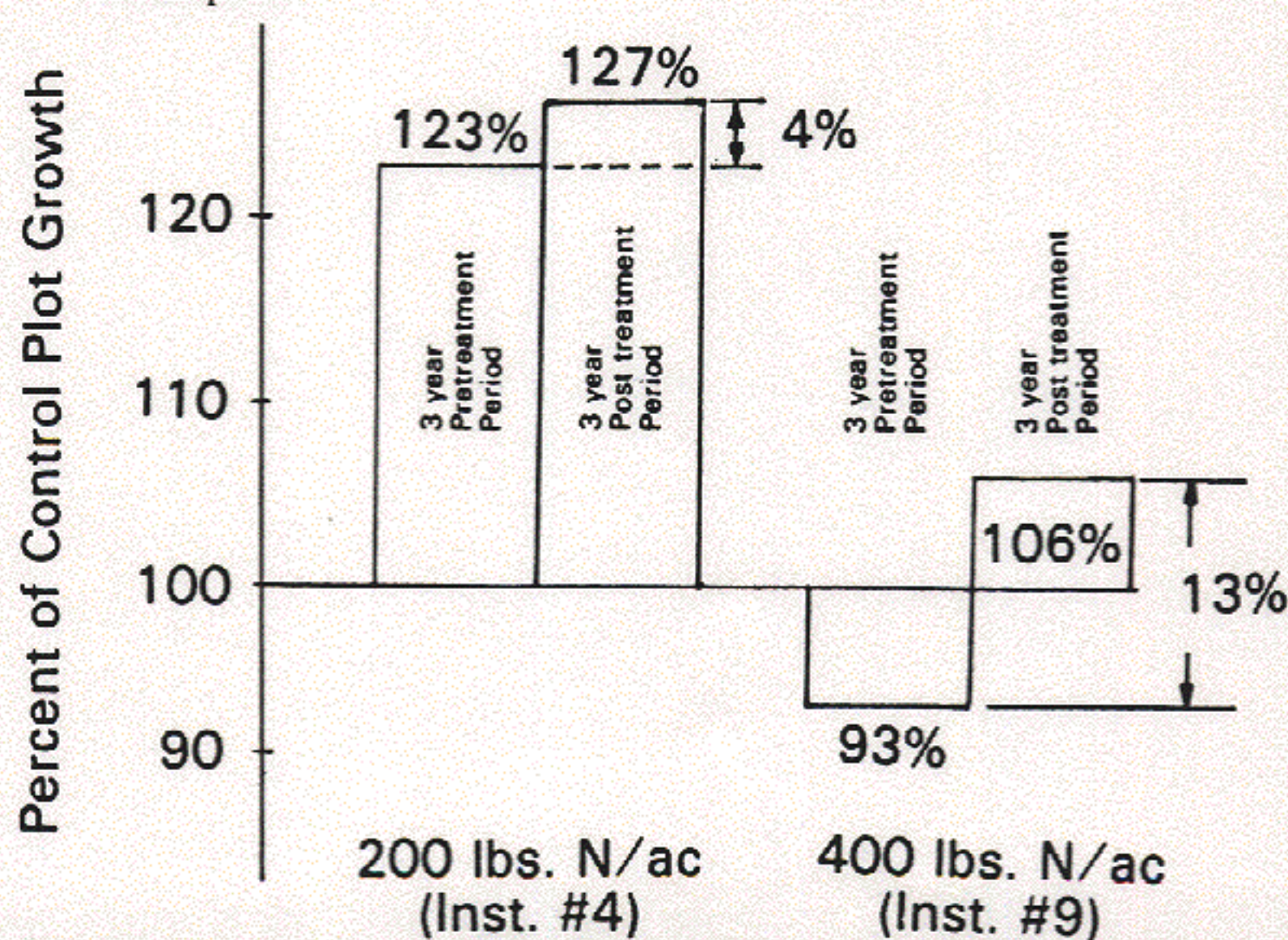


Figure 4. Average diameter growth difference between control and treated plots.



