RESPONSE OF INLAND DOUGLAS-FIR AND GRAND FIR TO THINNING AND NITROGEN FERTILIZATION IN NORTHERN IDAHO

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ABSTRACT

Thinning and fertilizer treatments were applied separately and in combination on thirty-six Douglas-fir and grand fir stands in northern Idaho. Basal area and volume growth increments of both species increased significantly ($\alpha = 0.01$) in response to all treatments, although considerable variation in response was noted. Effects of thinning and fertilization were additive. Thinning did not affect height growth, but application of nitrogen fertilizer accelerated it, especially in grand fir. Volume growth response of Douglas-fir to fertilization was correlated with the organic fraction of the soil beneath the volcanic ash layer; this factor explained about 40 percent of the observed variation. Response decreased as the organic fraction increased. No significant correlations were indicated with volume growth response of grand fir.

INTRODUCTION

Forest fertilization research in the Inland Empire (northern Idaho, eastern Washington, and western Montana) began in the early 1960's. The results of two studies (Loewenstein and Pitkin 1963, 1971) indicated that grand fir (*bies grandis* [Dougl.] Lindl.) and western white pine (*Pinus monticola* Dougl.) may respond substantially to N Fertilization, but ponderosa pine (*Pinus ponderosa* Laws) may not. Additions of K and P with N gave no higher response than with N alone.

These studies, along with other studies in the United States and Canada, sparked the interest of several land managers in the Inland Empire. They cooperated with the University of Idaho in a pilot study to investigate the potential of forest stands in that area to respond to N fertilization. They were primarily interested in the Douglas-fir (*Pseudotsuga menziesii* Dougl.) and grand fir components of these forests and the interrelation between fertilization and thinning effects. This report summarizes the results of the study four years after the treatments were applied.

CHARACTERISTICS OF THE STUDY AREA

VEGETATIONAL ZONES

Forested areas of the Inland Empire are characterized by five vegetational zones. At the warmest and driest end of the climatic spectrum and at lowest elevations, the forest is exclusively ponderosa pine in open stands with several types of grass or shrub understory, depending on the moisture regime. Just above this zone, the pine shares the habitat with Douglas-fir, which becomes the climax species. Western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*Pinus contorta* Dougl.) may also be present in this zone. The understory is predominantly tall shrubs. On moist sites at higher elevations, grand fir is the climax tree species with the understory being primarily low and medium shrubs, forbs, and ferns that vary in abundance according to moisture and temperature gradients.

Above the grand fir zone the climate becomes cooler and more moist and supports the richest forest flora of the region. Coniferous tree species include those mentioned above as well as western white pine (*Pinus monticola* Dougl.), western redcedar (*Thuja plicata* Donn.), and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.). In the northern portion of the region hemlock is the climax species, but farther south it is not represented and western redcedar assumes this role. No angiosperm tree species is climax in this region but paper birch (*Betula papyrifera* Marsh.), quaking aspen (*Populus tremuloides* Michx.), black cottonwood (*Populus tricocarpa* Torr. and Gray), and willow (*Salix scouleriana* Barratt) are represented.

The understory of the cedar-hemlock zone is quite complex, being characterized by grasses, forbs, ferns, and small, medium, and large shrubs that vary in dominance according to environmental gradients. At the coldest and wettest end of the climatic spectrum and the highest elevations, the cedar-hemlock ecosystem gives way to the vegetationally less complex forests characterized by Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.). Understory vegetation is generally composed of forbs, low and medium shrubs, and bear grass (*Xerophyllum tenax* [Pursh] Nutt.).

The natural occurrence of pure stands of any species in areas above the ponderosa pine zone is relatively rare, but plantations composed of only one species are common.

