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H.J. Barclay and H. Brix

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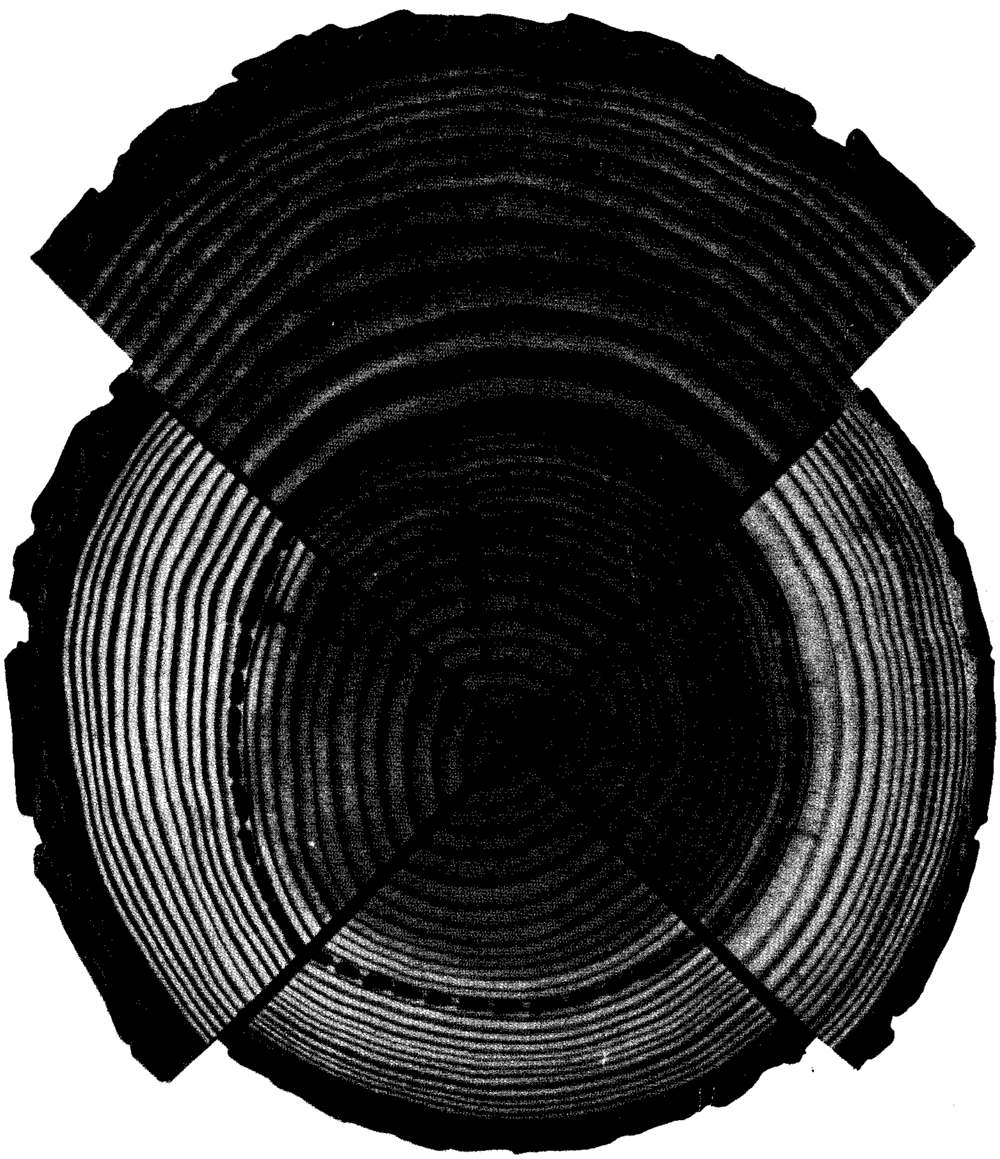

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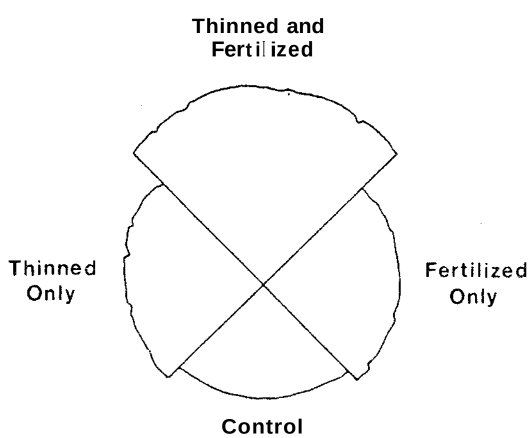
Thinned and Fertilized
Thinned Only
Fertilized Only
Control

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Abstract

This report documents the responses of tree and stand growth to thinning and nitrogen (urea) fertilization of a 24-year-old Douglas-fir (*Pseudotsuga meniiesii)* (Mirb) Franco) stand near Shawnigan Lake, British Columbia, 12 years after treatment. These responses were analyzed in four ways: land area basis, individual tree analysis using a restricted number of dbh classes, stand structure analysis and crop tree analysis.

Stem shape at 12 years was significantly affected by thinning but not by fertilization, although the magnitude of the effect even for thinning was small. Trees in heavily thinned plots had greater taper than unthinned trees. Although effects were small, this prompted the calculation of separate volume equations for each treatment.

Fertilization still had a considerable effect in years 9-12 on growth in diameter, height, total volume and merchantable volume over all levels of thinning on both an individual tree and land area basis. Thinning also increased diameter, height and volume growth of individual trees and total volume growth on a land area basis is equal to control level now (9-12 years) for both T, and T,. Annual measurements taken on the volume sample trees indicate that treatment effect on diameter growth is now declining, especially with fertilization.

Over the first 12-year period the yearly total volume growth was decreased 5.3 m^3/ha/yr by heavy thinning alone and increased 5.0 m^3/ha/yr by the high rate of fertilization (448kgN/ha) and 2.6 m^3/ha/yr by a combination of thinning and fertilization. This combination increased diameter growth fourfold compared to the untreated control.

Refertilization at year 9 has increased all growth attributes in the order of 20-40% using 448kgN/ha with somewhat less effect at the lower fertilizer rate.

Treatment effects on growth of trees which were initially in different diameter classes and of the largest 200 and 600 crop trees per hectare, are reported. Mortality is still slight; almost all dead trees were of small dbh and in unthinned plots.

Resume

Une eclaircie et une fertilisation azotee (uree) one ete pratiquees dans un peuplenient de douglas taxifolie (*Pseudotsuga menziesii* [Mirb.] Franco), âgé et 24 ans, situé pres du lac Shawnigan, en Colombie-Britannique. Les effets sur l'accroissement des arbres et du peuplement sont étudiés 12 ans plus tard et sont analyses de quatre façons: en fonction de la surface du terrain, par analyse d'arbres individuels à partir d'un nombre restreint de classes de dhp, par analyse de la structure du peuplement et par analyse d'arbres du peuplement final.

En ce qui concerne la forme de la tige, la 12^e année suivant les traitements, on observait un effet significatif, quoique peu prononce, de I'eclaircie, mais non de la fertilisation. Dans les parcelles ayant subi une forte eclaircie, les arbres presentaient un defilement plus accentue que ceux des parcelles non eclaircies. En consequence, il a fallu calculer des equations différentes de cubage pour chaque traitement.

Les 9^e et 12^e annees, I'effet de la fertilisation était encore considerable sur les accroissements du diamètre, de la hauteur, du volume total et du volume marchand, pour toutes les intensites d'eclaircie, et ce autant au niveau des arbres que par unite de surface. L'eclaircie a egalement augmente les accroissements en diametre, en hauteur et en volume des arbres pris individuellement, et I'accroissement total du volume par unite de surface est actuellement egal au niveau temoin (9^e a 12^e annees), aux deux intensites T_1 et T,. Les mesures annuelles des arbres d'échantillonnage pour le volume indiquent que I'effet des traitements sur I'accroissement en diametre diminue, surtout I'effet de la fertilisation.

Au cours des 12 premieres annees, l'accroissement annuel du volume total ($m^3.ha^{-1}.an^{-1}$) a diminue par un facteur de 5,3 suite a une eclaircie de forte intensite uniquement; il a augmenté par un facteur de *5,0* suite a la fertilisation a la dose elevee (448 kg/ha d'azote) et par un facteur de 2,6 sous I'effet d'une combinaison d'eclaircie et de fertilisation. Cette combinaison s'est traduite par une augmentation du diametre quatre fois plus élevée par rapport au temoin.

Une nouvelle fertilisation effectuée au cours de la neuvième année a entrain6 une augmentation de l'ordre de 20 9 40% pour tous les paramètres de croissance 9 la dose de 448 kg/ha d;azote, l'effet ktant un peu moins prononcé à la dose plus faible.

L'auteur présente les rksultats des traitements pour les accroissements en fonction de la classe initiale de diamètre et en fonction des 200 et 600 plus gros arbres du peuplement final par hectare. La mortalité est encore faible, presque tous les arbres morts étant des arbres de faible dhp se trouvant dans les parcelles non éclaircies.

Table of Contents

List of Tables

Introduction

Thinning and nitrogen fertilization are becoming increasingly attractive as silvicultural techniques to improve yield in Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco) and other important tree species. A major problem with the use of these practices, however, is the lack of detailed knowledge of long-term quantitative effects on tree growth for different levels of treatment and of site and stand factors affecting the response. Response periods of up to 14 years have been observed for nitrogen fertilization of Douglas-fir (Miller and Webster 1979) and often longer periods for thinning and spacing.

The present study reports the 12-year growth response in a project established in 1970 at Shawnigan Lake, British Columbia, to elucidate mechanisms of Douglas-fir response to thinning and fertilization at the ecosystem level. This project incorporates studies on growth and yield, tree physiology, nutrient and biomass distribution in the trees, soil and undergrowth, competitive interactions among trees and between trees and undergrowth, nitrogen movement in the soil, soil fauna and soil microflora (Crown and Brett 1975). Only mensurational aspects are dealt with here. The experimental design has been described by Crown and Brett (1975) and by Crown *et al.* (1977). In each of 1971 and 1972, eighteen 0.0405-ha (0.1-acre) plots were established on a low site (site index 21 m at 50 years). A completely randomized factorial design was used with three levels of thinning in which 0 (T_0), 1/3 (T_1) and 2/3 (T_2) of the original basal area of 23.1 m^2/ha were removed. In addition, three levels of urea fertilization were applied at rates of 0 (F_0), 224 (F_1) and 448 kg N/ha (F_2), providing nine treatment combinations. Each treatment combination had two replicate plots in each of the two treatment years. Surrounding each plot was a 15-m treated buffer strip to eliminate edge effects and to allow computation of competitive stress indices (Arney 1973). After 9 years the 1972 plots were refertilized at their original rates; the 1971 trees were not refertilized.

This report documents treatment effects on growth and yield based on 12 years of measurements in each of the 1971 and 1972 plots. It follows the format and type of analysis of the 6-year report (Hall *et al.* 1980) and the 9-year report (Barclay *et al.* 1982). Results of subsidiary experiments with ammonium nitrate and with higher rates of urea fertilization are reported separately (Barclay and Brix 1984; Barclay and Brix, in press).

Volume determination

There are two categories of tree measurements at Shawnigan Lake:

(a) All trees in each plot were measured for diameter at breast height (dbh), total height and height to live crown at 0, 3, 6 and 9 years after treatment. At 12 years, only dbh was measured for all trees.

(b) Measurements of dbh and height were made annually on a subset of 464 (now down to 413) trees called volume trees. In addition, every three years stem diameters at selected taper steps up the bole are also measured to allow for calculation of stem shape and tree volume by means of a numerical integration formula. These trees were selected to ensure a representative coverage of the range of thinning, fertilization, initial dbh, competitive stress index (CSI) (Arney 1973) and change in CSI.

Since the 1972 plots were refertilized in the spring of 1981 after the 9-year measurements were taken, the subsequent analysis has been done separately on the 1971 and 1972 trees to detect any differences due to refertilization. In many of the analyses of variance this distinction is incorporated as an extra factor.

Stem form

Stem form was estimated using the diameter measurements at selected heights up the bole. These heights originally represented the heights corresponding to 2.5-cm decrements in diameter although changes in bole shape have subsequently obscured this original relationship. From these measurements, form quotients (Husch *et al.* 1972) were calculated as:

$$d_{upper} / dbh$$

at 10%, 30%, 50%, 70% and 90% of total height above breast height. Table A1 in the appendix shows the average form quotients and the results of an analysis of variance testing the effects of thinning, fertilization and refertilization (year) on these form quotients. Only thinning had a significant effect on the form quotients; tree taper was increased slightly by thinning, although the magnitudes of the differences were very small. This same result was also found by Thomson and Barclay (1984) using a different type of analysis.

Volume equations

Although only thinning had a significant effect on the form quotients, 18 separate volume equations were calculated, representing the nine treatment combinations for each of 1971 and 1972; these are shown in Table A2. One equation was derived for each treatment using the volume trees, regressing log volume against log dbh and log height, where the logs are common logarithms (base 10). The general form of these equations is the linear regression:

$$\log(V) = a_1 + a_2 \log(D) + a_3 \log(H)$$

where V = total volume in m^3
D = dbh outside bark in cm
H = total height in m

These new equations were then used to calculate 12-year volumes for all the plot trees. Merchantable volumes were determined using the close utilization merchantable volume factors developed by the B.C. Forest Service (Browne 1962). These factors, although now outdated, were used to maintain continuity with previous reports. The use of 18 equations was designed to improve volume estimation; however, the removal of bias for each treatment is accomplished at the cost of a relatively small sample size for each equation.