METHODS

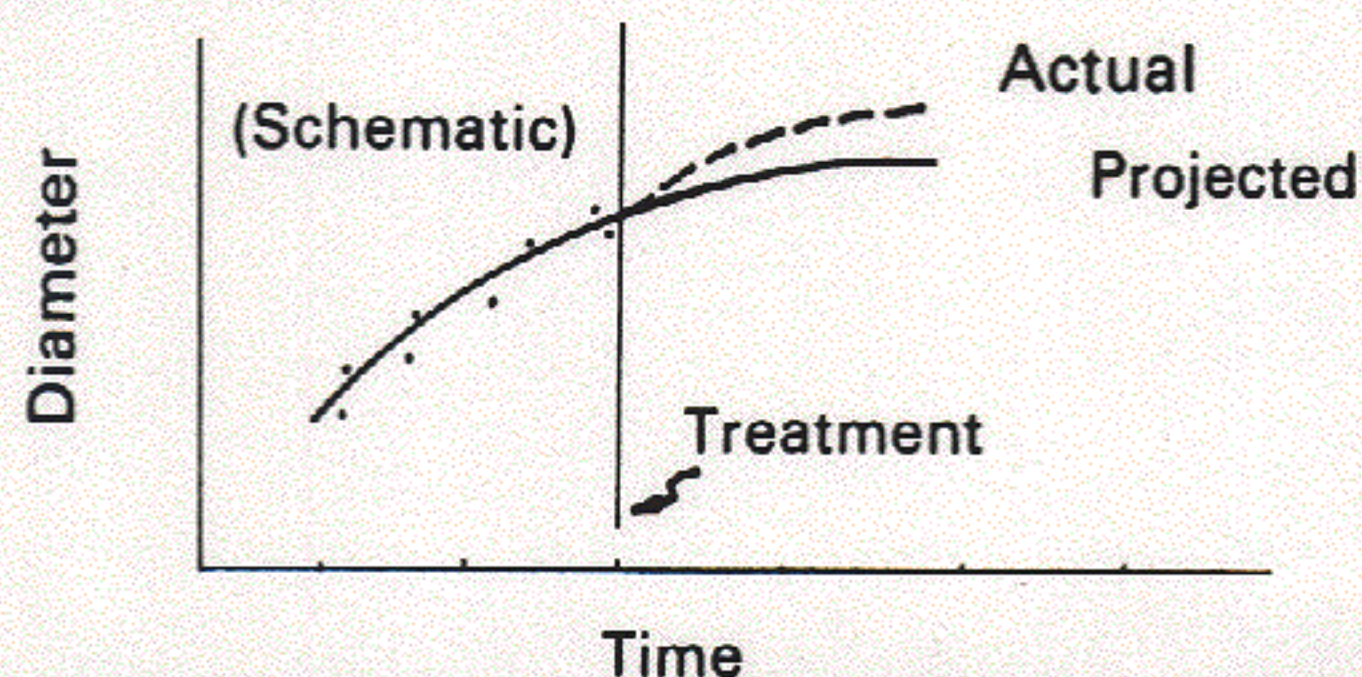
Three intensive analysis techniques, individual tree, plot analysis, and tree pairing, were developed and evaluated at two of 26 phase I (unthinned) hemlock installations. At each installation, two increment cores were extracted systematically from each control plot tree and from all trees \geq mean plot breast height diameter in the treated plots (~1600 cores total). Radial growth measured from the two cores per sample tree was averaged to provide an estimate for stem growth for a 7-yr period prior to and following the 1970 treatment. Location and number of cores were determined from preliminary studies (Olson and Atkinson 1977).

In theory, individual tree analysis is quite simple. Using increment core data, 7-yr pretreatment diameter growth for each sample tree is modeled using regression techniques. Projections of short term (7-yr) future growth are made and compared to actual growth measurements (Figure 5). Differences between actual and projected radial growth within control plots are considered to be due to stocking and environmental changes (rainfall, temperature, and the like) and model error. This deviation, if detected, is then used as a correction factor for growth projections of diameter growth within treated plots are assumed to be treatment effects. Individual tree responses can be summed or averaged by tree size and applied to stand tables to yield estimates of response on an area basis.

The plot analysis technique is similar in theory, but reduces computation time by generating a single growth model for the stand or installation as a whole for which all sample trees are utilized.

The third technique, tree pairing, is the most practical and the least costly of the three techniques evaluated. Pairs of treated and nontreated trees are selected based on similarity in current size breast height diameter, competitive status (crown class), and, most importantly, past diameter growth. Use of the last attribute enabled the grouping of individual trees that were not only of equal size and undergoing similar competition, but have attained their current status within the stand in a similar manner.

Figure 5. Estimation of treatment response using individual tree projections.



Results of an evaluation of these techniques indicated that installation response can be estimated using any of the three analysis methods if pretreatment radial growth trends are used.

Based on these findings, all remaining phase I (unthinned) and phase II (thinned) hemlock installations maintained by RFNRP were analyzed for 7-yr response to N fertilization using the tree pairing approach (34 installations total). Thirty sample trees per treatment (90 trees per installation) were selected from dominant and codominant crown classes based on vigor and relative stem location, as an effort was made to distribute sample trees uniformly within plot boundaries. Two increment cores per sample tree were extracted systematically, as previously described.

RESULTS

PHASE I (UNTHINNED)

When all 26 unthinned installations are examined together, a low average radial growth response to both 200 and 400 lb N/acre is indicated (Figure 6). Variability about these averages is high. Ranges in radial growth response for the 200 and 400 lb N/acre treatments are +38% to -25% and +54% to -33%, respectively.

Stratification of installations by age class shown positive trends in radial growth response occurring in the 15- to 24-yr (breast height age in 1970) class (Figure 7). Average response in the younger and older stands under study is considerably lower.

Response by geographic location and site class are shown in Figures 8 and 9. Average radial growth responses of 6% and 11% for 200 and 400 lb N/acre, respectively, within the Cascade zone (10 installations) are greater than estimates for either the Washington or Oregon coastal zones. No obvious trends in response by site class are indicated.

Significant "negative" response to N fertilizer treatments were occasionally noted. In many instances, this anomaly was explained by observed nonuniform disturbances (e.g., blow-down, disease) occurring within an installation after establishment.

Figure 10 indicates the geographic location of installations with growth responses of greater than 10%. Strong geographical trends are not apparent, but results cast in doubt the simplistic rule to avoid all coastal stands of hemlock in operational fertilization programs.

Conclusions for fertilized natural stands of western hemlock are: (1) Variability in response between installations is extremely high. Increasing the sensitivity of analysis did not greatly reduce installation-to-installation response variability, but does provide more accurate response estimates on an area-by-area basis. (2) Responding installations are not confined to

Figure 6. Average 7-yr radial increment response (26 installations combined).