STAND COMPOSITION

Early logging techniques resulted in residual stands that vary greatly in size, age, species composition, and individual tree quality. More recent operations have resulted in less variable stand structures. Many of these stands originated following a severe fire in 1910 and have been essentially unmanaged. This great diversity of stand structure and composition makes it extremely difficult to study a small portion of the stands in this region and draw conclusions about the behavior of individual species on a regional basis.

SOIL PARENT MATERIALS

The forested areas of the Inland Empire have been influenced by five major geologic events that determined the nature of the parent material from which the forest soils were derived.

Marine Deposits

Underlying the entire region are thick deposits of pre-Cambrian rock. These metasediments, belonging to the Belt Supergroup (Ross and Savage 1967), are marine deposits that have undergone extensive uplifting, faulting, and metamorphism. They form soils that vary greatly in texture, structure, and fertility.

Granitic Intrusions

In the southern portion of the region, soil parent materials are largely granitic rocks of the Idaho Batholith, which were implanted in the Mesozoic and Cenozoic eras. Soils of these areas are characteristically excessively drained and infertile. Similar soils are found in the northwestern portion of the region on granites of the Kaniksu Batholith, which is generally of the same age and composition as the Idaho Batholith.

Lava Flows

At the lower elevations, in areas representing major river drainages during the formation of the region, are found thick deposits of basalt. These deposits resulted from several "basalt flows"—volcanic eruptions that poured from vents and fissures rather than from volcanoes. The basalt lava flowed along the drainage channels and into draws and lowlands along the route. Soils of these areas are fine-textured and generally fertile. Many of the areas are characterized by paleosols of high bulk density which restrict moisture flow.

Aeolian Deposits

About 7000 yr ago, Mt. Mazama (Crater Lake) in Oregon violently erupted, sending a vast quantity of volcanic ash high into the atmosphere where it was blown over thousands of square miles (Fryxell 1965). Most of the Inland Empire was covered with this ash to a depth of 2 or 3 ft. An earlier eruption (about 12,000 yr ago) of Glacier Peak, in Washington, also deposited volcanic ash over most of northern Idaho.

Today only forested areas in the grand fir and cedar-hemlock zones are markedly affected by the Mt. Mazama and Glacer Peak eruptions. Most of the soils in these zones (especially the cedar-hemlock zones) are characterized by a mantle of reddish-brown volcanic ash varying from 6 in. (15 cm) in depth. This ash has a very high moisture-holding capacity as well as a tremendous phosphorus-fixing capacity (Brown and Loewenstein 1978). Massive deposits of loess comprise the Palousse Hills area, but loessial deposits influence the soils throughout northern Idaho to varying degrees.

Glacial Deposits

In the northern portion of the region, glacial activity also influenced soil development. Many deposits of glacial till can be found in mountain valleys and in the area known as the Rathdrum Prairie. Soils on these deposits are generally very shallow—those of the Rathdrum Prairie consisting of little more than volcanic ash on undecomposed glacial till. Except for the volcanic ash influence, they are largely infertile.

CLIMATE

Climatic conditions in northern Idaho are generally warm and dry during the summer and relatively mild and moist during winter. Occasionally, cold air masses settle in the area producing cold and clear conditions. The complex topography of this region is responsible for much of its climatic variation. Annual precipitation varies from about 20 in. (51 cm) in the western Palousse Hills area to about 60 in. (152 cm) in the Coeur d'Alene and Bitterroot Mountains. In most areas, the growing season is limited by the onset of a summer drought in July or August.

OBJECTIVE

The purpose of this study was to measure the response of two Inland Empire species (Douglas-fir and grand fir) to application of N fertilizer in unthinned and thinned stands. If possible, the magnitude of response was to be correlated with stand age and soil parent material.

METHODS

EXPERIMENTAL DESIGN

The stands of Douglas-fir and grand fir in the Inland Empire that occur on the glacial outwash deposits are not extensive and are of little economic importance; therefore they were excluded from this study. The remainder of the forested area of Idaho north of the Salmon River was subdivided into three intermeshed units representing soil parent materials of (1) the Idaho and Kaniksu batholiths, (2) basalt of the Columbia River basalt flows, and (3) the pre-Cambrian metamorphosed marine sediments. The areas were delimited with U.S. Geologic Survey maps.

