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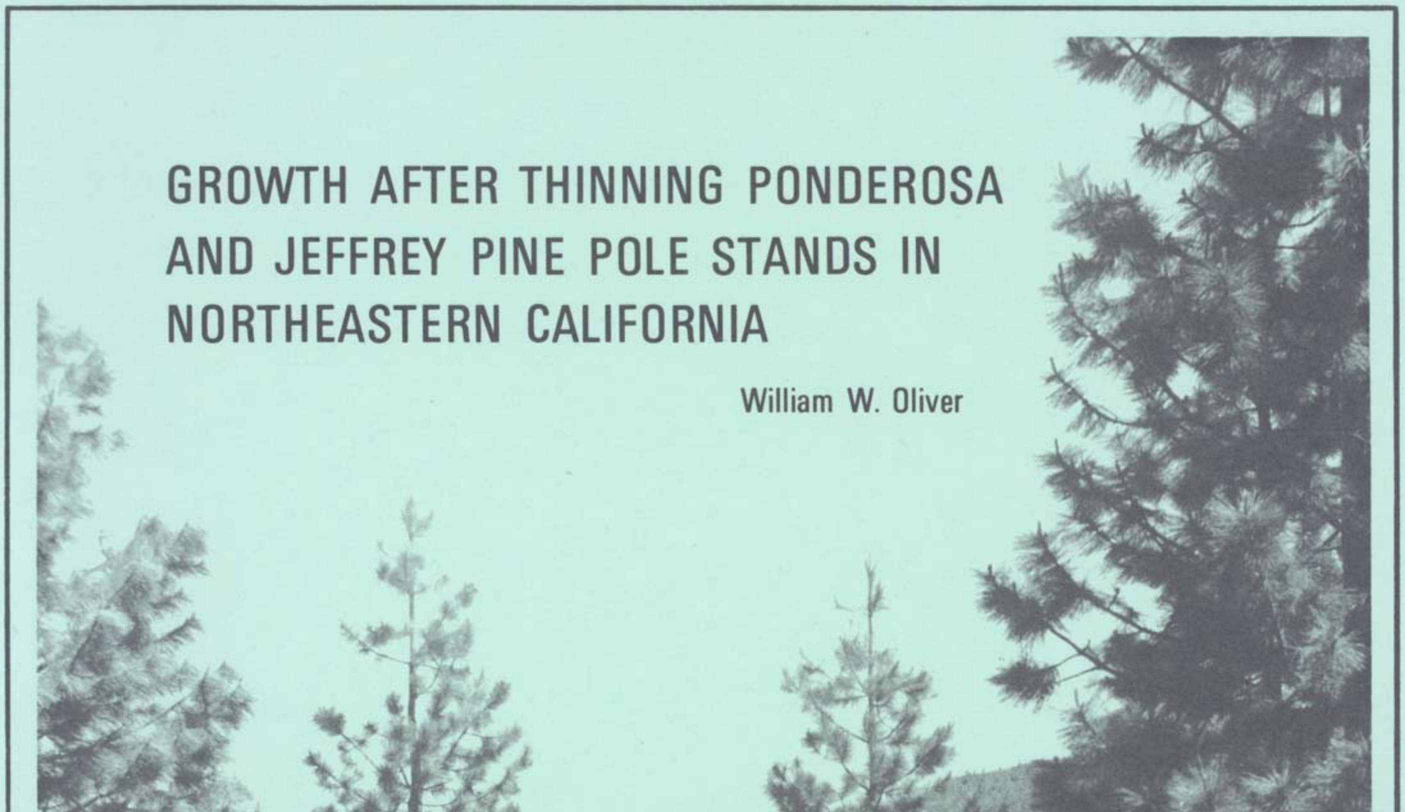
GROWTH AFTER THINNING PONDEROSA AND JEFFREY PINE POLE STANDS IN NORTHEASTERN CALIFORNIA

William W. Oliver



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Thinning ponderosa and Jeffrey pine pole stands (6 to 8 inches d.b.h.) on Meyer Site Classes IV and V land (site index 65 to 80) stimulates growth in diameter and height. This was concluded from data on 12 thinned plots scattered over northeastern California, in natural stands and in a plantation. Basal areas immediately after thinning ranged from 13 to 149 square feet per acre. Stands had many dissimilarities before thinning. Nevertheless, results allow the conclusion that thinning to about 80 square feet of basal area per acre will bring such stands to merchantable size as rapidly as possible with negligible loss of cubic-foot volume production.