12-Year growth response

Land area basis

The tables of volume on a land area basis (Tables 1 and 2) provide measures of actual standing total volume (m^3/ha) and net volume (excluding mortality) increments (m^3/ha/yr) resulting from treatments. The tables of diameter and height provide plot means for each treatment.

Volume

The term gross volume was used incorrectly in previous reports since the volume of dead trees was not included. We now use the term total volume in Table 1 and the figures. In addition, the increments for total volume, merchantable volume and diameter in the 9-year report (Barclay *et al.* 1982) were calculated on the basis of only trees alive 9 years after treatment, rather than using the means at each measurement period as had been done in previous years. We have now reverted to the earlier practice and have updated the 6-year and 9-year increments in Tables 1, 2, 4 and 5 accordingly. Using data for the 1971 plots, which were not refertilized, it can be seen that nitrogen fertilizer retained a considerable effect on volume increments for the 9-12 year period at all thinning levels (Figs. 1-4). Thus, F, increased the 9-12 year net total volume growth by 47, 58 and 66% for T_0, T_1 and T_2, respectively, with some T × F interaction still evident (Table 1). This is a higher response than in the 6-9 year period but less than that in the first two 3-year periods. The F, still produced a better response than F, by about 15% on the average for all thinning levels. The PAI for total net volume over the first 12 years for 1971 plots was increased 34, 67 and 85% at the T_0, T_1, and T_2 levels, respectively, by F_2 (Table 1).

The high level of thinning (T_2) has decreased net volume PAI over 0-12 years for all fertilizer regimes but increments have almost reached those for T_0 during the 9-12 year period. The T_1 has had a less drastic effect and it was only in the first three years that a reduction occurred with F_0 and F_1 but not with F_2. The T, and T, are still considerably below T_0 at year 12 in standing total volume but they are similar in merchantable volume (Table 2).

The net PAI for total volume over 12 years in 1971 plots was decreased 5.3 m^3/ha/yr by T_2F_0 and increased 5.0 m^3/ha/yr by T_0F_2 and 2.6 m^3/ha/yr by T_2F_2, relative to T_0F_0. The changes in merchantable volume PAI for these treatments were a decrease of 3.2 and increases of 4.9 and 4.5 m^3/ha/yr, respectively.

Refertilization of 1972 plots at year 9 had a considerable effect on volume growth (Tables 1, 2, 3). Table 3 gives increments in 1972 plots as a percentage of those in 1971 plots. The effect of

Table 1. Total volume (m³/ha) and net volume increment (**PAI:** m³/ha/yr) response by treatment-land area basis

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Total Volume	m³/ha								
− (initial)	144	136	101	88	87	88	46	49	46
− (3-year)	191	201	170	123	143	158	68	89	94
− (6-year)	223	246	226	158	185	219	93	123	137
− (9-year)	270	302	287	204	243	286	133	182	195
− (12-yr(71))	311	327	325	223	273	310	155	232	250
− (12 yr(72))	299	398	376	266	324	417	185	241	278
PAI	m³/ha/yr								
− (0-3 yrs)	15.9	21.8	23.0	11.4	18.6	23.4	7.4	13.5	15.9
− (3-6 yrs)	10.4	15.1	18.6	11.7	13.9	20.2	8.4	11.2	14.4
− (6-9 yrs)	15.7	18.7	20.3	15.3	19.3	22.3	13.3	19.7	19.3
− (9-12 yr(71))	12.6	16.1	18.5	12.5	16.8	19.8	10.3	15.7	17.1
− (9-12 yr(72))	14.2	24.9	24.8	15.0	21.8	32.5	14.3	20.4	29.3
− (0-12 yr(71))	14.6	17.2	19.6	11.8	16.3	19.7	9.3	15.2	17.2
− (0-12 yr(72))	13.8	21.7	22.7	14.4	19.1	26.5	11.4	16.1	19.3

refertilization is difficult to assess since only 2 of 3 years in the 9-12 year period were in common for the 1971 and 1972 plots and even the 1972 treatments which did not include fertilization had higher increments than the corresponding 1971 plots (Table 3). The effect of refertiliztion on volume growth appears to be in the range of 20-40% with use of F_2.

Diameter

Mean tree dbh (i.e. arithmetic means) and increments are shown in Table 4 and Fig. **5.** Initial dbh varied only slightly across fertilizer treatments but increased with level of thinning. The impact of this variation on stand growth was assessed by stand structure analysis (Anon. 1975) and found to be negligible. Treatment effects have decreased with time but are still considerable for the 9-12 year period, i.e., an increase of 70, 22, and 16% by F_2 (1971 plots) for T_0, T,, and T,, respectively (Table 4). Over the 12-year period the effect of T_2 was an increase of 145% whereas F_2 alone increased dbh increment by 105%. T_2F_2 increased dbh growth about fourfold compared to T_0F_0.

Refertilization increased the 9-12 year PAI for dbh by 15-30% (average 23%) with F_1 and 42-56% (average 47%) with F_2 depending on thinning level (Table 3). This is in addition to the effect which still remained following the initial fertilization.

The diameters at bh of the trees of mean basal area (see below) responded to thinning and refertilization in similar manner to the arithmetic mean dbh. Quadratic mean diameter (QMD) increased in response to both fertilization and thinning (Table 5), with T_2F_2 showing the largest increments.

Table 2. Merchantable volume (m^3/ha) and net merchantable volume increment (PAI: m^3/ha/yr) response by treatment-land area basis

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Merchantable volume	m^3/ha								
– (initial)	43	53	27	36	37	32	20	22	21
– (3-year)	77	106	79	65	87	96	42	62	69
– (6-year)	108	152	135	98	128	156	68	97	113
– (9-year)	148	202	194	140	183	220	105	152	168
– (12-yr(71))	191	229	225	161	215	248	128	201	222
– (12-yr(72))	180	297	293	201	262	346	156	212	250
PAI	m^3/ha/yr								
– (0-3 yrs)	11.2	17.7	17.3	9.7	16.4	21.2	7.4	13.5	15.8
– (3-6 yrs)	10.4	15.2	18.7	10.9	13.7	20.2	8.8	11.6	14.9
– (6-9 yrs)	13.3	16.7	19.7	14.0	18.3	21.3	12.3	18.3	18.3
– (9-12yr (71))	13.2	15.9	18.6	12.6	16.8	19.2	10.4	15.9	17.0
– (9-12yr (72))	13.5	25.1	25.0	14.9	21.9	32.4	14.1	20.4	28.6
– (0-12 yr (71))	12.4	15.3	17.3	10.8	15.4	18.7	9.2	14.9	16.9
– (0-12 yr (72))	11.8	20.0	21.4	13.5	18.3	25.5	11.2	15.8	19.0

Table 3. Effects of refertilization at year 9 on 9-12 year PAI in net total volume, diameter (dbh) and height. The numbers show the growth of 1972 refertilized plots as a percentage of growth of the corresponding non-refertilized 1971 plots

	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
volume	113	155	134	120	130	164	139	130	171
dbh	96	115	156	100	123	144	100	130	142
height	78	105	128	83	105	123	90	121	119

Table 4. Mean[1] stand diameter (dbh, cm) and increment (PAI: cm/yr) by treatment

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Diameter	cm								
– (initial)	7.81	8.60	8.04	9.65	9.91	9.53	10.63	10.71	10.69
– (3-year)	8.54	9.84	9.58	10.89	11.84	11.84	12.44	13.63	14.20
– (6-year)	9.31	10.88	11.08	11.95	13.09	13.50	14.12	15.57	16.69
– (9-year)	10.06	12.11	12.46	13.01	14.31	14.90	15.65	17.28	18.53
– (12-year(71))	10.59	12.80	12.79	13.47	15.32	15.76	16.82	18.77	20.27
– (12-year(72))	10.87	13.81	14.97	14.41	15.91	16.70	17.52	19.53	21.10
PAI	cm/yr								
– (0-3 years)	0.24	0.41	0.51	0.41	0.64	0.77	0.60	0.88	1.17
– (3-6 years)	0.26	0.35	0.50	0.35	0.42	0.55	0.56	0.74	0.83
– (6-9 years)	0.25	0.41	0.46	0.35	0.40	0.47	0.52	0.58	0.61
– (9-12 years (71))	0.23	0.41	0.39	0.32	0.39	0.39	0.51	0.54	0.59
– (9-12 years (72))	0.22	0.47	0.61	0.32	0.48	0.56	0.51	0.70	0.84
– (0-12 years (71))	0.22	0.35	0.45	0.34	0.46	0.54	0.54	0.68	0.81
– (0-12 years (72))	0.23	0.43	0.53	0.37	0.48	0.57	0.56	0.73	0.86

[1] The means calculated in this table are all arithmetic means. in conformity with those in previous reports in this series.

Basal area

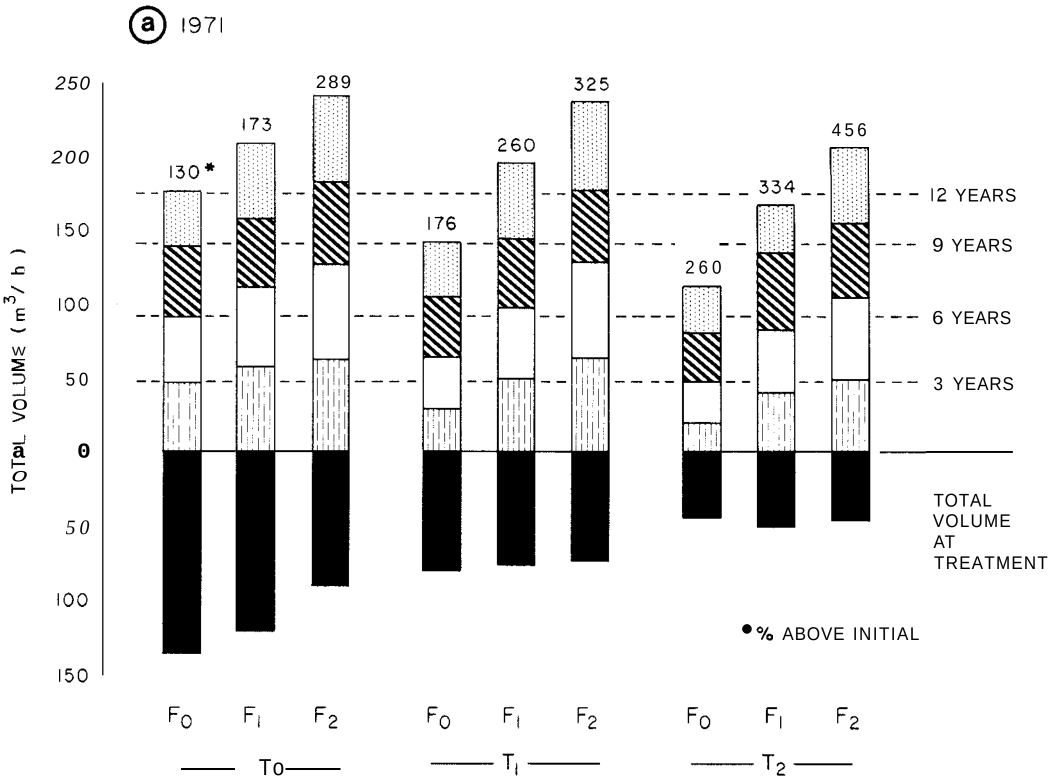
Mean basal areas for each treatment (m²/ha) are shown in Table 6. Basal area increased with level of fertilization but decreased with thinning due to removal of growing stock. By 12 years, the T_2F_2 basal area was still slightly less than that of the control (Table 6). Basal area appears to have responded to refertilization in the unthinned plots but not in thinned plots.

Height

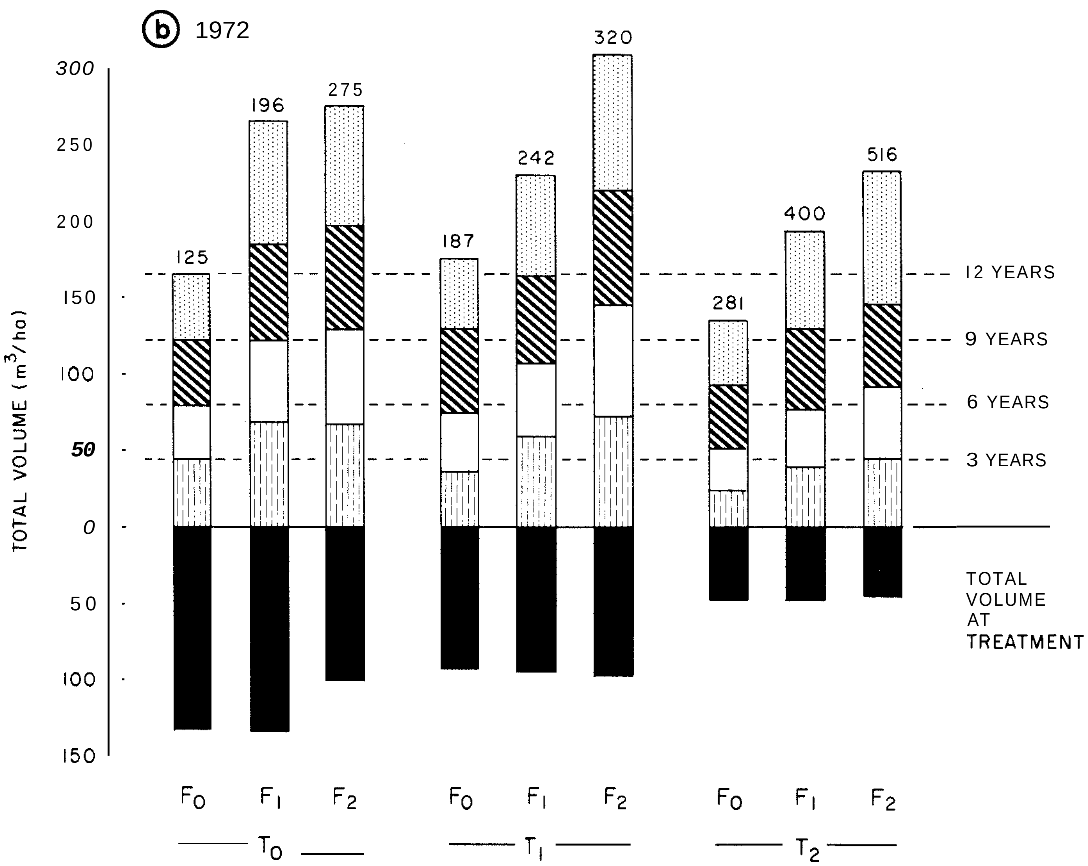
Mean stand height and height increments are shown in Table 7; the increments are also shown in Fig. 6. Fertilization has continued to increase height growth in years 9-12 at all thinning levels. Thinning without fertilization has also had a considerable effect whereas thinning combined with fertilization has not influenced height significantly above that provided by fertilization in any of the 3-year measurement periods (Table 7). Without fertilization height increment (0-12 years) was increased 25% by T_1 and 59% by T,. Part of this effect may be due to biased thinning procedures but this effect is likely to be small.