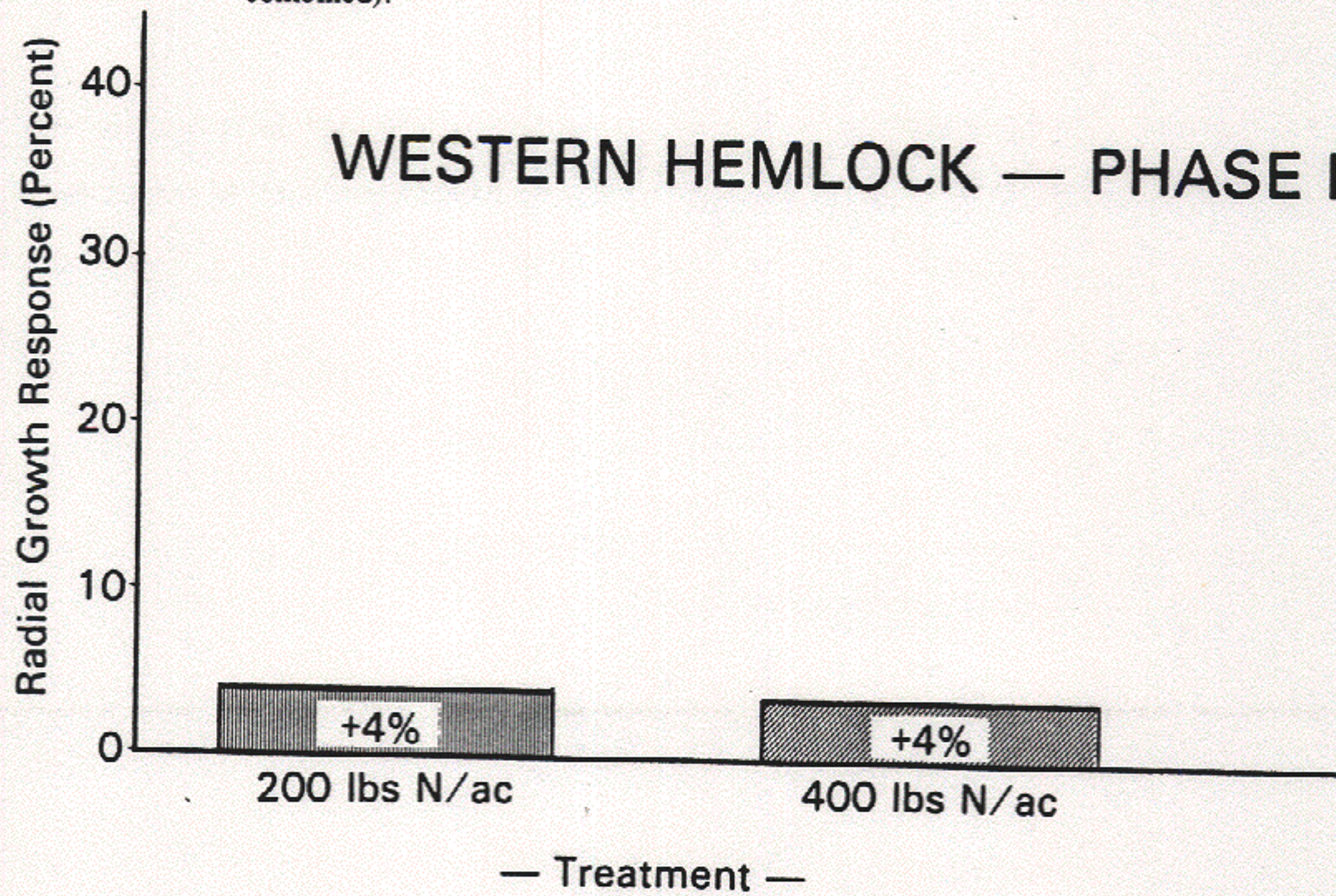


Figure 7. Average 7-yr radial increment response by age class (breast height age).