Oxford.: 174.7 *Pinus ponderosa* (794): 562.22 + 174.7 *Pinus jeffreyi* (794): 562.22.
Retrieval Terms: Pinus ponderosa; Pinus jeffreyi; thinning response; diameter growth; basal area; increment; stocking level; Lassen National Forest; Modoc National Forest.

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I am indebted to the California Region, U.S. Forest Service—especially timber management personnel of the Modoc and Lassen National Forests—for installing and maintaining the study plots upon which this report is based.

Controlling stand density by thinning is a vital part of the management of young stands. Thinning enables the forest manager to tailor the stand to fit his wood market and to reach that market sooner. East of the Sierra Nevada and Cascade Range in California, dense young stands of ponderosa pine *(Pinus ponderosa* Laws.*)* and Jeffrey pine *(Pinus jeffreyi* Grey. & Ralf.*)* also need thinning to shield them from insect attack. More than 7,000 acres of this eastside forest type are thinned each year, but the optimum stocking level for timber production remains in question.

The Modoc and Lassen National Forests, faced with a large thinning program in pole-size ponderosa and Jeffrey pine, had little local data on growth following thinning. To obtain this information, about 20 thinning plots were established, either singly or in groups, over the past 25 years. Some of these plots served also to demonstrate National Forest thinning practices to the public.

This paper analyzes results from 12 plots with nearly complete records from which comparable data could be assembled. Dissimilarities still exist, but taken together these plots provide an estimate of growth of pole-size ponderosa and Jeffrey pine stands in northeastern California thinned to different stand densities. In addition, the data suggest the optimum basal area stocking for timber production.

STAND CHARACTERISTICS

Eleven of the 12 thinning plots are in Modoc County on the Modoc National Forest; the other is in west-central Lassen County on the Lassen National Forest. Six plots are in a ponderosa and Jeffrey pine plantation on the west slope of the Warner Mountains near Sugar Hill Fire Lookout. The other six plots are in natural stands containing ponderosa pine with a few Jeffrey pine and ponderosa X Jeffrey pine hybrids.

At the time of thinning average stand age differed greatly between the plots in the Sugar Hill Plantation and the natural stands. The Sugar Hill Plantation was about 28 years old and the natural stands ranged from 50 to 70 years old *(table 1).*

Distribution of diameters also varied. As would be expected, the range of diameters in the Sugar Hill Plantation before thinning was narrow and the distribution slightly skewed toward larger diameters, whereas the range in the natural stands was wide and the distribution skewed toward smaller diameters. This difference was reduced but not eliminated by thinning.

Crowns of the leave trees in the natural stands were restricted by high initial stand densities–more so than the crowns of leave trees in the Sugar Hill Plantation. Growth response probably was delayed until the root systems and crowns expanded to reach their food-making potential as determined by the increased growing space following thinning. Fortunately, growth in all plots in the natural stands was measured at least twice in the years following thinning. Therefore, the first measurement data for plots in natural stands were not used in the analyses. The succeeding period should be more closely comparable to the full period after thinning plots in the Sugar Hill Plantation.

All plots but one contained an understory of basin sagebrush *(Artemisia tridentata* Nutt.*)* and tobacco brush *(Ceanothus velutinus* Dougl. ex Hook.*)*. The remaining plot, Jelly Camp, lacked brush but did contain a dense understory of mule ears *(Wyethia mollis* Gray*)*. In general, the amount of brush in the understory was light and inversely proportional to the overstory density.

Other stand characteristics differed between plots *(table 1).* Average stand diameters ranged from 5.5 inches to 9.3 inches breast height immediately after thinning, and site indices varied from 65 to 80 feet at 100 years (Meyer 1938).