Refertilization at year 9 increased height growth (9-12 years) at all thinning levels by an average of 27 and 40% for F_1 and F,, respectively (Table 3).

Figure 1. Land area growth responses of total volume by treatment (m³/ha). Initial total volumes for each treatment are shown below the solid line. Accumulated volumes at 3, 6, 9 and 12 years after treatment appear above the solid line together with 12-year percentage increases above control.
(a) 1971 trees, which were not refertilized
(b) 1972 trees, which were refertilized 9 years after initial treatment.



(a) 1971
250
200
150
100
50
0
50
100
150
TOTAL VOLUME (m³/h)
130*
173
289
176
260
325
260
334
456
12 YEARS
9 YEARS
6 YEARS
3 YEARS
TOTAL VOLUME AT TREATMENT
*% ABOVE INITIAL
F0 F1 F2 F0 F1 F2 F0 F1 F2
T0
T1
T2



(b) 1972
300
250
200
150
100
50
0
50
100
150
TOTAL VOLUME (m³/ha)
125
196
275
187
242
320
281
400
516
12 YEARS
9 YEARS
6 YEARS
3 YEARS
TOTAL VOLUME AT TREATMENT
F0 F1 F2 F0 F1 F2 F0 F1 F2
T0
T1
T2

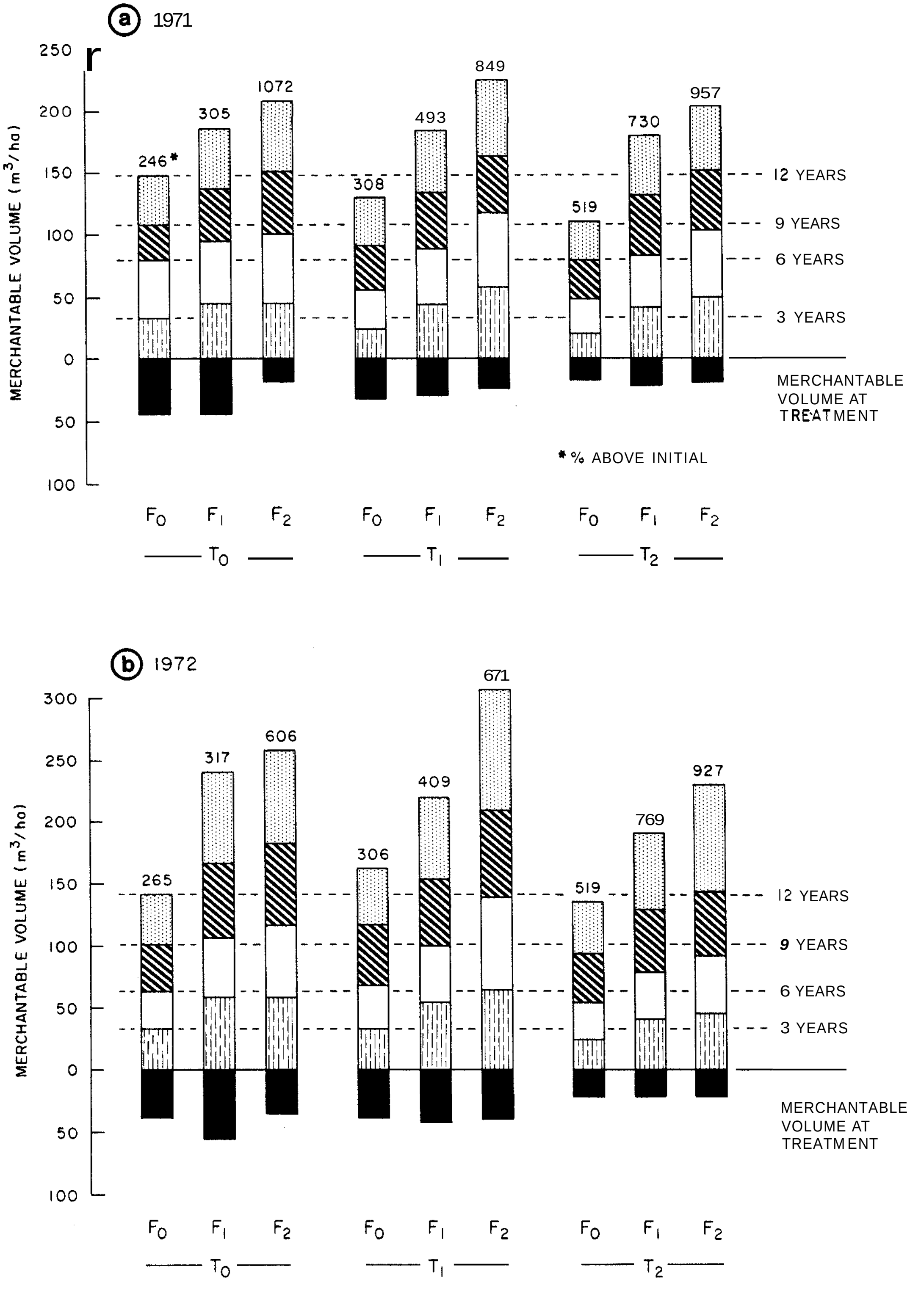


Figure 2. Land area growth responses of merchantable volume by treatment. The format is the same as for total volume (Fig. 1).

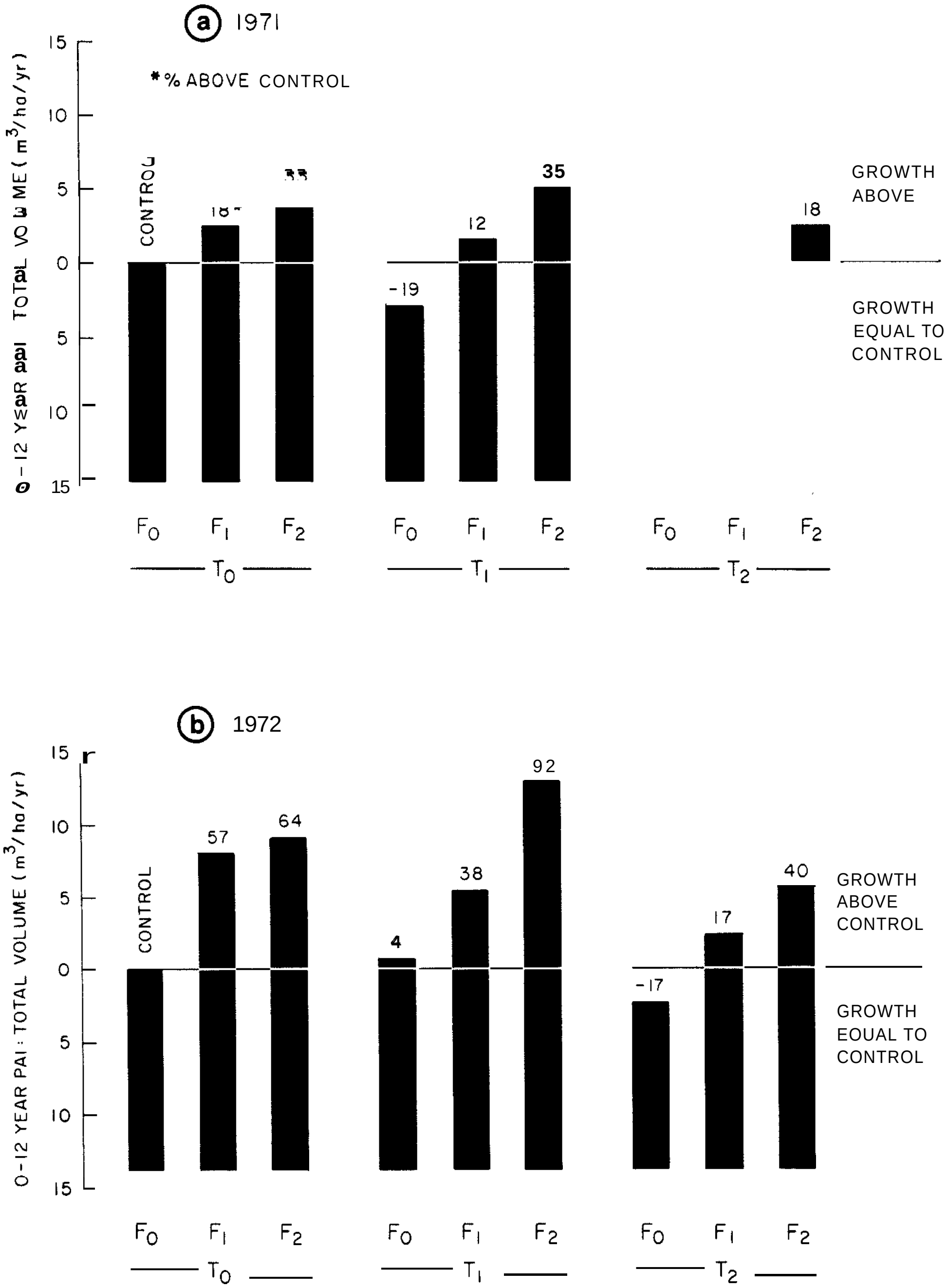


Figure 3. Total volume 0-12 year PAI above control are shown above the solid line for each treatment; numbers show gain above control. Amounts equal to control are shown below the solid line.

(a) 1971 plots – non-refertilized
(b) 1972 plots – refertilized after 9 years.