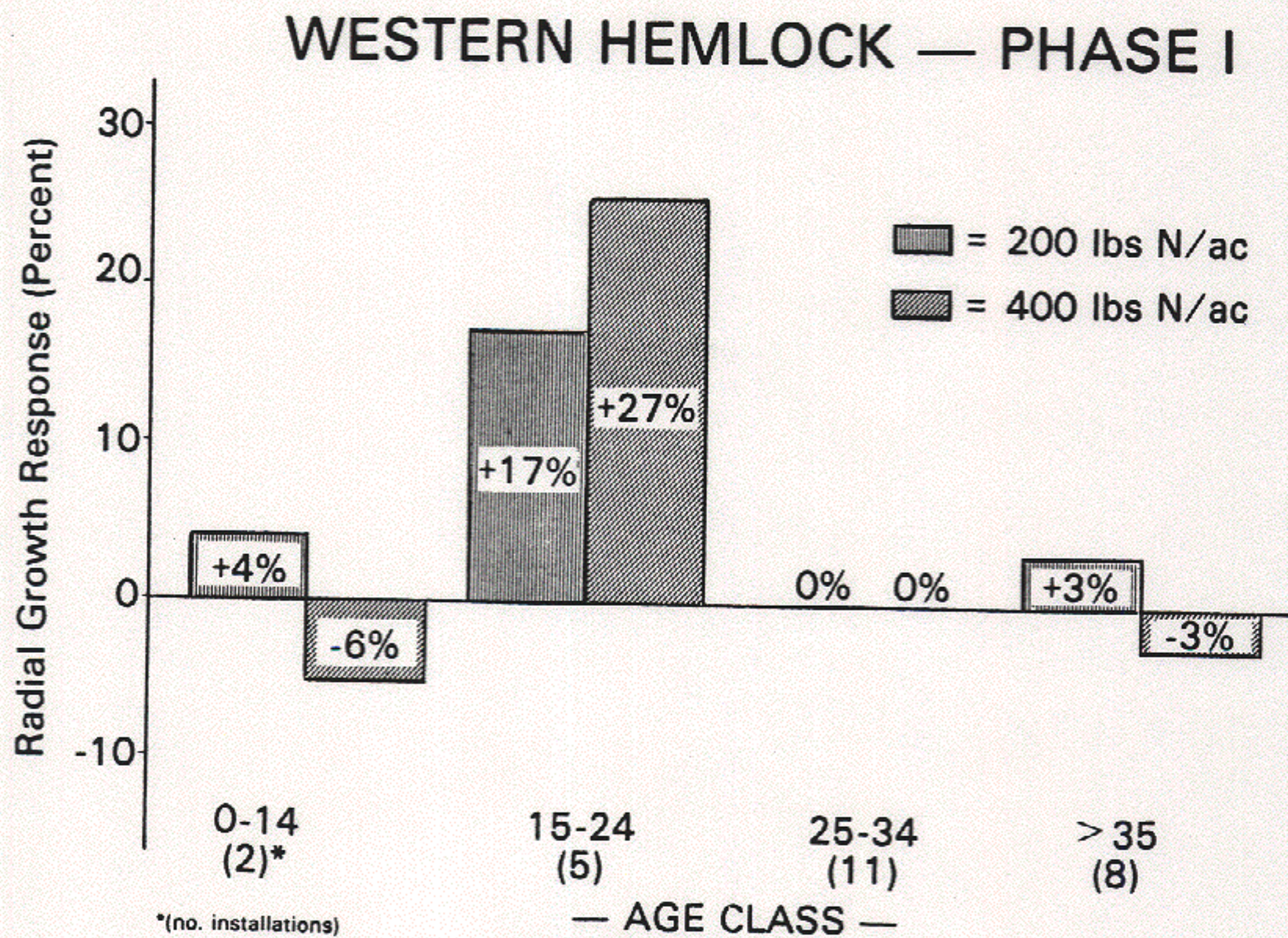


Figure 8. Average 7-yr radial increment response by geographical zone.