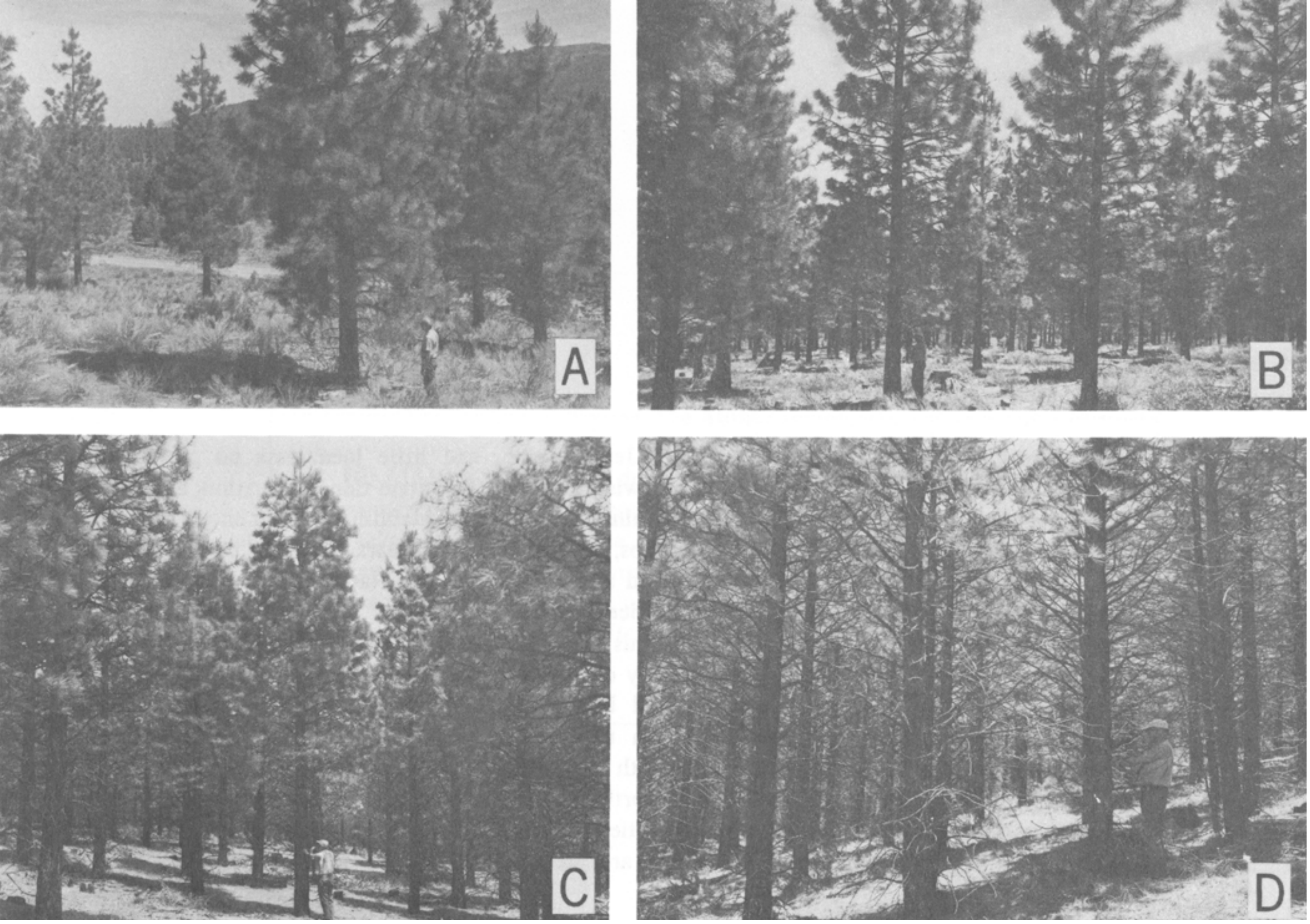

Figure 1–A, Sugar Hill Plantation Plot 3D was thinned in 1959 to 12.9 square feet of basal area per acre; 13 years later it contained 36.4 square feet. **B**, Sugar Hill Plantation Plot 2D was thinned in 1959 to 24.4 square feet of basal area per acre; 13 years later it contained 54.2 square feet. **C**, Sugar Hill Plantation Plot 200 was thinned in 1961 to 60.8 square feet of basal area per acre; 11 years later it contained 97.8 square feet. **D**, Sugar Hill Plantation Control Plot contained 74.8 square feet of basal area per acre; 12 years later it contained 146.7 square feet.