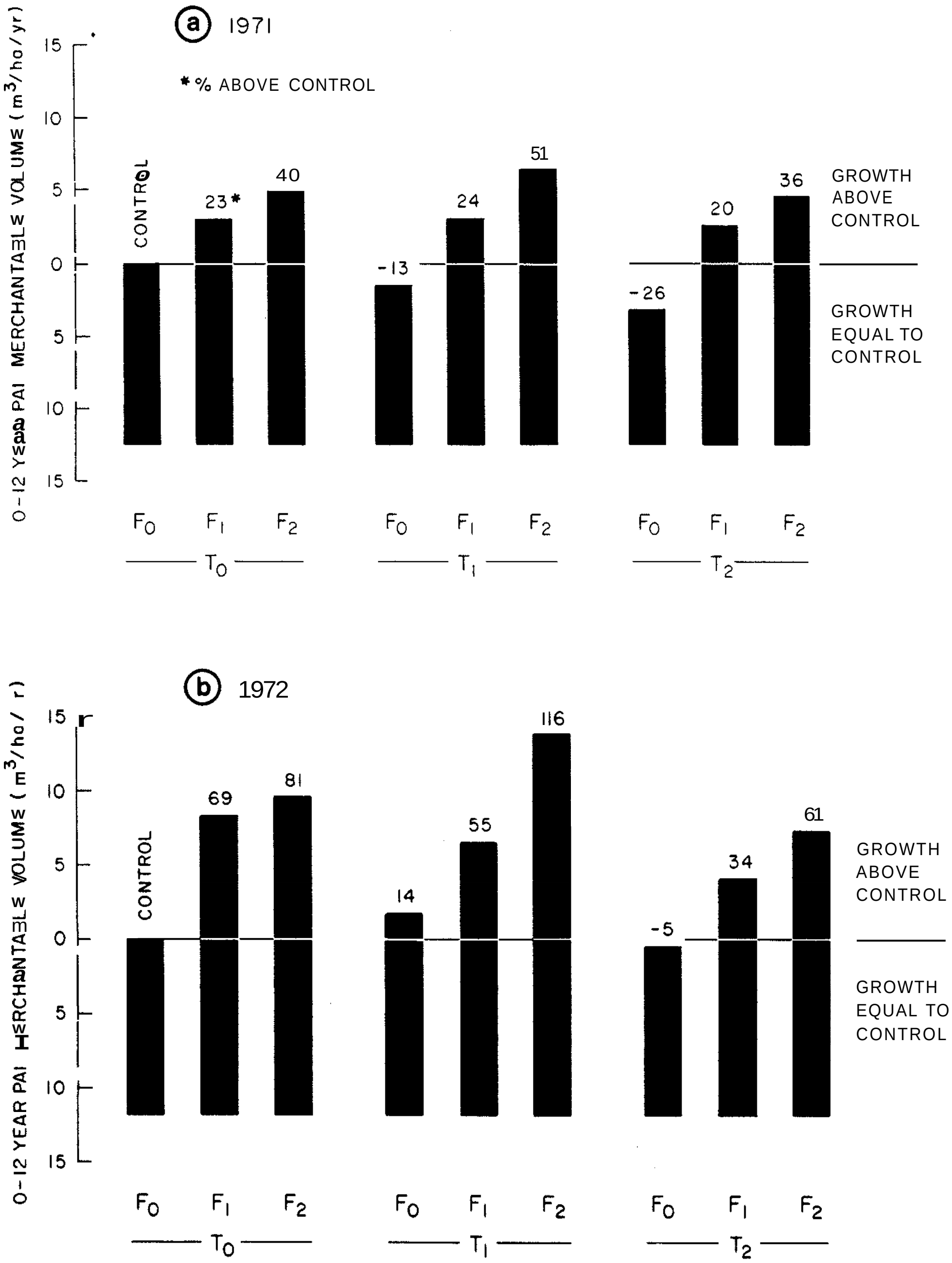
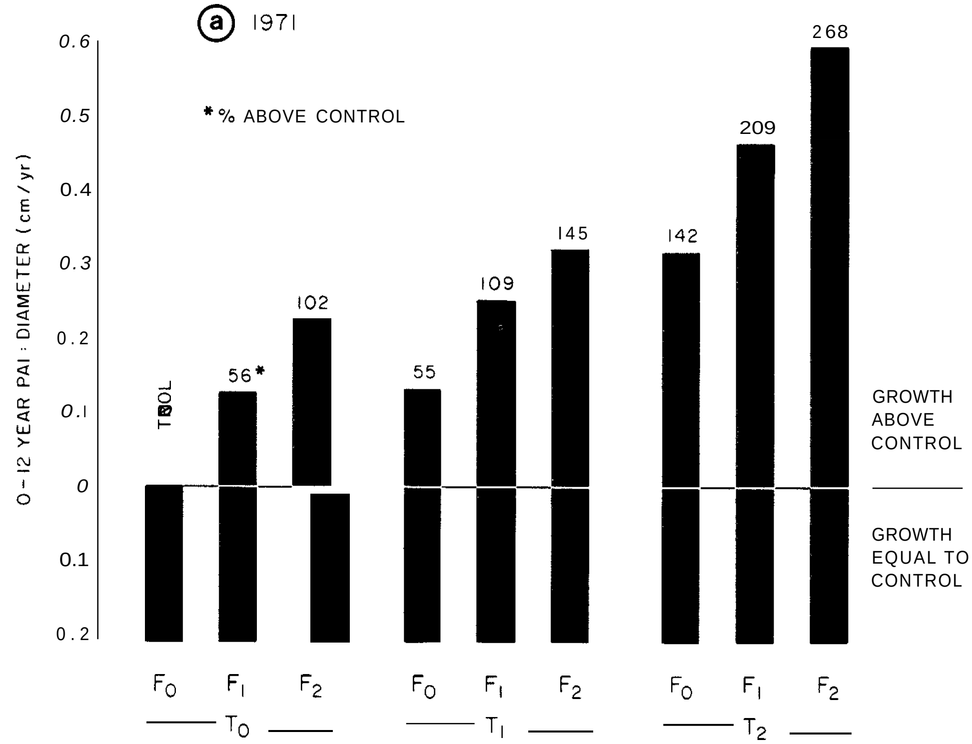
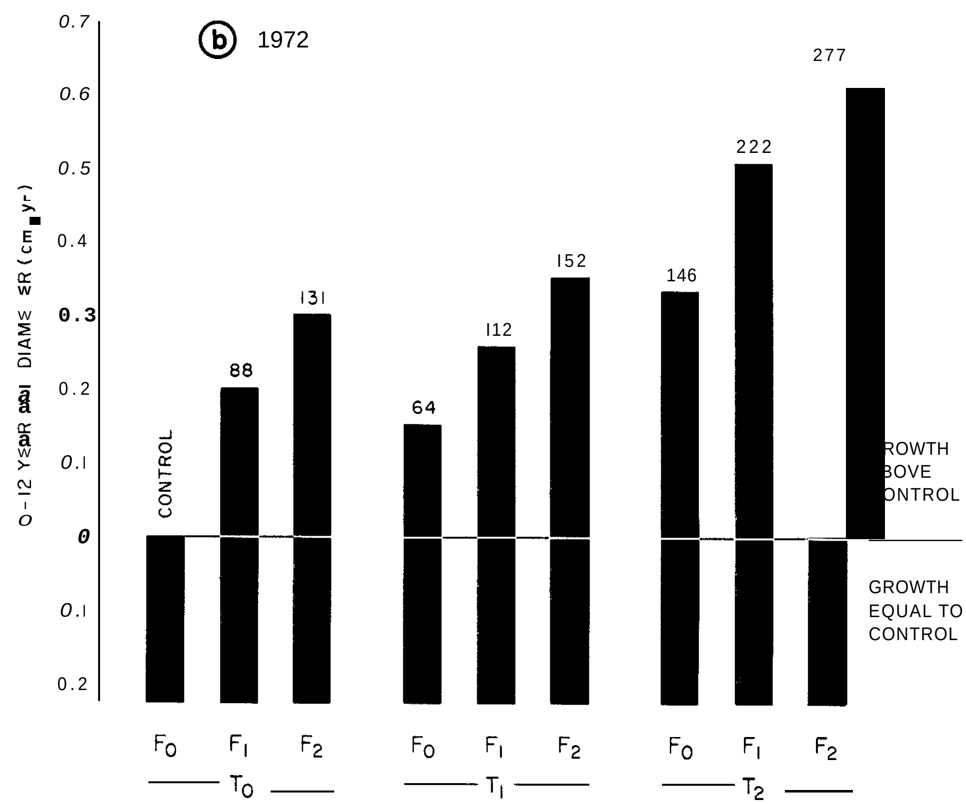


Figure **4.** Merchantable volume 0-12 year PAI above control (above the solid line). Amounts below the line are equal to control.
(a) 1971 – non-refertilized plots
(b) 1972 – refertilized after 9 years.

Figure 5. Diameter – mean annual increments (0-12 years) above control are shown above the solid line for each treatment; numbers show the percentage gain over control. Increments equal to control are shown below the solid line.
(a) 1971 plots – non-refertilized
(b) 1972 plots – refertilized after 9 years.



a 1971
* % ABOVE CONTROL
0-12 YEAR PAI : DIAMETER (cm / yr)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
56*
102
55
109
145
142
209
268
GROWTH ABOVE CONTROL
GROWTH EQUAL TO CONTROL
F_0 F_1 F_2
T_0
F_0 F_1 F_2
T_1
F_0 F_1 F_2
T_2



b 1972
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
CONTROL
88
131
64
112
152
146
222
277
GROWTH EQUAL TO CONTROL
F_0 F_1 F_2
T_0
F_0 F_1 F_2
T_1
F_0 F_1 F_2
T_2

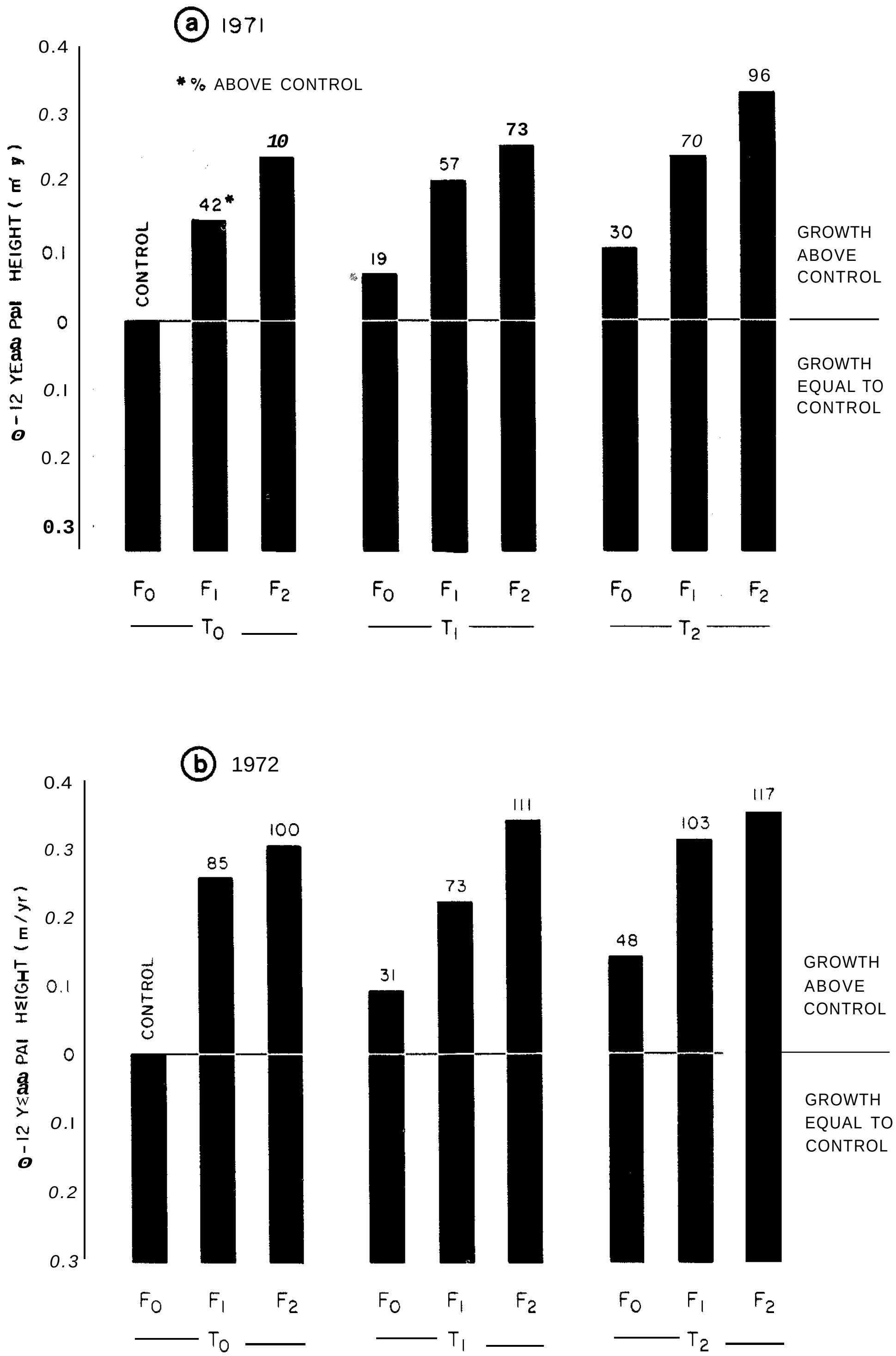


Figure 6. Height – mean annual increments (0-12 years) above control are shown above the solid line for each treatment; numbers show the percentage gain over control. Increments equal to control are shown below the solid line.
(a) 1971 plots – non-refertilized
(b) 1972 plots – refertilized after 9 years.

Table 5. Quadratic mean diameters (dbh, cm) and increments (PAI: cm/yr) by treatments

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Quadratic mean diameter	cm								
– (initial)	7.43	8.12	7.43	8.89	9.10	8.76	9.60	9.66	9.68
– (3-year)	8.16	9.32	8.90	10.03	10.85	10.86	11.22	12.28	12.81
– (6-year)	8.74	10.30	10.26	11.00	12.00	12.41	12.73	14.02	15.04
– (9-year)	9.33	11.15	11.35	11.95	13.09	13.57	14.13	15.59	16.69
– (12-year (71))	9.87	11.66	11.72	12.47	14.00	14.41	15.21	16.93	18.25
– (12-year (72))	10.06	12.94	13.65	13.20	14.55	15.34	15.79	17.62	18.91
PAI	cm /yr								
– (0-3 years)	0.24	0.40	0.49	0.38	0.59	0.70	0.54	0.87	1.04
– (3-6 years)	0.19	0.33	0.46	0.33	0.38	0.52	0.50	0.58	0.74
– (6-9 years)	0.20	0.28	0.36	0.32	0.36	0.39	0.47	0.52	0.55
– (9-12 years (71))	0.22	0.34	0.34	0.30	0.36	0.35	0.46	0.49	0.53
– (9-12 years (72))	0.20	0.42	0.51	0.30	0.44	0.52	0.46	0.63	0.74
– (0-12 years (71))	0.21	0.31	0.40	0.32	0.43	0.49	0.48	0.61	0.73
– (0-12 years (72))	0.21	0.39	0.47	0.34	0.44	0.53	0.50	0.65	0.76

Individual tree basis

Within a stand, trees of different dbh would be expected to grow at different rates even if all other factors affecting growth were constant throughout the stand. Among stands of differing dbh distribution this confounding factor can be partially eliminated by a comparison of the growth rates of trees of similar dbh. Figures 7 and 8 compare growth on an individual tree basis (PAI, 0 to 12 years) across treatments and selected dbh classes. We have again used 2.5-cm dbh classes in Figures 7 and 8 to facilitate comparison with earlier reports, although current convention calls for 2-cm dbh classes. Since thinning and subsequent differential growth in response to treatments have yielded heterogeneous dbh distributions across treatments, only those dbh classes common to all treatments were used. The classes are 2.5 cm wide and range from a lower limit of 5.0 cm (class 3) to 17.5 cm (class 7). Diameter distributions at 12 years are shown in the Appendix (Table A3).