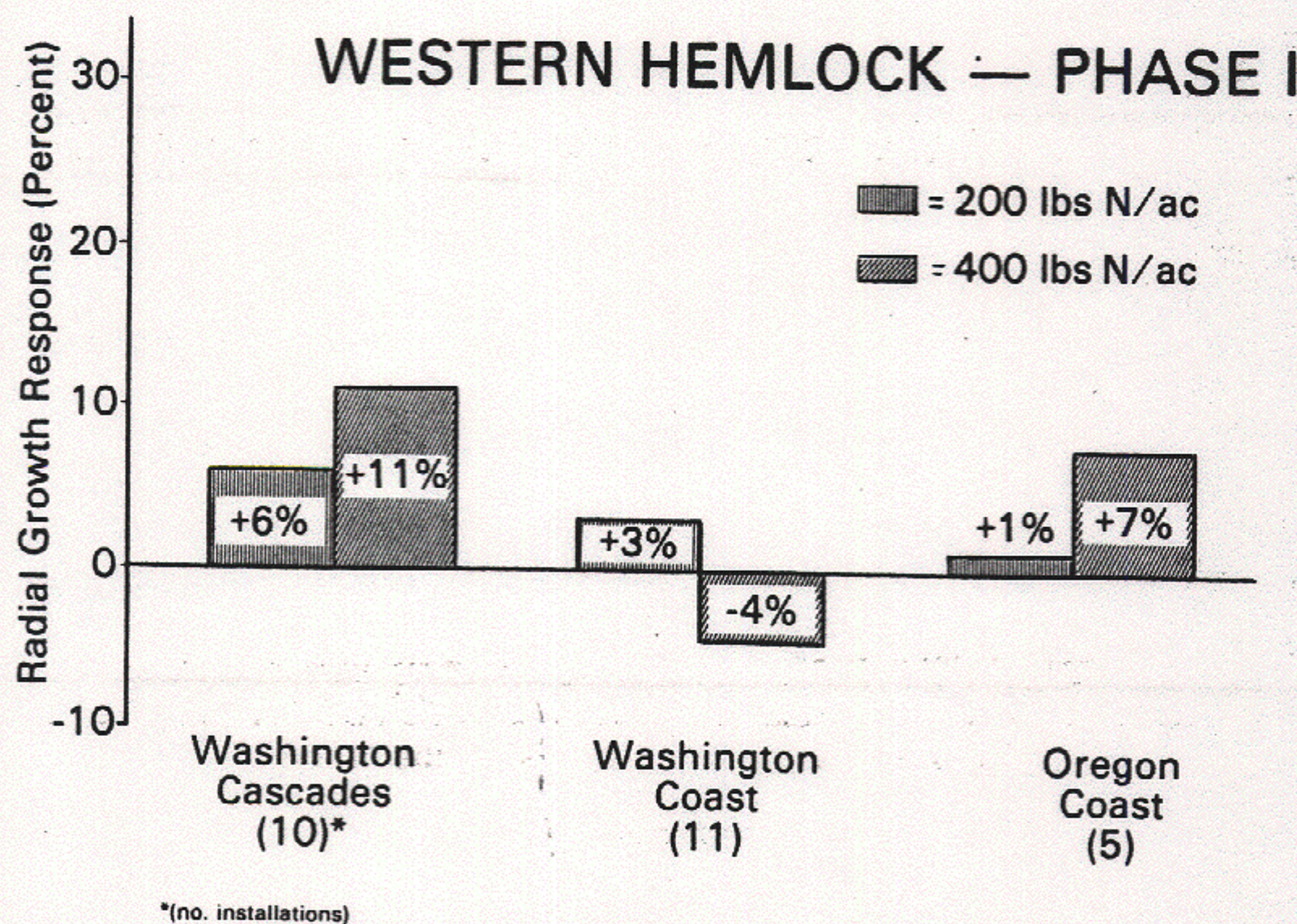
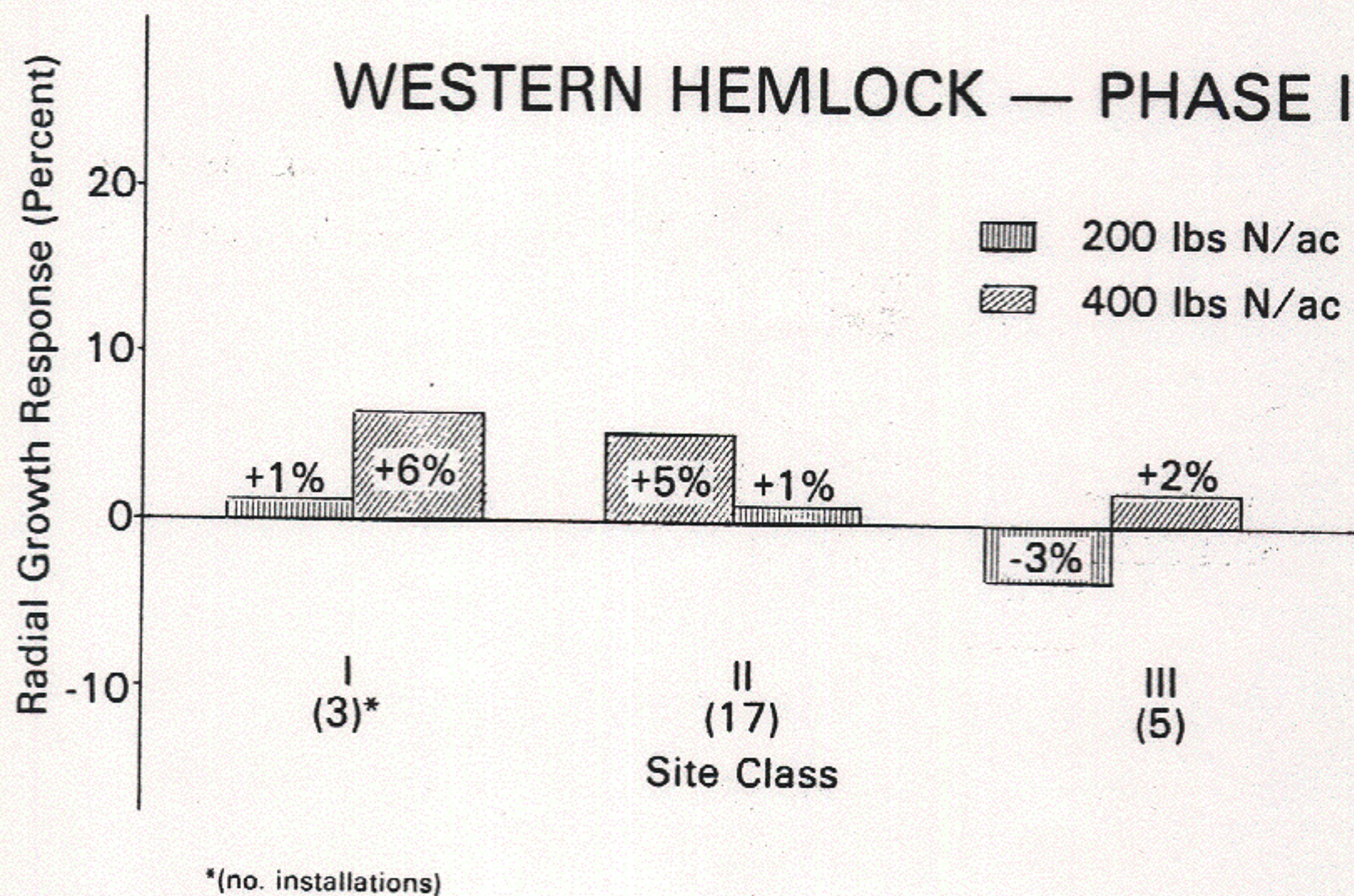


Figure 9. Average 7-yr radial increment response by site class.



any one of the three designated geographic zones (Figure 10). Stands with breast height ages of 15–25 yr at time of treatment generally responded better than younger or older stands. (3) In general, radial growth response to fertilization in natural stands of western hemlock appears low.

PHASE II (THINNED)

The eight thinned and fertilized hemlock stands maintained

by RFNRP are widely distributed throughout the western Oregon and Washington region (Figure 1).