Table 1–*Plot and stand characteristics at beginning of growth period after thinning of ponderosa and Jeffrey pine poles in northeastern California*

Plot	Plot description				Stand description on acre basis					
	Year established	Growth period analyzed	Plot size	Site index	Stand age	Number of trees	D.b.h.[1]	Height	Basal area	Total volume
		Years	*Acres*		*Years*		*Inches*	*Feet*	*Sq. ft.*	*Cu. ft.*
Sugar Hill 3D	1959	11	1.36	75	27	43	7.4	23	12.9	124
Sugar Hill 2D	1959	11	2.00	75	27	80	7.5	22	24.4	235
Sugar Hill 100	1960	10	1.00	70	28	100	6.7	21	24.4	204
Washington Mt.	1959	6	.50	80	50	108	7.7	25	33.3	324
Adin Pass	1958	5	.38	70	62	117	7.2	29	33.5	360
Sugar Hill 200	1961	9	1.00	65	29	200	7.5	22	60.8	546
Jelly Camp	1963	5	1.16	65	65	190	7.8	46	62.4	885
Sugar Hill Control	1960	11	1.00	75	28	456	5.5	16	74.8	551
Little Lavas No. 3	1945	16	.26	65	68	221	8.2	34	81.1	1,244
Sugar Hill 300	1960	10	1.00	75	28	300	7.2	24	85.5	784
Hog Lake No. 1	1945	16	.32	65	66	260	8.3	35	98.6	1,322
Little Lavas No. 2	1945	16	.12	65	69	312	9.3	35	148.6	3,034

[1]Quadratic mean.

METHODS

The 12 plots selected for analysis had been thinned to a wide range of basal areas. They ranged from 12.9 to 85.5 square feet per acre in the Sugar Hill Plantation *(figs. 1A, B, C, D),* and from 33.3 to 148.6 square feet per acre in the natural stands.

Plot size and installation methods varied widely as might be expected of plots established over so long a time span. Of the six plots in natural stands, five had no isolation strips and three had a scattered old-growth overstory influencing part a the plot. Fortunately, because all trees were tagged and the original plots were at least one acre, smaller, homogeneous areas could be carved out for analysis of data.

All plots were thinned by the usual standard; that is, the most vigorous, well-formed dominants and codominants were selected as leave trees, as far as this was compatible with reasonably uniform spacing. Plots were thinned outside the growing season except for Hog Lake No. 1 and Little Lavas No. 3, which were thinned late in the growing season.

Slash disposal varied. All slash was removed from the Sugar Hill Plantation plots 100, 200, 300, and half of 2D, and at Washington Mountain and Adin Pass. At Jelly Camp, Little Lavas Nos. 2 and 3, Hog Lake No. 1, and Sugar Hill Plantation Plots 3D and half of 2D, the slash was lopped and scattered.

At each measurement, diameters of all trees were recorded to the nearest 0.1 inch. Every fifth tree was measured to the nearest 1 foot in height. Total cubic-foot volumes were found by determining the height/d.b.h. relationship for each plot at each measurement and interpolating volumes for the nearest 1 foot in height from *table 32* in Meyer's (1938) yield table for ponderosa pine. Volume estimates would have been better had upper stem diameter measurements been available. Nevertheless, the height/d.b.h. relationship accounts for most of the volume differences due to changes in stem form.

RESPONSE TO THINNING

Diameter and Basal Area Increment

Thinning had a marked effect on diameter growth, and the effect was noticeable throughout the range of post-thinning basal areas *(table 2).* Mean annual diameter growth was 0.46 inch for trees in the plot of lowest post-thinning basal area–12.9 square feet per acre. Diameter growth values ranged downward at a steadily decreasing rate to 0.08 inch per year for trees in the plot of highest basal area–148.6 square feet per acre.