Six stands composed predominantly of Douglas-fir, and another six composed predominantly of grand fir, ranging in age from 15 to 70 yr, were selected within each geologic unit. Elevations varied between 2500 and 5000 ft (762 and 1524 m). At each of the 36 locations, a series of eight 0.1-acre (0.0404-ha) square plots were installed, giving a total of 288 plots for the study. The arrangement of these plots varied from location to location, depending on the lay of the land and stand composition. The combination of changes in aspect, slope, soil characteristics, stand composition, and structure made it impossible, in most cases, to install all eight plots in a completely uniform habitat.

TREATMENTS

At each location, four replicated treatments were provided: (1) control, (2) fertilized only, (3) thinned only, and (4) thinned and fertilized.

In the fall of 1972 and fall of 1973 (not all locations were selected by the fall of 1972) four randomly selected plots at each location were thinned to approximately 15 + 15 ft (4.6 + 4.6 m) spacing, favoring the species of interest. Urea fertilizer was applied at the rate of 200 lb/acre (220 kg/ha) of N to two thinned and two unthinned plots the following spring. A buffer zone of about 10 ft (3 m) outside the plot boundary was also fertilized to ensure that the trees near the border of the plot and those in the center of the plot received equivalent amounts of fertilizer.

Weather data were not collected for each site following fertilization; however, some sites had an inch (2.5 cm) or so of snow remaining at the time of fertilization and all sites had moist soil and litter. Most of the sites received rain either the day of fertilization or within a few days after application. Air and soil temperatures were still cool during this period.

MEASUREMENTS

At each of the 36 sites the following data were tabulated or measured: elevation, depth of volcanic ash, depth of solum, soil texture, soil structure and bulk density, and abundance of each species of understory vegetation. Aspect and slope were recorded for each plot at each location. In addition, data for each tree were collected, including species, initial diameter (at breast height), and a defect rating and description. The species of interest at each location (either Douglas-fir or grand fir) was subsampled on each plot to obtain information on total height, age, crown ratio, and past-10-yr radial growth.

The plots were revisited at 2-yr intervals after treatment. Diameters were remeasured and the subsample of trees was measured for height growth as well.

ANALYTICAL PROCEDURE

Because of the great variability in stand composition within locations and the small sample size (two replications), significant differences between treatments could not be demonstrated statistically at each location. On a regional basis, however, trends could be established. Because of the complex stand composition and structural differences that existed among the locations in this study, analytical procedures and summaries involving whole-plot means were not applicable or meaningful in meeting the objectives of this study. Therefore, this report is confined to the interpretation of response of the species of interest as indicated by the subsample of trees on each plot.

Tree and stand data for all of the control plots were used to define equations (Table 1) to predict the mean basal area, height, and total cubic foot volume increments per tree for a 4-yr period when no treatment was administered. For both species, the mean basal area and volume increments per tree for the 10-yr period prior to treatment were found to be the best predictors of the respective posttreatment increments. No pretreatment height growth information was obtained for the sample trees and the height growth prediction equations were less precise than those of basal area and volume growth, as indicated by the lower coefficients of determination (r^2, Table 1).

The predicted increments explained much of the variation among the observed values on control plots during the treatment period (Figure 1). Application of these equations to treated plots yields estimates of the 4-yr basal area, height growth, and volume growth, respectively.