Average 7-yr radial growth response by treatment for all installations is shown in Figure 11. Thinning response alone averaged 18%, while the combined thinning and fertilization treatment only slightly exceeded this value. As with phase I installations, variability about these averages was extremely high. Ranges of +20% to –15%, +38% to –24%, and 0 to

Figure 10. Responding installations.

PHASE I WESTERN HEMLOCK

- x = Installations showing response of greater than 10% to both 200 lbs N/ac and 400 lbs N/ac
- = Installations showing response of greater than 10% on either 200 lbs N/ac or 400 lbs N/ac

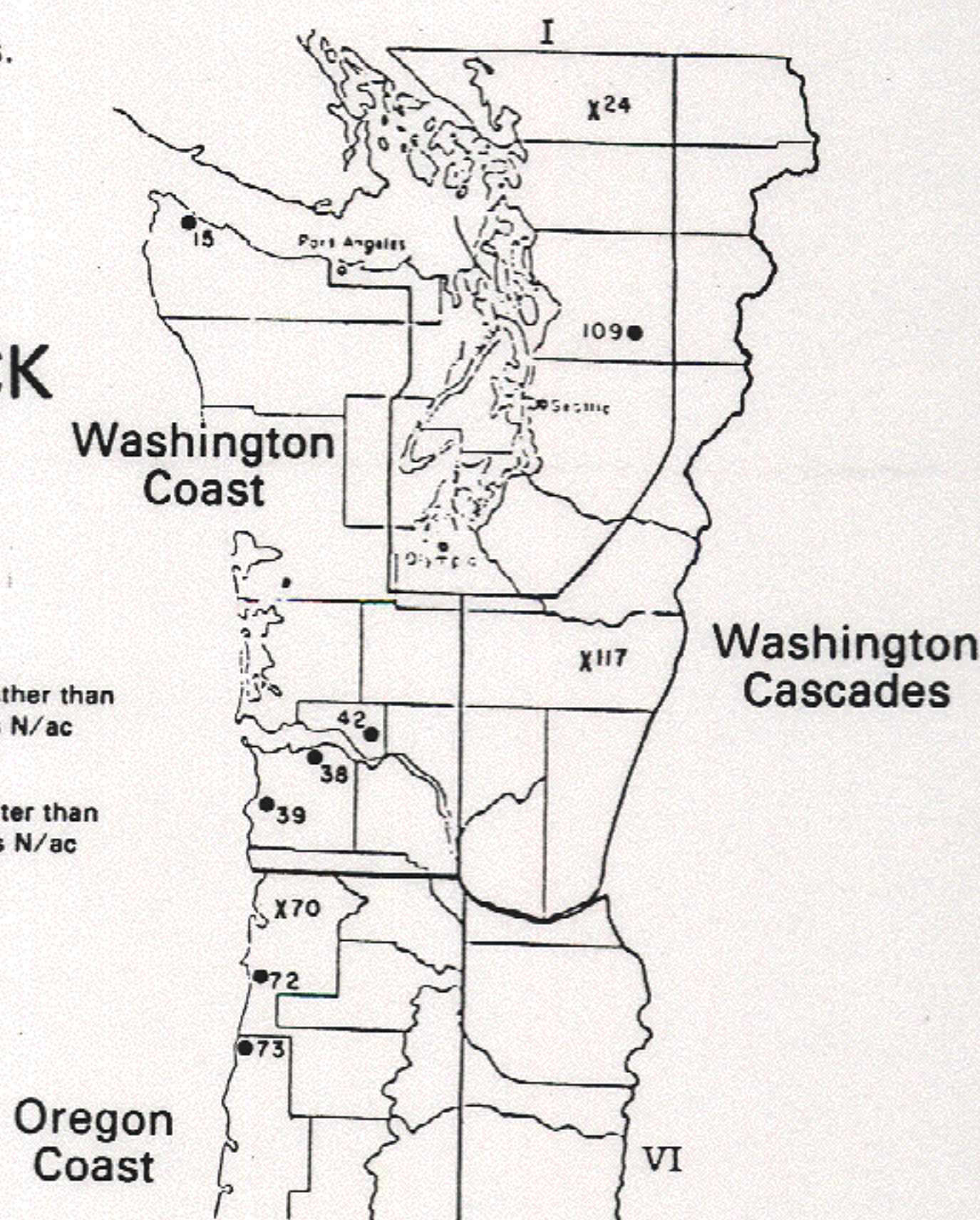
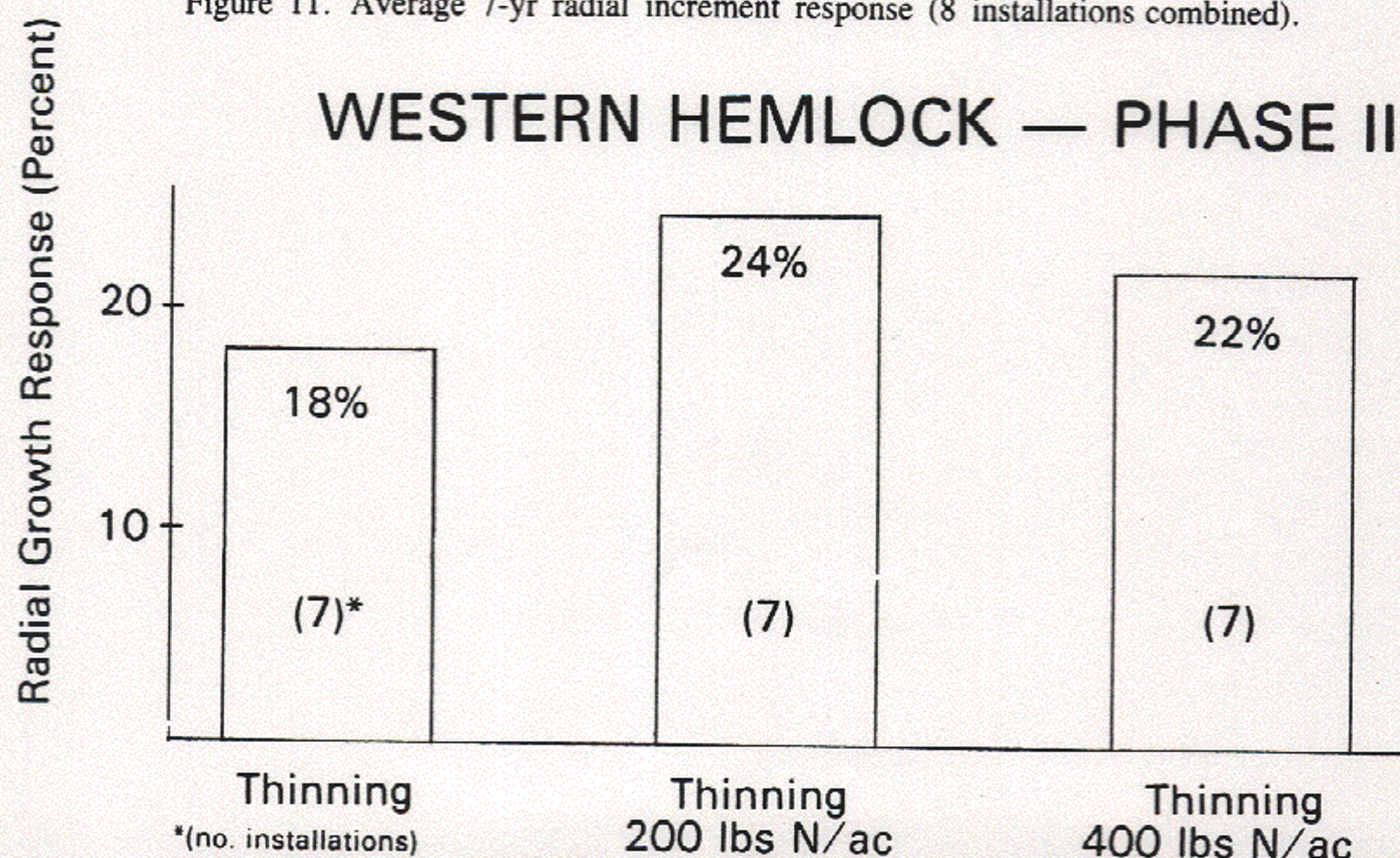