Since height was not measured for all the plot trees but was obtained by regression, height and basal area are simple functions of diameter and are thus not shown. Volume also was obtained by regression (based on measurements from the volume trees) but it is of major interest to the forest manager and is presented here. The numbers above the PAI bars in Figs. 7 and 8 give percent gain over control for a given dbh class. Both diameter and total volume show increasing increment the larger the initial dbh; however, the proportional growth relative to the original size is generally much greater in the smaller dbh classes, especially in thinned plots (Figs. 7 and 8). For purposes of comparison on a heuristic basis, the growth of each size class in Figure 8 was divided by the fraction of the total basal area represented by that size class for each treatment. This standardized the volume increments for each size class and yielded the volume increment expected if all trees were of that dbh class. The smaller trees produced more volume for the thinned plots per unit of basal area than larger

Table 6. Mean stand basal area (m^2/ha) and increments (PAI: m^2/ha/yr) by treatment

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Basal area	m^2/ha								
– (initial)	25.4	23.6	19.7	15.6	15.3	15.6	8.3	8.5	8.4
– (3-year)	30.3	30.4	28.0	19.7	21.8	24.0	11.3	13.7	14.6
– (6-year)	34.4	35.2	34.2	23.6	26.5	30.6	14.5	17.8	20.1
– (9-year)	38.6	39.5	38.8	21.7	31.4	35.9	17.9	22.1	24.8
– (12 year (71))	43.8	42.1	41.7	29.6	34.6	39.7	20.6	26.9	30.4
– (12 year (72))	41.8	46.5	46.7	34.4	39.2	44.5	22.5	27.2	30.9
PAI	m^2/ha/yr								
– (0-3 years)	1.65	2.26	2.78	1.36	2.16	2.80	1.01	1.71	2.07
– (3-6 years)	1.37	1.61	2.04	1.31	1.58	2.19	1.08	1.39	1.84
– (6-9 years)	1.39	1.43	1.55	1.36	1.64	1.78	1.12	1.40	1.55
– (9-12years (71))	1.56	1.52	1.36	1.36	1.62	1.73	1.18	1.50	1.68
– (9-12 years (72))	1.23	1.86	2.23	1.50	2.03	2.37	1.25	1.83	2.27
– (0-12 years (71))	1.54	1.66	1.89	1.25	1.69	2.10	1.05	1.52	1.84
– (0-12 years (72))	1.36	1.83	2.19	1.49	1.91	2.31	1.16	1.56	1.87

dbh classes (Table 8), while the reverse is true for unthinned plots.

The 12-year individual tree response is similar to those at 3 years (Crown *et al.* 1977), 6 years (Hall *et al.* 1980) and 9 years (Barclay *et al.* 1982). Generally, small trees have benefited more by thinning and large trees by fertilization.

As in the 6-year and 9-year reports, a stand structure analysis (Anon. 1975) was performed to assess differences in growth due to heterogeneity of dbh distributions among plots. The differences were found to be negligible and are thus not presented here.

Crop tree analysis

For this analysis, the trees of largest initial dbh from each plot were used for calculating Total volume increments; equal numbers of trees were used from each plot and they represent the largest (a) 200 (Fig. 9 a,b) and (b) 600 trees (Fig. 9 c, d) per hectare. Thus the initially largest (still living) 8 or 25 trees per plot were chosen for this analysis. The total volume increments per plot, shown on a per hectare basis, are presented both as measured and also adjusted for initial dbh using covariance analysis (Fig. 9).

The 12-year total volume increment for the 200 largest trees per hectare increases with both fertilization and thinning although the measured increments show a somewhat different pattern than do the adjusted increments (Fig. 9a); however, in both cases the response to thinning is less than that to fertilization. The largest response for the refertilized trees was 207% (measured) over control as compared with 72% over control for the non-refertilized trees (Fig. 9 a,b). This degree of difference is too large to be explained solely on the basis of refertilization and it does not appear to be reflected in the growth of all the trees (compare Fig. 1a and 1b). This difference may partly result from the lower growth on control trees in the 1972 plots than those of 1971, as

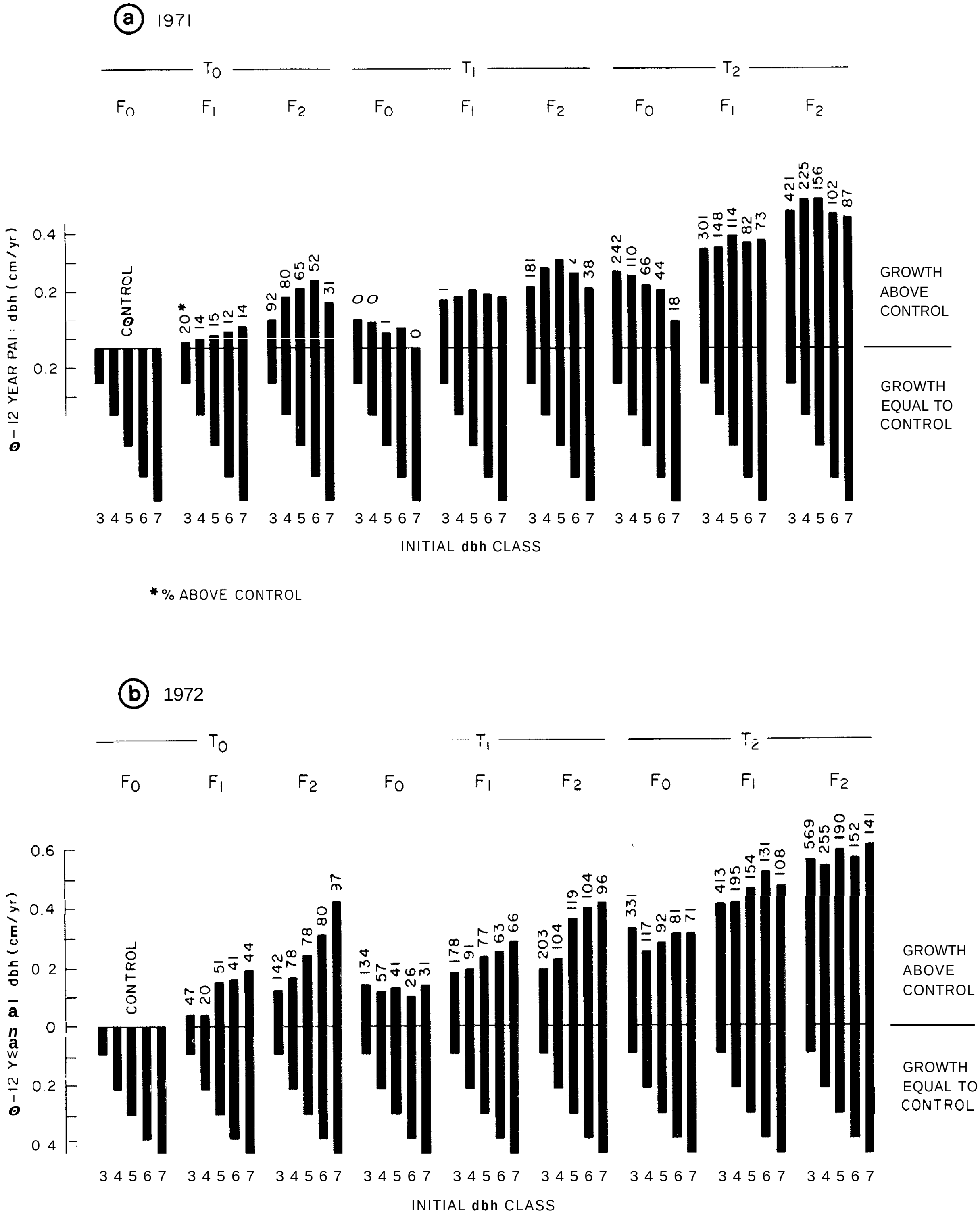
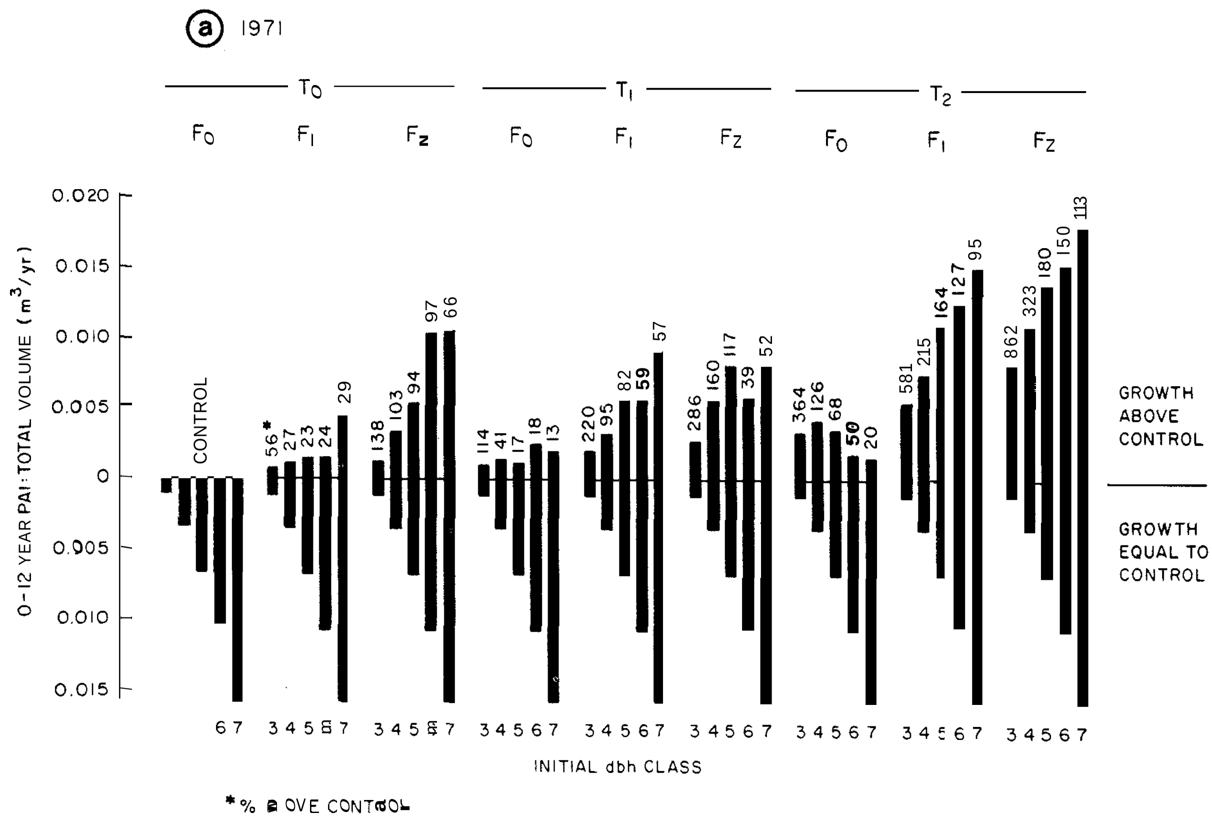


Figure 7. Dbh – individual tree analysis (0-12 years). Growth is graphed by treatment and by dbh class within each treatment. Actual amounts (cm/yr per mean tree) are graphed while percentage gain above control is shown above the bars.

(a) 1971 plots – non-refertilized

(b) 1972 plots – refertilized after 9 years.


a
1971
T0
T1
T2
F0
F1
F2
0-12 YEAR PAI: TOTAL VOLUME (m3/yr)
CONTROL
GROWTH ABOVE CONTROL
GROWTH EQUAL TO CONTROL
INITIAL dbh CLASS
*% ABOVE CONTROL

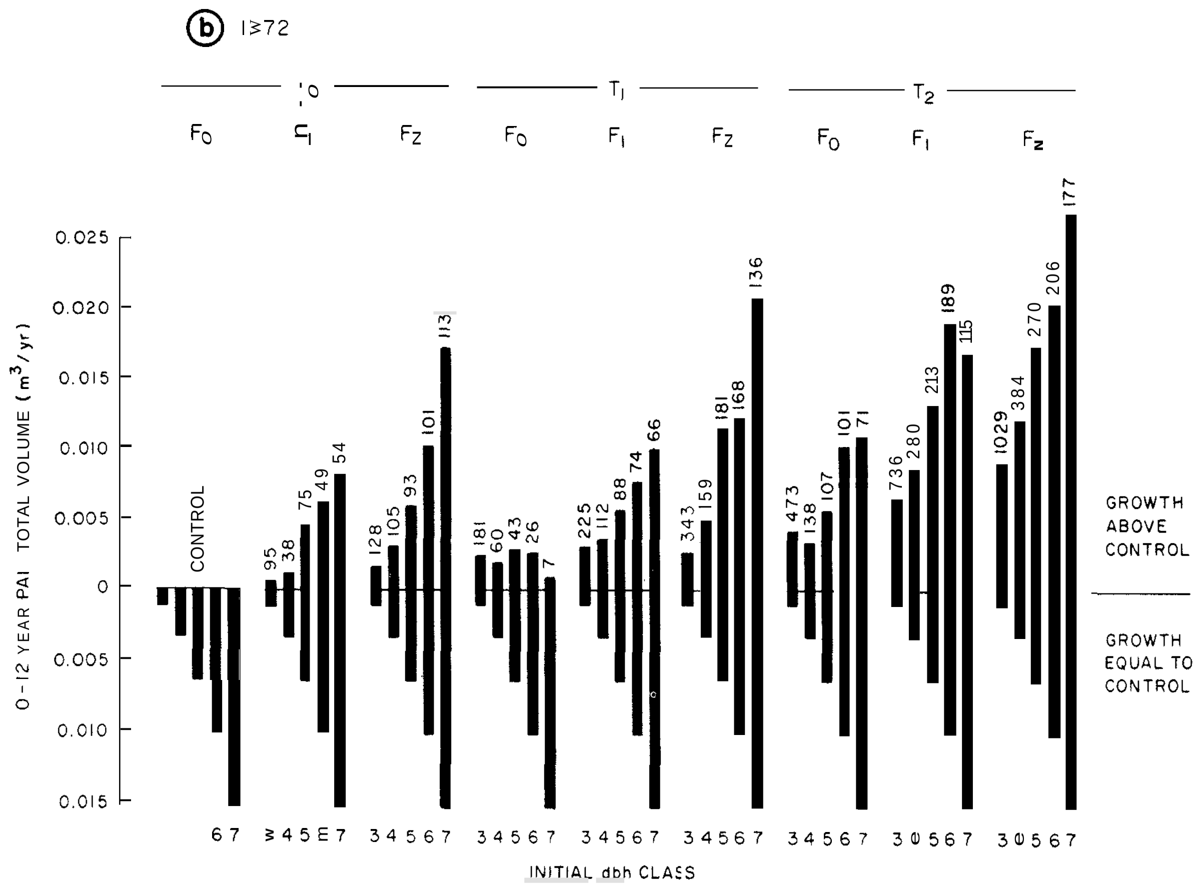

b
1972
T0
T1
T2
F0
F1
F2
0-12 YEAR PAI TOTAL VOLUME (m3/yr)
CONTROL
GROWTH ABOVE CONTROL
GROWTH EQUAL TO CONTROL
INITIAL dbh CLASS