An analysis of covariance (SAS Institute 1979) of the observed increments with the predicted increments as covariables provided the tests of significance ($\alpha = 0.01$) for the following null hypotheses:

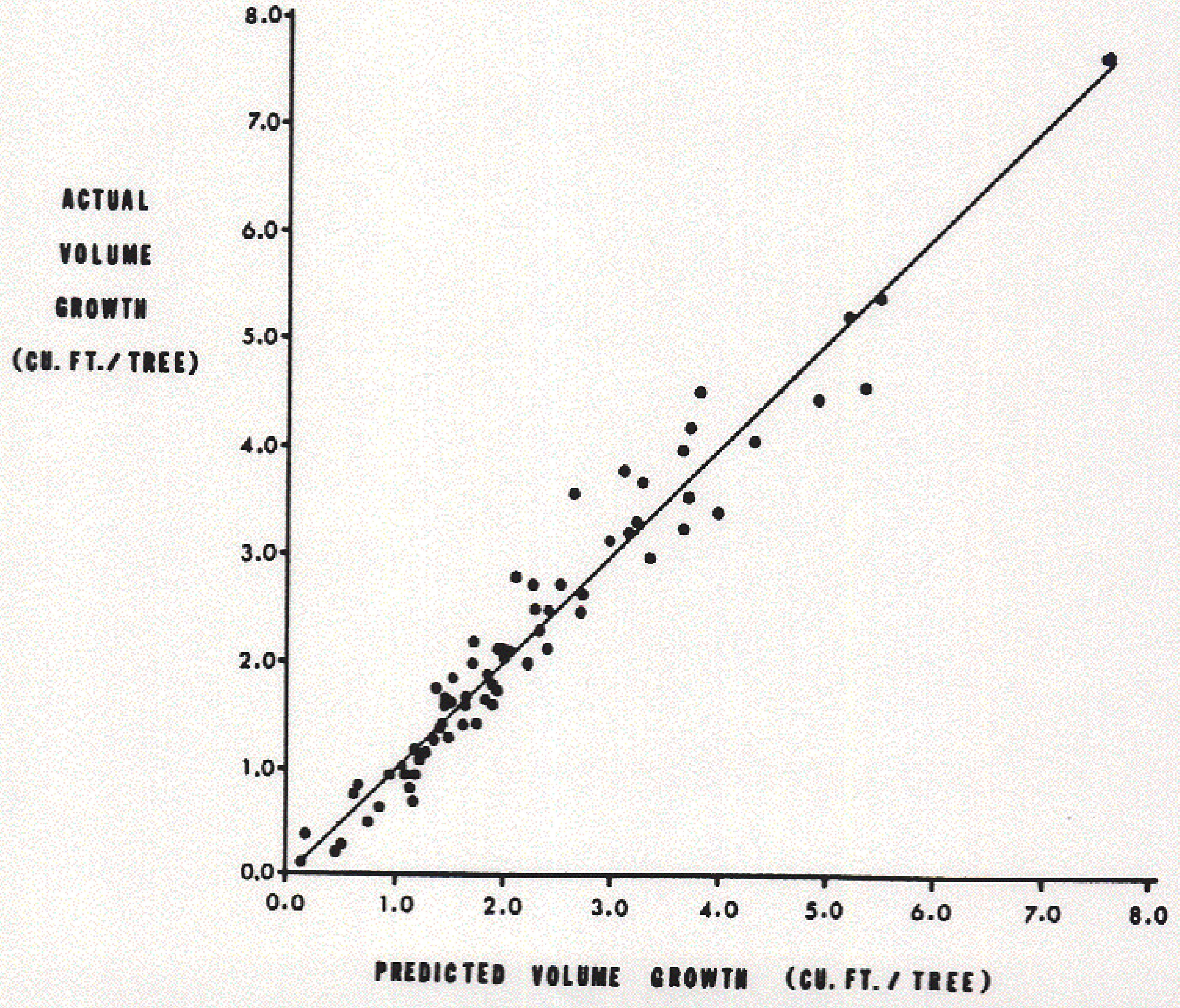
1. Nitrogen fertilization has no effect on basal area growth, height growth or cubic foot volume growth of Douglas-fir or grand fir in the Inland Empire.
2. Thinning has no effect on basal area growth, height growth, or volume growth of Douglas-fir or grand fir in the Inland Empire.
3. The combination of thinning and N fertilization does not produce a synergistic effect in Douglas-fir or grand fir.