The relationship of mean annual diameter growth to stand basal area appears to be curvilinear and can be expressed by the second degree polynomial:

$$\text{Mean annual d.b.h. growth} = 0.48344 - 0.00564\ \text{b.a.} + 0.00002(\text{b.a.})^2$$

in which b.a. = basal area in square feet per acre. Basal area is highly significant, explaining 91 percent of the variation in mean annual diameter growth between plots. Even though the relationship seems curvilinear, as experience tells us it must be, statistically speaking the data do not depart significantly from linearity.

Trees in the plot thinned to 12.9 square feet of basal area probably are free-growing. They are growing in diameter at about the same rate as open-grown ponderosa pine.[1] Trees in the plots thinned to the next higher density–24.4 square feet—were probably competing for moisture and nutrients. Barrett (1968) found intertree competition at 26 square feet of basal area in a ponderosa pine pole stand in eastern Washington. Since, in the present study, only one plot was thinned to this lowest basal area (12.9 square feet), I cannot test the statistical significance of the increase in diameter growth at this level over the four plots thinned to about 30 square feet. Nevertheless, the actual effect of post-thinning basal area on mean annual diameter growth probably is similar to that shown in *figure 2A.*

Stand basal area slowed the annual diameter growth of the 43 largest trees per acre, also. Rather surprisingly, the influence was as great as that felt by the stand as a whole. The 43 largest trees per acre grew slightly faster in diameter-0.04 inch per year–but the reduction in diameter growth with increasing density was nearly identical to that in the entire stand.

Basal area growth per acre varied widely with stand basal area *(table 2).* No clear relationship was

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[1]Unpublished data on file at the Pacific Southwest Forest and Range Experiment Station, Redding, Calif.

Table 2–*Growth after thinning ponderosa and Jeffrey pine pole stands in northeastern California)*

Plot	Basal area at start of growth period	Total plot Mean annual growth in:				43 largest trees Mean annual growth in:		
		D.b.h.	Basal area	Height	Volume	D.b.h.	Basal area	Height
	Sq. ft.	*Inches*	*Sq. ft.*	*Feet*	*Cu. ft.*	*Inches*	*Sq. ft.*	*Feet*
Sugar Hill 3D	12.9	0.5	2.1	1.4	34	0.5	2.1	1.4
Sugar Hill 2D	24.4	.3	2.7	1.1	39	.4	2.0	1.0
Sugar Hill 100	24.4	.3	3.1	.9	41	.4	1.6	1.1
Washington Mt.	33.3	.3	3.2	1.6	49	.4	1.7	1.6
Adin Pass	33.5	.3	3.2	1.1	46	.4	1.6	1.3
Sugar Hill 200	60.8	.2	4.1	.7	55	.3	1.3	1.0
Jelly Camp	62.4	.2	2.6	.8	49	.2	1.0	.7
Sugar Hill Control	74.8	.2	6.5	.9	79	.2	1.0	1.2
Little Lavas No. 3	81.1	.1	3.1	.5	76	.2	1.2	.8
Sugar Hill 300	85.5	.2	5.6	.8	76	.2	1.1	.9
Hog Lake No. 1	98.6	.1	3.2	.4	78	.2	1.1	.6
Little Lavas No. 2	148.6	.1	2.8	.3	76	.1	.6	.3

[1]All values on acre basis.

evident when all plots were analyzed together, probably owing to the disparity in diameter distributions between the Sugar Hill Plantation plots and the plots in natural stands. Basal area growth responded differently to stand basal area in the two sets of plots. At Sugar Hill basal area growth increased rapidly with increases in stand basal area throughout the range tested–12.9 to 85.5 square feet per acre. In the natural stands, basal area growth was about the same for all plots.

Further evidence can be found in the basal area growth response of the largest 43 trees per acre *(fig. 2B).* Here where the distribution of diameters is about equal, both sets of plots behaved the same. Mean annual basal area growth per acre decreased consistently with increases in stand basal area.