Table 7. Mean stand height (m) and increment (PAI: m/yr) by treatment

	Treatment								
	T_0			T_1			T_2		
	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
Height	m								
– (initial)	8.9	9.2	8.2	9.7	9.9	9.8	9.9	10.3	9.9
– (3 year)	10.1	10.8	10.0	10.9	11.7	11.8	10.9	12.1	12.0
– (6 year)	10.9	12.3	11.8	12.0	13.1	13.6	12.1	13.7	13.8
– (9 year)	11.8	13.6	13.2	13.2	14.5	15.1	13.4	15.3	15.5
– (12 year (71))	13.0	14.7	14.6	14.4	15.9	15.9	14.9	17.2	17.6
– (12 year (72))	12.5	16.1	16.1	14.6	16.5	18.4	15.5	17.6	18.0
PAI	m/yr								
– (0-3 years)	0.39	0.56	0.60	0.39	0.62	0.67	0.34	0.59	0.70
– (3-6 years)	0.29	0.49	0.59	0.37	0.47	0.59	0.40	0.55	0.60
– (6-9 years)	0.28	0.42	0.49	0.40	0.44	0.51	0.45	0.54	0.57
– (9-12 yr (71))	0.37	0.59	0.60	0.48	0.57	0.61	0.61	0.63	0.70
– (9-12 yr (72))	0.29	0.62	0.77	0.40	0.60	0.75	0.55	0.76	0.83
– (0-12 yr (71))	0.34	0.48	0.57	0.40	0.53	0.58	0.44	0.57	0.66
– (0-12 yr (72))	0.30	0.56	0.61	0.40	0.52	0.64	0.45	0.62	0.66

this would bias the comparisons of the other treatments with control. The actual amount of growth of T_2F_2 for 1971 was 2.0 m³/ha/yr (measured) as compared with 4.5 m³/ha/yr for the 1972 plots. The growth of the largest 600 trees per hectare closely parallels the above trends (Fig. 9 c,d). Actual growth of T_2F_2 for 1971 was 7.0 m³/ha/yr against 11.0 m³/ha/yr for the 1972 plots. Analyses of variance for the crop trees are shown in the appendix (Tables A4 and A5); a T x F interaction is still apparent.

←

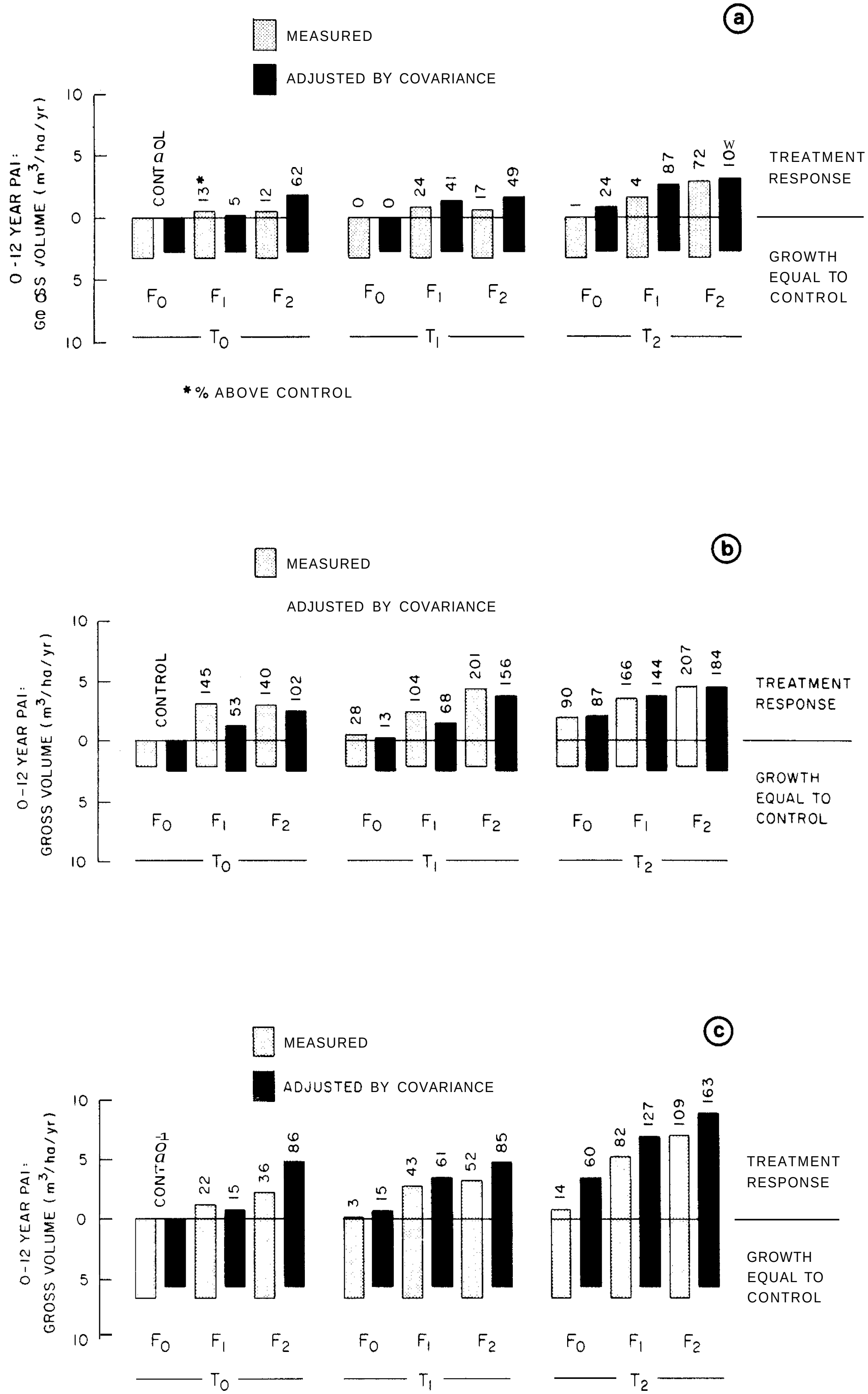
Figure 8. Total volume – individual tree analysis (0-12 years). Growth is graphed by treatment and by dbh class within each treatment. Actual amounts are graphed (m³/yr per mean tree) while percent gain over control is shown above the bars.
(a) 1971 plots – non-refertilized.
(b) 1972 plots – refertilized after 9 years.

Mortality

Tree mortality for the first 12 years after treatment totals 333 out of 3343 initially live plot trees, or 0.83% per year (Table A6 in the appendix). The trends observed in the 6-year and 9-year reports continue here: (a) mortality increases with fertilization, in agreement with Miller and Pienaar (1973) and Lee (1974); (b) mortality decreases with thinning; (c) mortality is highest in trees of small dbh (Fig. 10).

Volume tree response

The trees used for calculating the regression of volume on dbh and height were a subset of about 10% of the experimental plot trees. They were chosen to span the range of initial dbh and competitive stress indices (Arney 1973) found at Shawnigan. These volume trees were measured annually for dbh and height. The CAI for the nine treatments at six years appeared to be con-



a
MEASURED
ADJUSTED BY COVARIANCE
0 -12 YEAR PAI:
GR OSS VOLUME (m3/ ha / yr)
CONTROL
13*
5
12
62
0
0
24
41
17
49
1
24
4
87
72
10W
TREATMENT RESPONSE
GROWTH EQUAL TO CONTROL
F0 F1 F2
T0 T1 T2
*% ABOVE CONTROL
b
MEASURED
ADJUSTED BY COVARIANCE
0 -12 YEAR PAI:
GROSS VOLUME (m3/ ha / yr)
CONTROL
145
53
140
102
28
13
104
68
201
156
90
87
166
144
207
184
TREATMENT RESPONSE
GROWTH EQUAL TO CONTROL
c
MEASURED
ADJUSTED BY COVARIANCE
0 -12 YEAR PAI:
GROSS VOLUME (m3/ ha / yr)
CONTROL
22
15
36
86
3
15
43
61
52
85
14
60
82
127
109
163
TREATMENT RESPONSE
GROWTH EQUAL TO CONTROL

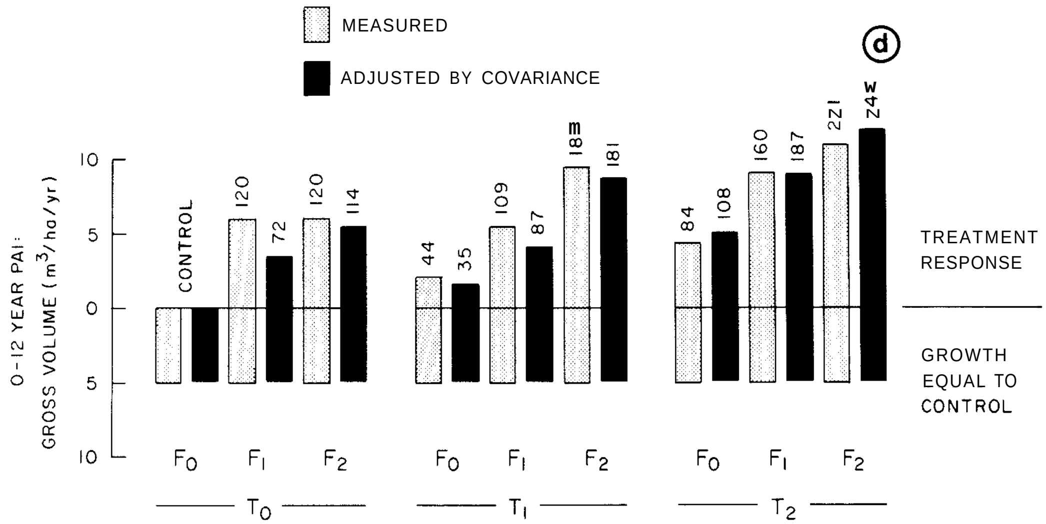


Figure 9. Crop tree analysis — total volume increments by treatment, unadjusted and adjusted by covariance for initial dbh. Mean treatment responses are graphed together with percent gain above control.

(a) 200 largest trees per hectare; 1971 plots — non-refertilized.

(b) 200 largest trees per hectare; 1972 plots — refertilized after 9 years.

(c) 600 largest trees per hectare; 1971 plots — non-refertilized.

(d) 600 largest trees per hectare; 1972 plots — refertilized.

verging (Hall *et al.* 1980), however, by nine years it was apparent that weather patterns were strongly affecting the CAI for both dbh and height (Barclay *et al.* 1982). At 12 years differences in CAI for dbh and height due to treatments are still apparent (Fig. 11a; 12a); also refertilization has increased diameter and height growth since nine years (Fig. 11, 12). Thinning now has a greater effect on diameter growth than fertilization in the non-refertilized plots (Fig. 11a) and the CAI are almost perfectly ordered with respect to thinning ($T_2 > T_1 > T_0$), the only exception being T_0F_1, but the ordering is no longer clear with respect to fertilization.

Discussion

Extensive studies of nitrogen fertilization effects on Douglas-fir growth have been made over a wide range of sites in western Oregon and Washington under the Regional Forest Nutrition Project (RFNP) (Anon. 1982). The 10-year total volume response of unthinned stands has averaged 12 and 15% for all sites with the use of 224 and 448 kg N/ha, respectively, or 2.8 and 3.5 m^3/ha/yr. These average responses are well below those obtained at Shawnigan for unthinned plots over 12 years, i.e., 34% or 5.0 m^3/ha/yr with 448 kg N/ha. However, their PAI for merchantable volume response on low sites (class IV) measured over a 8-year period are similar to our PAI for 12 years, i.e., 4.6 versus 4.9 m^3/ha/yr. Handley and Pienaar (1972) reported increases in total annual volume increments ranging from 1.75 to 2.5 m^3/ha/yr per 112 kg N/ha over a 5-year period for Douglas-fir stands on Vancouver Island.