Table 1. Equations for predicting mean 4-yr basal area, height, and volume increments (based on data from sample trees on control plots in 36 northern Idaho stands).

Predicted growth variable	Equations[a]	r^2
	Douglas-fir	
Basal area (ft^2/tree)	0.05419 + 0.28470 (MPBAG) - 0.00098 (AGE) + 0.2843	0.83
Height (ft/tree)	8.31910 + 0.25782 (MDBH) - 0.11957 (AGE)	0.72
Volume (ft^3/tree)	1.43285 + 0.44147 (MPVG) - 0.02711 (AGE)	0.93
	Grand fir	
Basal area (ft^2/tree)	0.0283 + 0.00544 (MPVG) - 0.03120 (SIN (ASPECT)) (% SLOPE)	0.90
Height (ft/tree)	5.13585 - 0.04457 (AGE) - 4.38992 (SIN (ASPECT)) (% SLOPE) + 0.02811 (SI)	0.55
Volume (ft^3/tree)	1.89133 + 0.36706 (MPVG) - 1.21019 (SIN (ASPECT)) (% SLOPE) + 0.0004416 (ELEV)	0.97

[a] MPBAG = mean past-10-yr basal area growth of sample trees (measured from increment cores); AGE = mean total age of sample trees; MBA = mean initial basal area of sample trees; MDBH = mean initial diameter breast height of sample trees; MPVG = mean past 10-yr cubic foot volume growth of sample trees (estimated from past basal area increment, initial height, and age); ASPECT = aspect of site, recorded as azimuth; % SLOPE = percent slope or tangent of slope angle; SI = site index for species of sample trees; ELEV = site elevation in feet.

Figure 1. Relation between predicted and actual mean volume growth for Douglas-fir and grand fir trees on control plots from 36 northern Idaho stands.



An earlier report (Scanlin et al. 1976) indicated that the two species differed significantly in mean growth and in growth response to fertilization and thinning. Therefore the two species were tested separately in this report.

Since stands of widely differing ages were to be compared, the response to each treatment at each site was expressed in relative terms:

$$\text{response (\%)} = \frac{\text{observed growth—predicted growth}}{\text{predicted growth}} \times 100$$

The estimates of volume growth response to nitrogen fertilization were regressed on various site and stand attributes to get an indication which environmental factors, if any, may be used to predict response.