Height Increment

Height growth was sensitive to basal area. It ranged from 1.4 feet per year in the plot with lowest basal area–12.9 square feet per acre–to 0.3 feet per year in the plot with highest basal area–148.6 square feet per acre *(table 2).* The height growth at Washington Mountain of 1.6 feet per year seems excessive and may be the result of faulty records. The height growth/basal area relationship appears to be slightly curvilinear and can be expressed by the second degree polynomial:

Mean annual height growth = 1.50274 - 0.01272 b.a. + 0.00003(b.a.)^2

in which b.a. = basal area in square feet per acre.

Similar to the diameter growth/basal area relationship, a curvilinear trend exists but the departure from linearity is nonsignificant, statistically. The curve explains 70 percent of the variation between plots–slightly more than the linear relationship. *Figure 2C* illustrates the effect of stand basal area on mean annual height growth, again assuming that the trees in the plot with lowest basal area are free-growing.

Thinning stimulated the height growth of the 43 largest trees on each plot, also. Their response was nearly identical to that of the stands as a whole. They averaged about 0.1 foot per year more in height growth over the range of stand densities.

In this analysis height growth response to basal area density appears to be real. Sometimes apparent height growth response is in reality a function of differences in average stand diameter after thinning. When a homogeneous stand is thinned to different densities, average stand diameter tends to increase with increasing thinning intensity. This can confound height growth data because the trees of larger diameter in a stand often grow faster in height. I found, however, no significant relationship between average d.b.h. of the plots immediately after thinning and their mean annual height growth. In the nine plots in which this relationship could be studied, differences in average d.b.h. after thinning explained only 6 percent of the height growth variation between plots.

Height growth response to thinning has been highly variable as reported by others. It is well known

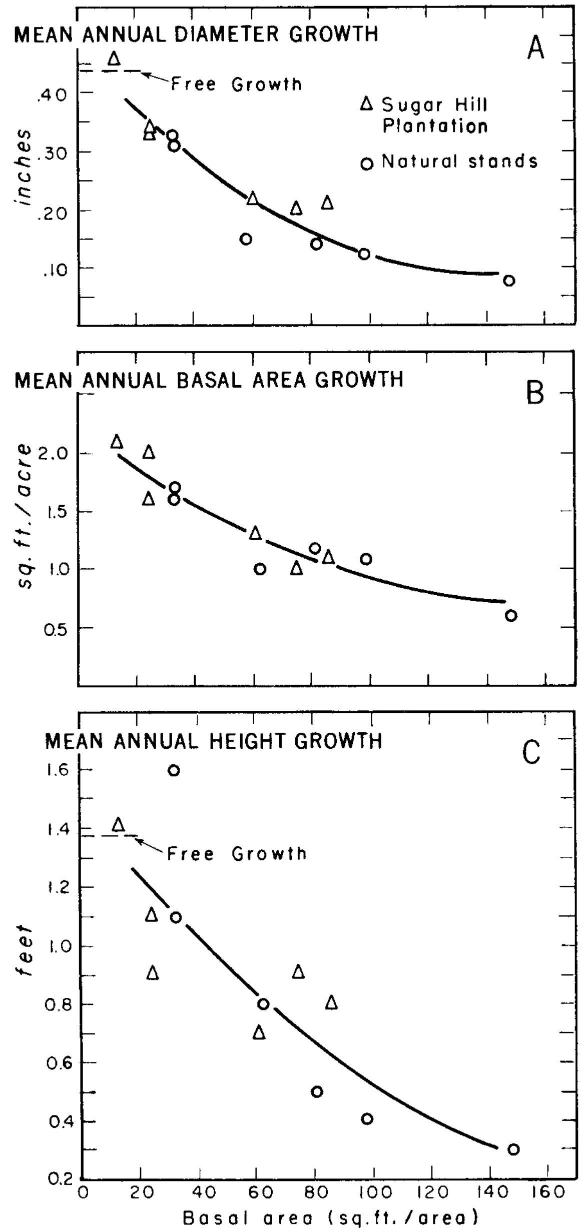

Figure 2—After ponderosa and Jeffrey pine pole stands in northeastern California were thinned, **A**, mean annual diameter growth was slower in plots with larger basal areas. **B**, mean annual basal area growth of the largest 43 trees per acre was slower in plots with larger basal areas. **C**, mean annual height growth was slower in plots with larger basal areas.

that height growth is less responsive to thinning than diameter growth. In fact, Barrett (1963, 1968) found no significant response from two thinning studies in pole-size ponderosa pine on comparable sites in the Pacific Northwest; neither did Schubert (1971), reporting on a thinning study in pole-size ponderosa pine on a slightly poorer site in northern Arizona. These three reports were based on the first 5 or 6 years following thinning of dense natural stands.