The total volume response has been excellent even in the 9-12 year period amounting to 47% for T_0F_2. This contrasts to the insignificant aver-

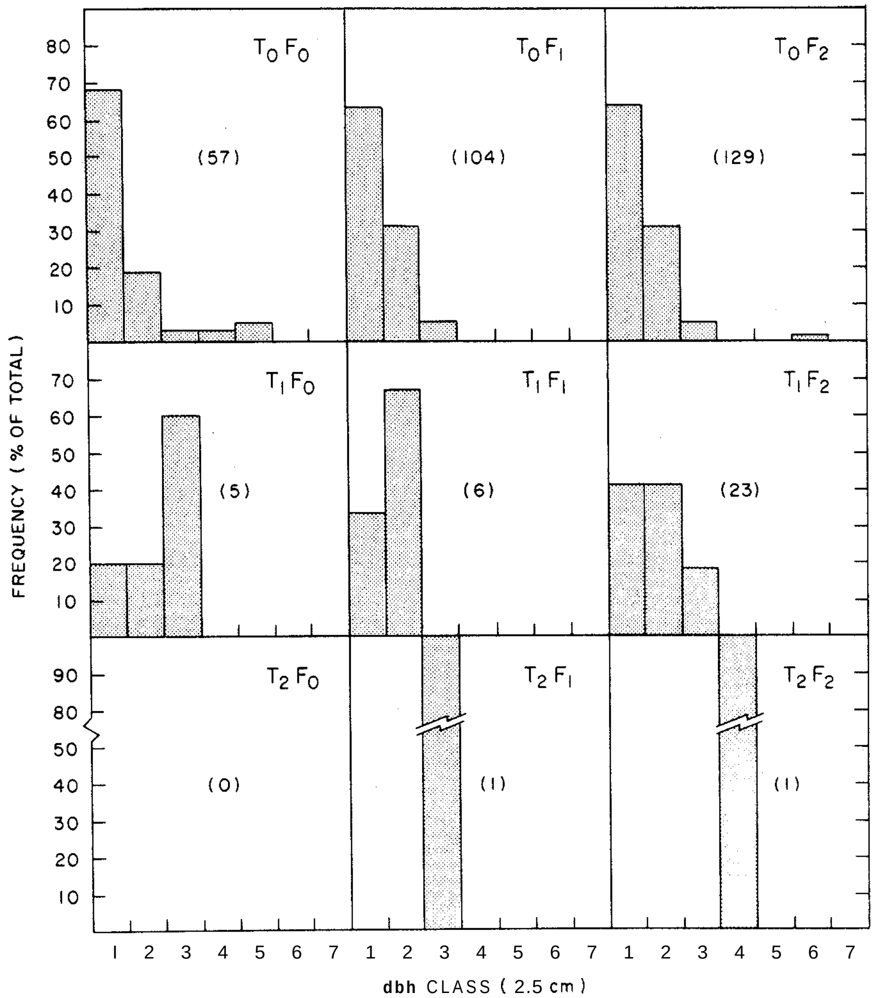


Figure 10. Mortality of trees by treatment and 2.5-cm dbh class. Class 1 is 2.5 – 5.0 cm. Numbers in parentheses refer to numbers dead in the four plots.

age response for years 8-10 in the RFNP (Anon. 1982). **As** pointed out by Miller (1981) one should be careful in evaluating response periods solely on the basis of volume increments. Fertilization will accelerate stand development and, if the stand is at a stage at which volume CAI increases with age at the time of fertilization, long-term responses may be more apparent than real. Miller suggests considering responses of different growth parameters which have maximum CAIs over different age ranges. In our case the CAI for diameter in control plots would have reached its maximum at the time of fertilization yet diameter increments are still considerably above control for all fertilizer regimes for years 9-12. Also, the **CAI** for volume for control plots appears to have reached a plateau in the 0-12 year study period. Growth responses for years 9-12 are therefore considered real rather than apparent.

Changes in stand structure with thinning were minor and had no significant influence on stand growth. However, as shown by the individual tree analysis, trees of different diameter classes have responded differently to thinning so potentially this treatment could have a great influence on growth responses as a result of changes in stand structure. This point was emphasized by 'Oliver and Murray (1983). In their study, trees in the larger diameter classes grew more volume

Table 8. Standardized volume increments (m^3/ha/yr) for selected diameter classes by treatments. These increments represent those that would have been obtained from each dbh class if all trees in the plot had been of that size and if growth were unaffected by stand structure. The plot basal area in each case is assumed constant within a given treatment

Year of treatment	Treatment	Dbh class (cm)				
		5-7.5	7.5-10	10-12.5	12.5-15	15-17.5
1971	T_0F_0	7.6	14.1	17.0	18.2	19.1
	T_1F_0	9.4	11.5	11.5	12.4	12.5
	T_2F_0	11.1	10.0	9.0	8.6	7.3
	T_0F_1	9.0	16.1	18.7	20.2	22.1
	T_1F_1	13.8	14.7	17.4	16.6	17.0
	T_2F_1	17.7	15.3	15.1	14.0	12.7
	T_0F_2	13.5	20.9	24.8	26.8	23.9
	T_1F_2	16.9	21.2	21.3	14.5	16.6
	T_2F_2	24.4	19.7	16.2	15.1	13.5
1972	T_0F_0	7.3	13.4	16.0	17.3	18.6
	T_1F_0	13.4	13.9	14.9	14.2	13.0
	T_2F_0	14.0	10.7	11.2	11.7	10.7
	T_0F_1	13.7	17.8	26.9	24.8	27.6
	T_1F_1	15.0	18.2	19.6	19.4	19.7
	T_2F_1	20.3	16.9	16.6	16.6	13.1
	T_0F_2	13.3	22.0	24.7	27.8	31.5
	T_1F_2	21.1	22.5	29.6	30.1	28.9
	T_2F_2	27.3	21.4	19.5	17.2	17.0

per unit basal area than smaller trees following thinning. Thinning to a given basal area would therefore produce the best volume response if larger trees were left. This would not be the case in our study where small trees produced the best relative response.

It is generally believed that stand density and thinning have little or no influence on height growth. However, initial spacing in a Douglas-fir plantation on a low site had a great effect on tree height **43** years after planting (Curtis and Reukema 1970). Similarly, a precommercial thinning of a 27-year-old Douglas-fir stand on a low site reduced height growth for the first 10 years, but growth exceeded that of control over a 25 year period (Harrington and Reukema 1983). In our study height growth was decreased the first two years after thinning but was increased 25% by T_1 and 38% by T_2 in unfertilized plots for the 12-year period. Thinning had little or no effect when combined with nitrogen fertilization suggesting that the response to thinning alone was mediated by a reduction in tree competition for nitrogen.

Summary

(1) Thinning increased dbh, height and total volume of individual trees over the 12-year period. This increase in increments over control is still evident for the period 9-12 years after treatment.

(2) Thinning has decreased total volume per hectare due to removal of growing stock. After 12 years, heavy thinning alone still resulted in a deficit of about 36% compared with control plot volumes.

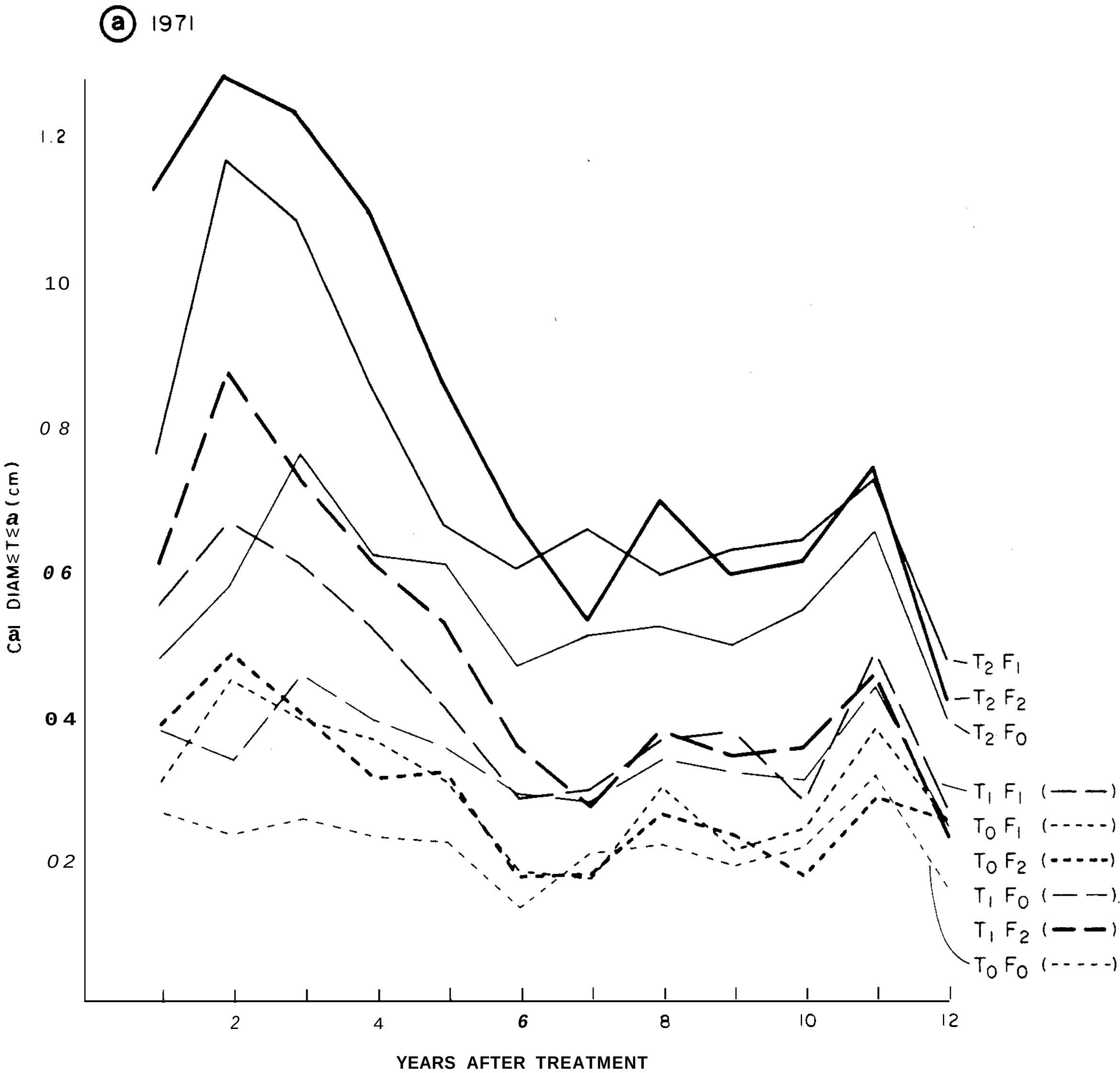


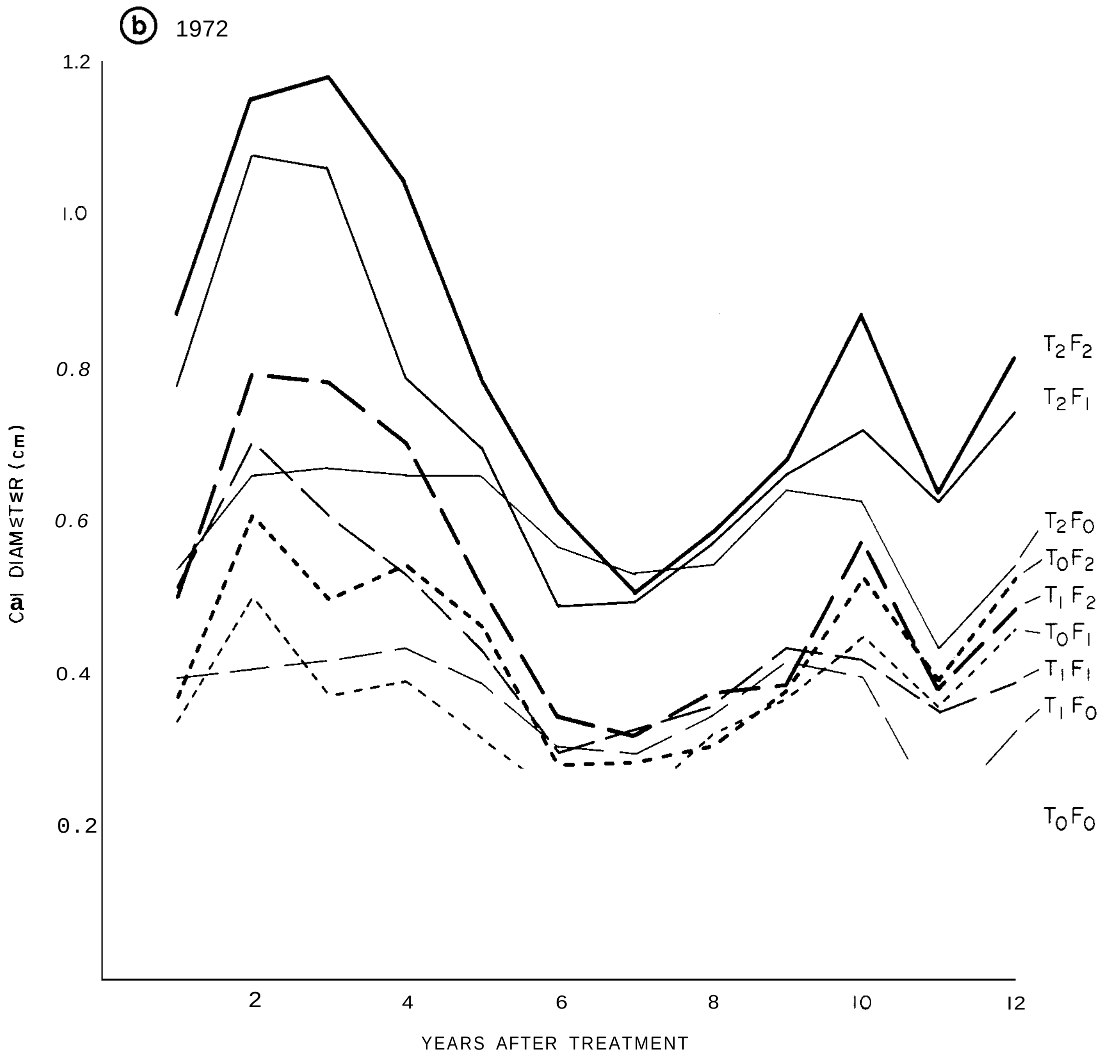
Figure 11. **CAI** for diameter for all volume sample trees **by** treatment and time.
(a) 1971 plots – non-refertilized
(b) 1972 plots – refertilized.