RESULTS AND DISCUSSION

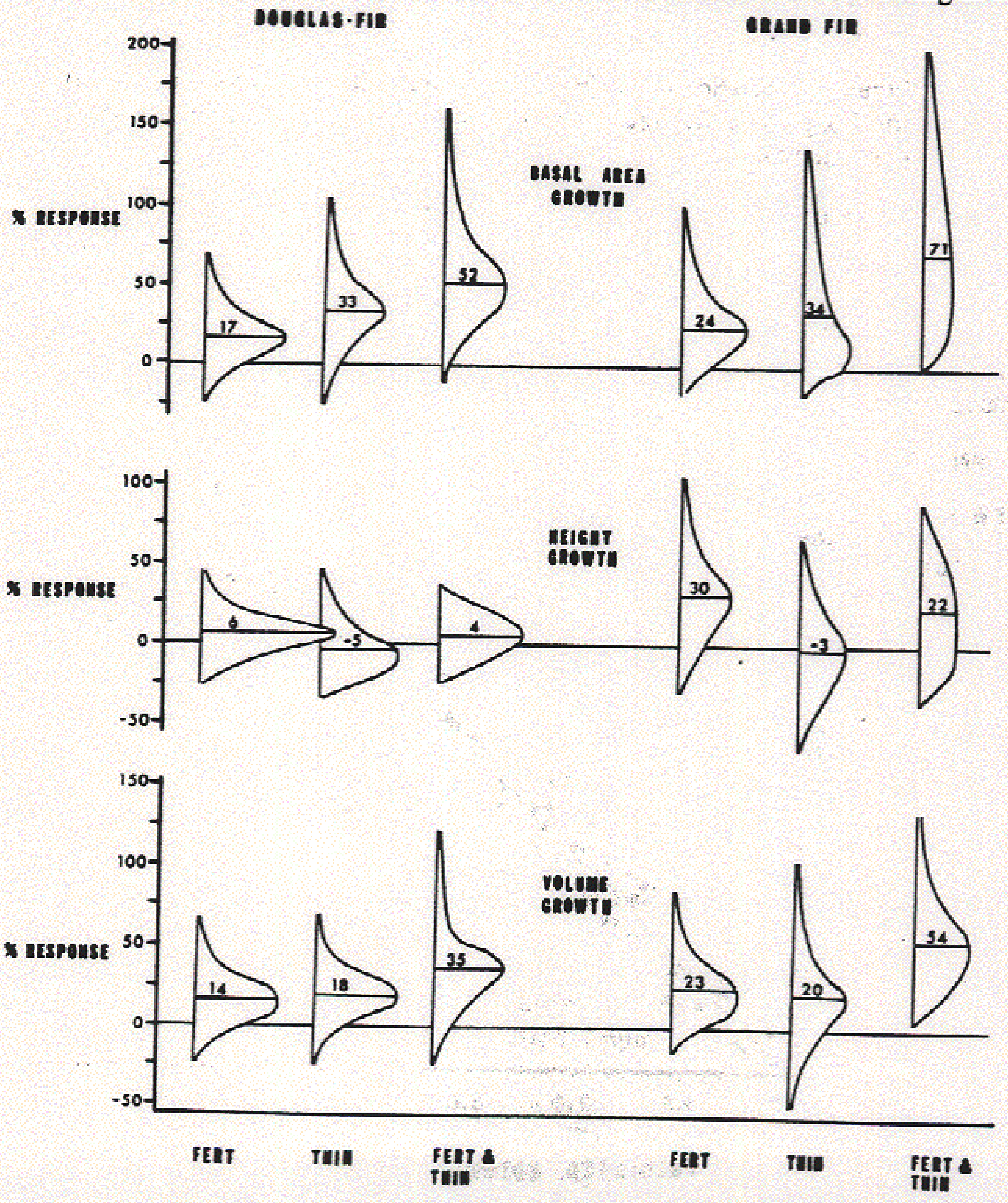
The analysis of covariance procedure revealed significant differences ($\alpha = 0.01$) in fertilizer and thinning effects for both species, but treatment interaction was statistically nonsignificant. Apparently, after 4 yr, the effects of thinning and fertilization are additive; our 2-yr results indicated a significant interaction between these treatments (Scanlin et al. 1976).

Mean response estimates for grand fir and Douglas-fir (Figure 2) indicate that basal area growth, height growth, and volume growth of the two species are affected in a similar manner by N fertilization and thinning, but they differ in the magnitude of the mean response and in the variation about the mean.

In general, basal area growth is increased more by thinning alone than by fertilization alone. This difference is more apparent and more consistent, however, with Douglas-fir than with grand fir. Because effects of fertilization and thinning are additive, the combination of thinning and fertilization is superior to either treatment alone.

Height growth of Douglas-fir was stimualted only slightly by fertilization alone, but grand fir responded to a much greater degree, although there was more variation in the response with this species. Both species showed less-than-expected height growth on thinned plots. This effect was not observed on all sites and was not considered significant in this analysis; the growth reduction was significant 2 yr after thinning, however (Scanlin et al. 1976). Fertilizing trees on thinned plots seems

Figure 2. Distribution of response of Douglas-fir and grand fir to N fertilization and thinning in 36 northern Idaho stands.



to overcome this "shock" effect, but mean height growth is still less than on plots that were fertilized but not thinned.