When height growth has been followed for longer periods, most investigators report a marked response (Stage 1958; Myers 1958; Boldt 1970). Three or 4 years often is needed for the released trees to build up their crowns sufficiently to produce the additional food required for increased height growth. This delay in height growth response is illustrated by the Washington Mountain and Adin Pass plots. Both were in heavily thinned dense natural stands. Height growth the second 5 years following thinning exceeded height growth the first 5 years by 87 percent and 59 percent, respectively.

Volume Increment

Over half the plots were thinned so heavily that volume production suffered. Volume growth was only 34 cubic feet per acre per year in the plot thinned to 12.9 square feet of basal area per acre. Volume growth levels rose rapidly with increases in basal area up to about 75 square feet per acre *(fig. 3)* All plots with basal areas of about 75 square feet and above produced nearly identical volume growth. It varied between 75 and 80 cubic feet per acre per year.

The relationship appears to be curvilinear and can be expressed by the second degree polynomial:

Mean annual cubic foot volume growth = 19.537 + 0.934 b.a. - 0.0036(b.a.)^2

in which b.a. = basal area in square feet per acre.

In this equation basal area explains 88 percent of the variation in cubic-foot volume growth between plots. Nevertheless, further tests show that the data do not depart significantly from linearity, probably because there are not enough plots at the higher stand densities.

No data on upper stem diameters were available. Thus volumes were based solely on d.b.h. and total height of the tree. Differences in stem form between thinning intensities could alter the relationship somewhat, but I believe the inflection of the volume over stand density curve would be about the same.

Because cubic-foot volume production held constant over a wide range of basal areas–75 to 150 square feet per acre–the forest owner can manage his

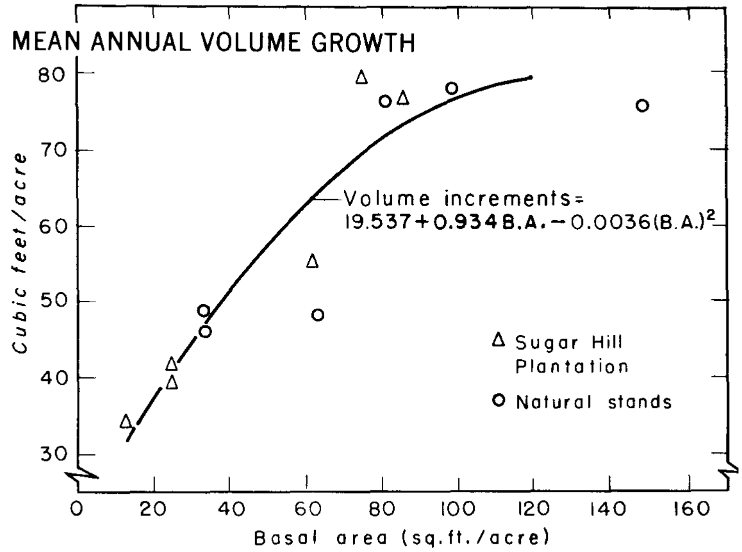

Figure 3—After ponderosa and Jeffrey pine pole stands in northeastern California were thinned, cubic-foot volume production was greater in plots of larger basal area, up to about 80 square feet per acre.

stands to fill a variety of wood markets with little or no loss of volume growth. In northeastern California where the market is for lumber, primarily, he may wish to bring ponderosa and Jeffrey pine pole stands to merchantable size as quickly as possible. *Figure 3* suggests that thinning to about 80 square feet of basal area per acre will meet this objective.

Table 3 shows the average response in diameter, height, and volume growth throughout the range of plot basal areas studied.