(3) The shape of the trees in thinned plots is more tapered than that of unthinned trees although the magnitudes of the differences were very small.

(4) Thinning increased the growth of trees of small dbh more than that of trees of large dbh.

(5) Fertilization increased dbh, height and total volume increments both for mean trees and on a land area basis over the 12-year period. After 12 years these effects are still evident in the respective increments compared with those of control.

(6) In combination with intermediate (F_1) or heavy (F_2) fertilization, even heavy thinning (T_2) has resulted in increased merchantable volume on **a** land area basis.



(7) Refertilization of half the plots after nine years has resulted in substantial increases in diameter, height and total volume increments.

(8) Tree mortality is decreased greatly by thinning but increased to some extent by fertilization. Trees of small dbh are more likely to die than larger trees.

Acknowledgements

It is a pleasure to acknowledge the technical assistance of Mr. C.R. Layton in making the measurements analyzed in this report.

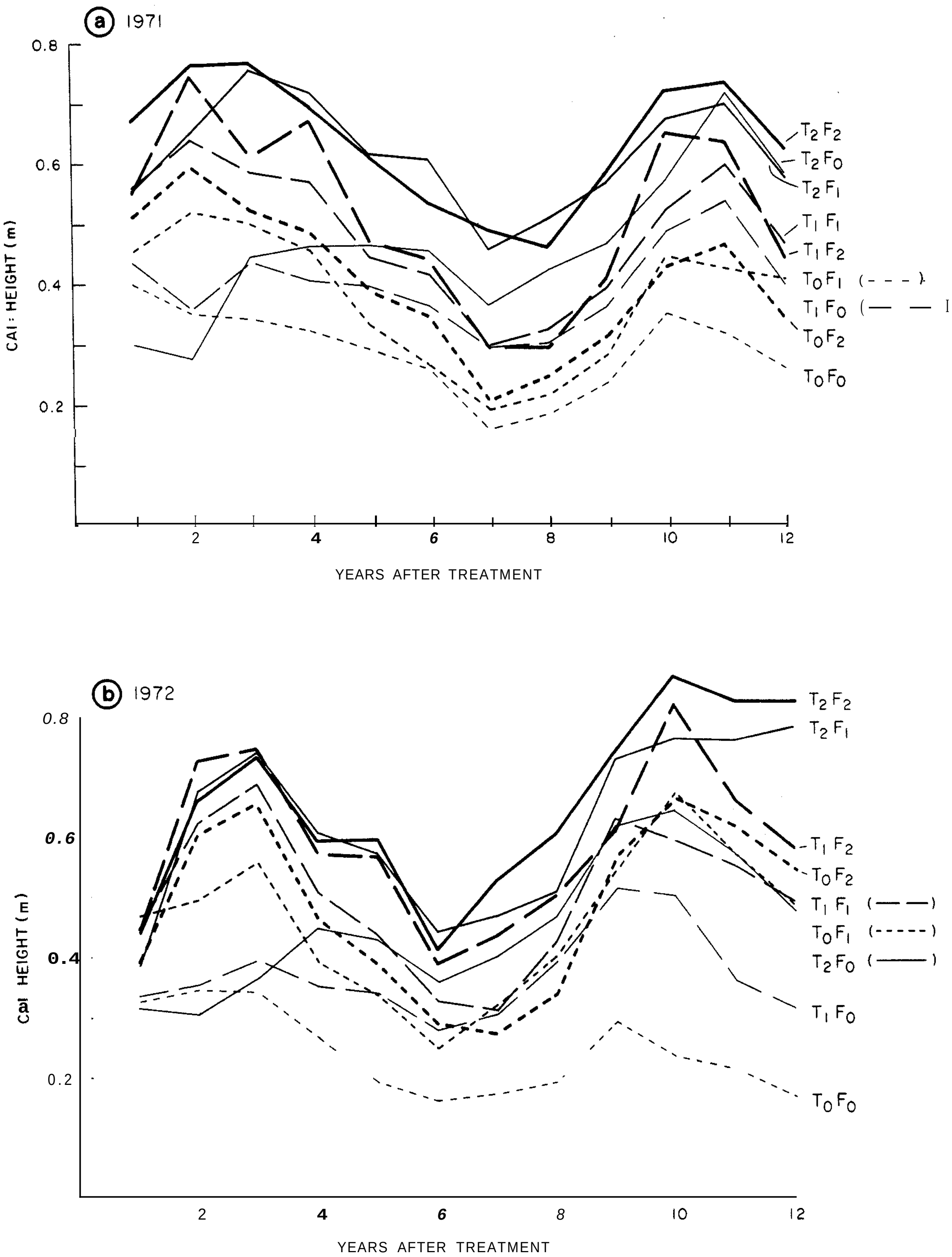


Figure 12. **CAI** for height for all volume sample trees by treatment and time.
(a) 1971 plots – non-refertilized
(b) 1972 plots – refertilized.

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Appendix

Table A1. Form quotients at five stem heights for the three levels of thinning (each form quotient is the diameter at that height divided by dbh converted to a percentage)

	% Total Height Above Breast Height				
Thinning level	10	30	50	70	90
T_0	92.7	80.2	61.6	37.1	12.4
T_1	93.0	80.9	61.4	37.0	12.4
T_2	92.3	79.9	59.9	36.0	12.0
Thinning*	< 0.05	> *0.05*	< *0.05*	< 0.05	< 0.05
Fertilization*	> 0.1	> 0.5	> 0.5	> 0.1	> 0.1
Refertilization" +	> 0.1	> 0.05	> 0.1	> 0.1	> 0.1

* Probabilities obtained from nested analysis of variance which test for differences in form quotients resulting from treatments.

+ The **1972** plots were refertilized 9 years after treatment while the 1971 plots were not refertilized

Table A2. Volume equation coefficients by treatment. The equation used was log (v) = a, + a_2 log (D) + a_3 log (H), where log is the common logarithm

Year of treatment	Treatment	Number of trees	Regression Coefficients				
			a_1	a_2	a_3	R^2	SEE[1]
	T_0F_0	28	−4.3468	1.8915	1.0377	0.9966	0.0433
	T_0F_1	18	−3.9750	1.9589	0.6730	0.9958	0.0249
	T_0F_2	15	−4.1691	2.1118	0.6901	0.9975	0.0283
	T_1F_0	40	−4.3561	.7531	1.1946	0.9974	0.0239
1971	T_1F_1	31	−4.3092	.8320	1.0692	0.9973	0.0233
	T_1F_2	21	−4.2476	.9093	0.9430	0.9984	0.0175
	T_2F_0	12	−3.8517	1.9227	0.6068	0.9942	0.0165
	T_2F_1	19	−3.6423	2.0960	0.2785	0.9940	0.0211
	T_2F_2	19	−4.4207	1.8010	1.1973	0.9924	0.0183
	T_0F_0	27	−4.2521	2.0139	0.8650	0.9972	0.0374
	T_0F_1	21	−4.0470	2.0023	0.7020	0.9965	0.0264
	T_0F_2	22	−4.0221	2.0636	0.6102	0.9963	0.0242
	T_1F_0	29	−4.3334	1.7475	1.1928	0.9969	0.0272
1972	T_1F_1	26	−4.3039	1.8987	1.0013	0.9948	0.0290
	T_1F_2	24	−4.2510	2.9794	0.7898	0.9959	0.0263
	T_2F_0	21	−4.0524	1.9789	0.7362	0.9909	0.0249
	T_2F_1	16	−4.0036	1.8752	0.8007	0.9832	0.0328
	T_2F_2	19	−3.8942.	2.2104	0.3646	0.9871	0.0291

[1] Both R^2 and SEE relate to the logarithmic measurements rather than the untransformed measurements

Table A3. Frequency distribution of trees/ha for several dbh classes across treatments.

	T_0			T_1			T_2		
Diam. Class	F_0	F_1	F_2	F_0	F_1	F_2	F_0	F_1	F_2
(a) 1971 trees									
2.5 – 5.0	345.66	37.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0 – 7.5	753.04	320.97	259.24	98.76	49.38	37.03	0.00	0.00	0.00
7.5 – 10.0	913.53	456.77	567.87	271.59	111.11	111.11	0.00	0.00	0.00
10.0 – 12.5	851.80	580.21	555.52	469.11	308.63	283.93	49.38	37.03	0.00
12.5 – 15.0	592.56	617.25	666.63	456.71	345.66	370.35	246.90	86.42	37.03
15.0 – 17.5	395.04	481.46	456.77	320.97	370.35	444.42	271.59	209.87	185.18
17.5 – 20.0	148.14	222.21	345.66	135.79	382.70	370.35	209.87	222.21	209.87
20.0 – 22.5	61.73	61.73	61.73	86.42	74.07	234.56	61.73	271.59	246.90
22.5 – 25.0	12.35	37.03	24.69	24.69	61.73	12.35	24.69	49.38	135.79
25.0 – 27.5	12.35	24.69	0.00	0.00	24.69	12.35	12.35	61.73	49.38
27.5 – 30.0	0.00	24.69	0.00	0.00	0.00	12.35	12.35	0.00	37.03
30.0 – 32.5	0.00	0.00	0.00	12.35	0.00	0.00	0.00	0.00	0.00
32.5 – 35.0	12.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35.0 – 37.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	4098.54	2864.04	2938.11	1876.44	1728.30	1888.79	888.84	938.22	901.18
(b) 1972 trees									
2.5 – 5.0	259.24	0.00	12.35	0.00	0.00	0.00	0.00	0.00	0.00
5.0 – 7.5	641.94	209.87	61.73	14.07	49.38	12.35	0.00	0.00	0.00
7.5 – 10.0	716.01	481.46	271.59	234.56	111.11	123.45	0.00	0.00	0.00
10.0 – 12.5	975.25	567.87	407.39	345.66	259.24	308.63	24.69	24.69	12.35
12.5 – 15.0	777.73	419.73	506.15	358.01	345.66	234.56	209.87	37.03	61.73
15.0 – 17.5	395.04	419.73	444.42	506.15	382.70	395.04	209.87	259.24	74.07
17.5 – 20.0	135.79	333.32	382.70	358.01	333.32	345.66	283.93	185.18	148.14
20.0 – 22.5	12.35	123.45	160.49	49.38	246.90	296.28	111.11	185.18	222.21
22.5 – 25.0	12.35	74.07	61.73	37.03	74.07	74.07	49.38	111.11	222.21
25.0 – 27.5	0.00	49.38	37.03	0.00	0.00	49.38	12.35	49.38	86.42
27.5 – 30.0	0.00	0.00	37.03	0.00	0.00	24.69	0.00	12.35	0.00
30.0 – 32.5	0.00	12.35	0.00	0.00	0.00	12.35	0.00	12.35	24.69
32.5 – 35.0	0.00	0.00	0.00	0.00	12.35	0.00	0.00	0.00	0.00
35.0 – 37.5	0.00	12.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	3925.71	2703.55	2382.59	1962.86	1814.72	1876.44	901.18	876.49	851 80

Table A4. Analysis of variance results (F values) for effects of establishment year, thinning and fertilization on 0-3, 3-6, 6-9 and 9-12-year volume increments of the 200 largest trees per hectare

	Period (years after treatment)			
Treatment	0-3	3-6	6-9	9-12
Year (Y)	1.08	2.11	2.54	34.7***
Thinning (T)	105.7***	138.7***	135.8***	129.9***
Fertilization (F)	330.7**	290.5***	222.2***	214.5***
Y × T	1.03	2.02	1.40	4.73**
Y × F	1.38	1.37	4.38*	8.45***
T × F	7.03***	4.27**	5.94***	2.95*
Y × T × F	4.19**	5.61***	6.46***	6.94***

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

Table A5. Analysis of variance results (F values) for effects of establishment year, thinning and fertilization on 0-3, 3-6, 6-9 and 9-12-year volume increments of the 600 largest trees per hectare

	Period (years after treatment)			
Treatment	0-3	3-6	6-9	9-12
Year (Y)	0.05	12.99***	2.24	55.13***
Thinning (T)	356.8***	481.1***	527.8***	511.0***
Fertilization (F)	999.2***	934.9***	658.9***	603.2***
Y × T	3.40*	3.03*	2.92	5.97**
Y × F	2.88	0.80	2.25	12.10***
T × F	13.28***	8.15***	8.80***	4.84***
Y × T × F	7.66***	9.55***	10.20***	11.17***

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

Table A6. Tree mortality by treatment for the combined 1971 and 1972 plots over the 12-year period

	F_0		F_1		F_2	
	%	No.	%	No.	%	No.
T_0	7.3	57	17.7	104	23.1	136
T_1	1.6	5	2.0	6	6.9	23
T_2	0.0	0	0.7	1	0.1	1