When response is measured in terms of cubic foot volume growth, the superiority of the thinning treatment over the fertilizer treatment is greatly reduced. Grand fir is apparently stimulated more by fertilization than is Douglas-fir, while thinning appears to affect both species to about the same degree although the response is more consistent with Douglas-fir.

Figure 2 illustrates very well that response to treatment depends greatly on the parameter used to represent response. Thus, if height growth is used as the measure of response, completely different conclusions may be drawn as to the effect of treatment than if basal area growth or volume growth is used. The variability is likely the result of assumptions in the analytical procedures. It is also likely that much of the variation in response results from variation in environmental factors associated with each plot. The study plots differed widely in species composition, stand age, density, structure, and vigor. The sites differed in aspect and slope, soil type and depth, and elevation. Other factors, measured and unmeasured, may also influence the response of a particular stand to a particular fertilizer treatment or thinning regime.

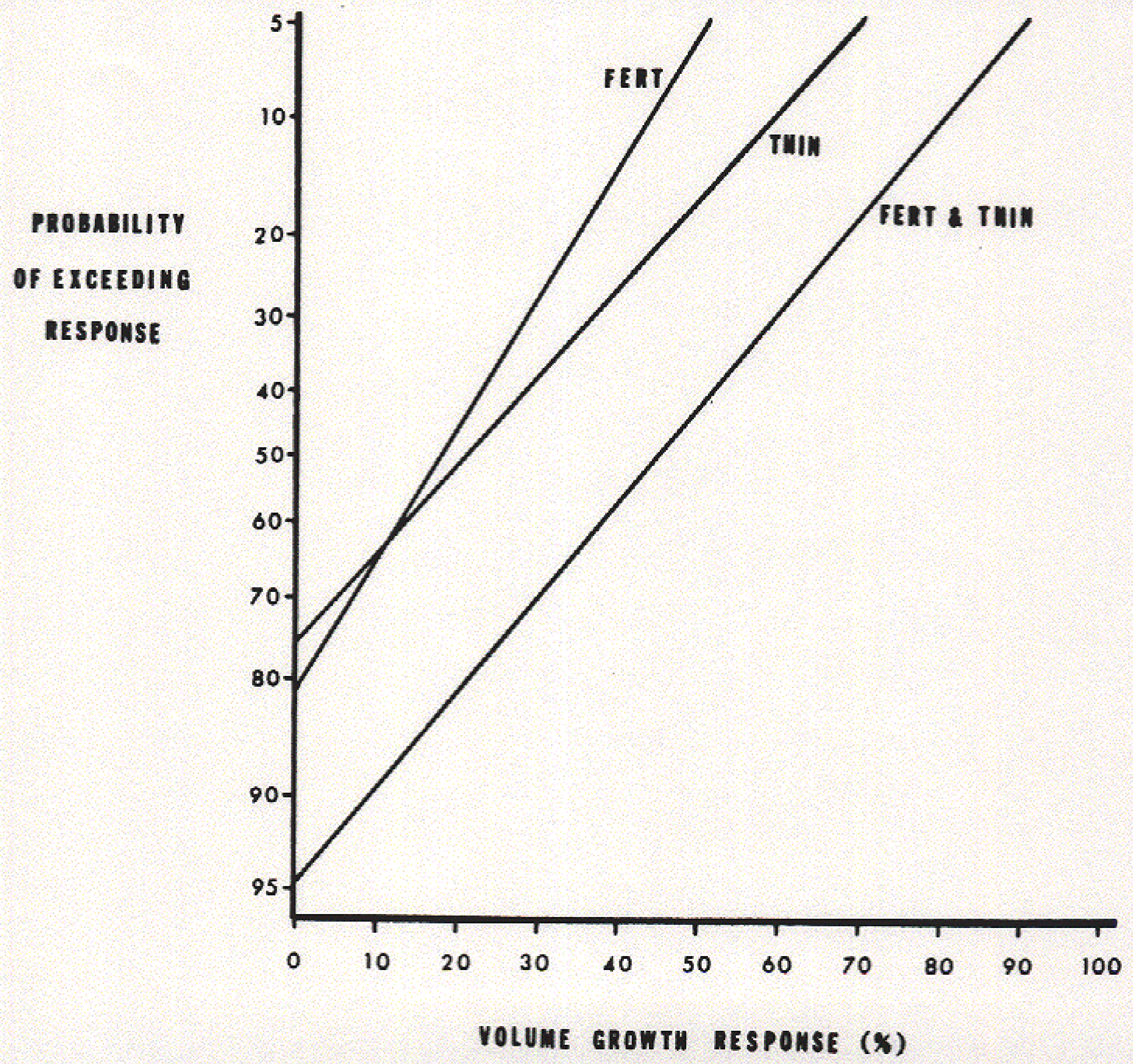
Soil profile descriptions at each location indicated that the geologic rock type classification (indicated on geologic survey maps) used to stratify the stands was not always correct; therefore the influence of rock type on treatment response was not tested directly. Several parameters related to parent material, as well as other site and stand parameters, were regressed on the estimates of volume growth response to N fertilization.