Figure 11. Average 7-yr radial increment response (8 installations combined).



40% were estimated for the 200 lb N/acre (thinned), 400 lb N/acre (thinned), and thinned only treatments, respectively.

Stratification by age class provides interesting results (Figure 12). In younger stands (10–20 yr), radial growth response following fertilization and thinning was quite high; 33% and 34% for 200 and 400 lb N/acre, respectively, while response to thinning alone was low (9%). Older stands, however, indicate opposite results; thinning produced extremely high responses (24%), while fertilization had little to no effect.

By design, five of the eight phase II installations were established adjacent to phase I sites. Thus a direct comparison between thinned, fertilized, and thinned/fertilized treatments can be made within a single stand type. Results of such comparisons indicate a general consistency in response to N fertilization between thinned (phase II) and unthinned (phase I) areas. In other words, stand types responding to N following thinning also responded to the same treatment in an unthinned situation.

Results of this analysis indicate that growing space limitations may not be the sole factor in obtaining response to N fertilization, and though geographical distribution of these eight areas is spotty, no obvious trend in response was indicated. As with the unthinned (phase I) stands of hemlock, younger stands (10–25 yr) appear to respond best to N fertilizer treatments.

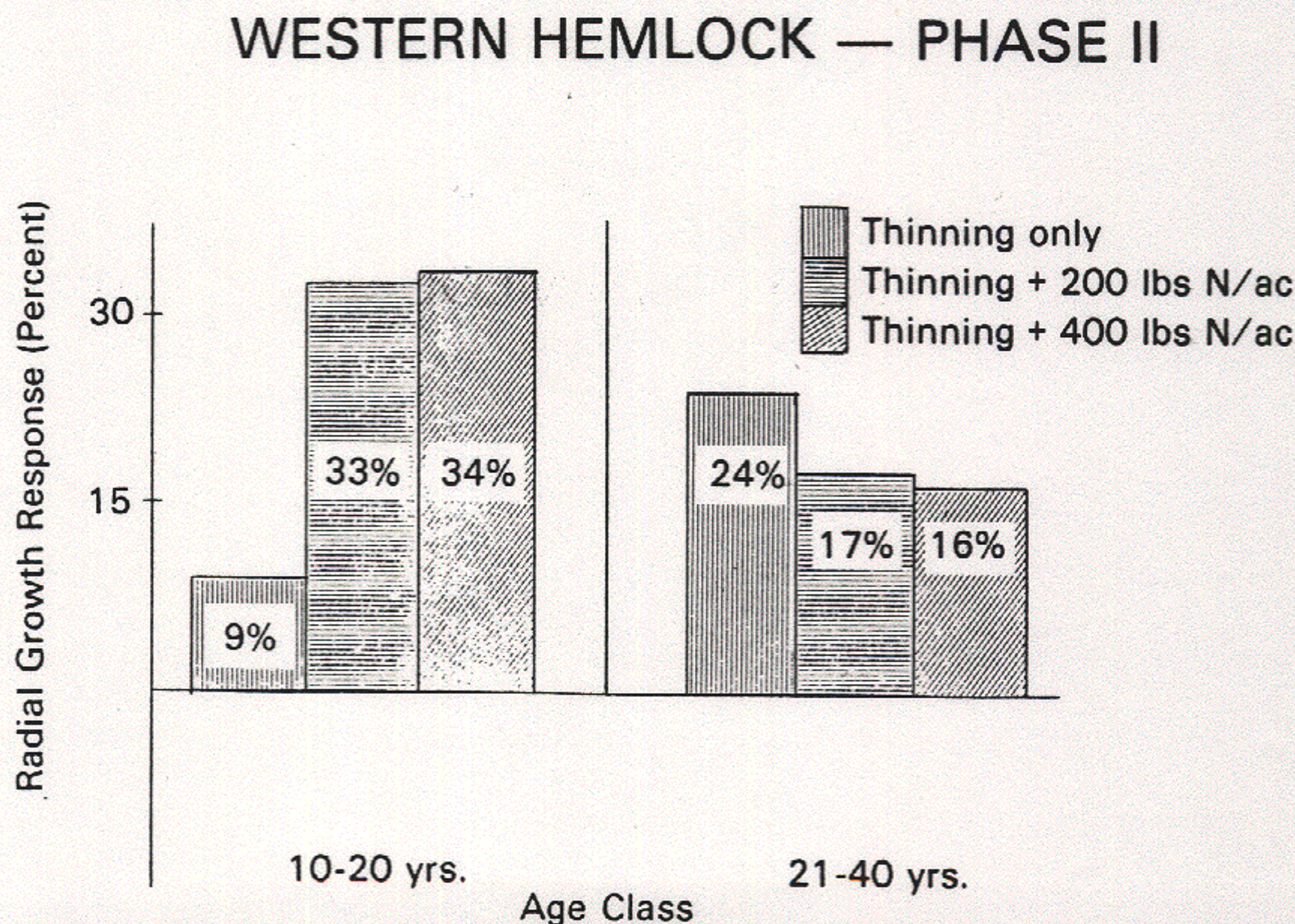
GENERAL CONCLUSIONS

1. Radial growth response to N fertilization, thinning, or both in stands of western hemlock remains extremely variable. Such variability in response is logically associated with factors such as variability in stand structure, disease incidence, N availability, and other nutrient limitations. Results from this study should provide justification for more intensive investigations into causes of response, or lack of response.

2. In comparing response of phase I and phase II installations located within the same stands, it is apparent that stands indicating response to N fertilizer following thinning have also responded to fertilization without thinning. This suggests that factors other than growing space may govern the potential for response to N fertilization. This observation is strengthened by the fact that thinned stands of western hemlock (phase II) did not consistently respond to the N treatment.

3. In general, younger stands responded best to N fertilizer, while older stands appear to have responded best to thinning. Several physiological explanations are possible. A plausible explanation might be that the younger stands are more likely to be in the period of crown expansion, a time during which both nutrient requirement and uptake are high; older stems, however, have moved from this stage to one of differentiation where competition for growing space may be more important.

Figure 12. Average 7-yr radial increment response by age class (breast height age).



4. Over a wide range of geographical and environmental conditions, average response of hemlock to N fertilization is low. Further investigations are needed in coastal hemlock areas where high responses have been documented before large-scale operational fertilization can be adequately justified.

LITERATURE CITED

- Beswick, R.
1976. An overview of the western hemlock. *IN* Western hemlock management. Coll. For. Resour., Inst. For. Prod. Contrib. 34. W. A. Atkinson and R. J. Zasoski, eds. p. 1-6. Univ. Washington, Seattle.
- DeBell, D. S., E. H. Mallonee, J. Y. Lin, and R. F. Stand.
1975. Fertilization of western hemlock: A summary of existing knowledge. 15 p. Crown Zellerbach Corporation, For. Res. Note 5.
- Olson, J. R., and W. A. Atkinson.
1977. Measurement of basal area and radial growth in out-of-round stems of western hemlock. Paper (in press) presented to IUFRO, Instruments Section, Corvallis, Oreg.
- University of Washington, College of Forest Resources.
1972. Regional Forest Nutrition Research Project, Annual Report 1971-72. 25 p. Institute of Forest Products, College of Forest Resources, Univ. Washington, Seattle.
- University of Washington, College of Forest Resources.
1974. Regional Forest Nutrition Research Project, Biennial Report 1972-74. 39 p. College of Forest Resources, Univ. Washington, Seattle.
- University of Washington, College of Forest Resources.
1974. Regional Forest Nutrition Research Project, Biennial Report 1974-76. 67 p. Coll. For. Resour., Inst. For. Prod. Contrib. 25. Univ. Washington, Seattle.
- University of Washington, College of Forest Resources.
1979. Regional Forest Nutrition Research Project, Biennial Report 1976-78. 46 p. Inst. For. Prod. Contrib. 37, Coll. For. Resour., Univ. Washington, Seattle.