The best correlation with response ($r^2 = 0.4$) in Douglas-fir stands was with the organic content of the soil beneath the ash layer. The response tended to decline as the level of organic matter increased. In grand fir stands none of the factors we tested significantly correlated with relative response.

Immature, second-growth stands cannot be viewed as being in dynamic equilibrium with their environment, but it is reasonable to assume that the course of their development is determined by the complex of environmental stimuli that influence growth. It is unlikely that reasonable variations in the magnitude of one of those stimuli will correlate well with growth differences unless all the other factors are held constant (which is of course not possible). It is equally unlikely that fertilizer additions or thinning regimes would not affect the ecosystem significantly. When the ecosystem is altered by such treatments, adjustments are likely to be made in components of the system that cannot be measured directly in the tree attributes such as basal area, height, and volume. The system readjusts after weeks, months, and perhaps years, and the response indicated in the tree component is in reference to the total influence on the environment affecting tree growth rather than on a specific component.

Assuming the system of abiotic and biotic factors in each

Figure 3. Probability of obtaining a response from thinning and fertilizing Douglas-fir and grand fir in the Inland Empire.



stand is unique to begin with, it is not surprising that each system responds to an identical treatment in a slightly different way, resulting in variation in the response of the target component (i.e., the trees). We must accept such variation and begin to deal with it in terms of the probability that a given treatment will result in a given response. To illustrate this point, the volume growth response estimates of both Douglas-fir and grand fir were combined to produce volume growth probability curves for N fertilization, thinning, and the combination of fertilization and thinning (Figure 3).

In the Inland Empire, according to the results of our study, there is about a 75% chance that thinning a stand of Douglas-fir or grand fir will increase the cubic foot volume growth rate of residual trees, but there is only a 25% chance of the response exceeding 40% over the unthinned growth rate of the same trees during the 4 yr following treatment. Likewise, there is an 80% chance that cubic foot volume growth will be increased by the addition of 200 lb/acre (220/ha) of urea-N, but less than a 15% chance that the 4-yr response will exceed 40% over the unfertilized growth rate. If the treatments are applied together, residual grand fir and Douglas-fir in nearly all stands will increase their rate of growth, and in about 60% of the treated stands the mean growth on these trees after 4 yr will be at least 40% greater than if neither treatment had been applied.

Perhaps, as more factors of the environment are evaluated in relation to growth response of trees to N supplements, useful correlations will become apparent and general guidelines can be established to limit fertilization to stands having a high probability of response.

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