Comparing normal yields (Meyer 1938) with the stand and growth data from this study helps to put the results in perspective If an average site index of 70 feet at 100 years and equivalent stand diameters are assumed, and stand age is disregarded, approximate comparisons are as shown in *table 4.* These comparisons are rough because site quality and stand age varies widely between plots in this study. Nevertheless, with thinning to 80 square feet of basal area per acre (43 percent of normal), volume growth on these pole stands exceeds that shown for unmanaged stands by 18 cubic feet per year. This growth is achieved on 59 percent fewer stems.

Table 3–*Effect of stand basal area on diameter, height, and total volume growth following thinning ponderosa and Jeffrey pine poles in northeastern California*[1]

Basal area (Sq. ft./acre)	Growth in: D.b.h.	Height	Total volume
	Inches	*Feet*	*Cu. ft. /acre*
20	0.38	1.3	37
40	.29	1.0	51
60	.22	.8	62
80	.16	.7	71
100	.12	.5	76
120	.10	.4	79
140	.09	.1	79

[1]Average values from regression.

Table 4–*Average stand characteristics and volume growth of plots thinned to 80 square feet in present study compared with normal, unmanaged stands*[1]

Source	Number of trees	Average d.b.h.	Basal area	Volume growth
		Inches	*Sq. ft.*	*Cu. ft./yr.*
Present study	261	7.5	80	71
Unmanaged stands[2]	632	7.3	184	53

[1]All values on acre basis.
[2]See Meyer (1938).

Mortality

Only a few trees have died since thinning. An occasional tree of intermediate crown class died shortly after the natural stands were thinned, but they represent a negligible amount of volume or basal area loss. Mortality was surprisingly low considering that some plots were lightly thinned 26 years ago. No trees died in the plots in the Sugar Hill Plantation.

All plots but one were free of insect, disease, or animal damage. Substantial mortality is expected in the Sugar Hill Plantation Control Plot. Attacks by the mountain pine beetle *(Dendroctonus monticolae* Hopk.*)* have built up in recent years. No trees have succumbed so far, but elsewhere within the unthinned portion of the plantation, small groups of trees have died. These attacks on trees weakened by intertree competition are expected to increase unless the plantation is thinned.

SUMMARY AND CONCLUSIONS

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For control of stand density in ponderosa and Jeffrey pine pole stands by- thinning, information on optimum stocking level for timber production is needed. On 12 plots thinned to various densities, growth results over periods of from 5 to 16 years were analyzed. Plots included both natural stands and plantations in the Modoc and Lassen National Forests. At time of thinning, plots differed in stand age, distribution of diameters, and other characteristics.

Basal areas after thinning ranged from 12.9 square feet to 85.5 square feet in plantation plots and from 33.3 to 148.6 square feet in natural stand plots. At each measurement, records were taken of diameter of all trees and height of every fifth tree; total cubic-foot volumes were calculated for each plot from height/d.b.h. and Meyer's yield table.

The effect of thinning on diameter growth was noticeable throughout the range of basal areas (as measured after thinning). Mean annual diameter growth values ranged downward from 0.46 inch per year for 12.9 square feet basal area to 0.08 inch per year for 148.6 square feet basal area; the relation of diameter growth to stand basal area appears curvilinear, and basal area explains 91 percent of the variation between plots. Influence of stand basal area on the 43 largest trees was similar to that on the entire stand. The relation of basal area growth to stand basal area was unclear for all plots together (probably owing to differences in diameter distribution), but for the largest 43 trees per acre, mean annual values decreased consistently with increase in stand basal area. The inverse relation of height growth to stand basal area was almost linear; basal area explained 70 percent of the variation. Volume growth levels increased with increase in basal area but leveled out at 75 square feet per acre basal area. Tree mortality was slight, and plots were free of insect or disease damage.

In spite of the difficulties of comparing plantation and natural stands, the plots demonstrate the potential diameter and height growth increase from thinning Meyer Site Class IV and V ponderosa and Jeffrey pine stands 6 to 8 inches d.b.h. in northeastern California. Thinning to about 80 square feet of basal area per acre will bring these pole stands to merchantable size as quickly as possible without sacrificing much cubic-foot volume production. At this optimum stand density for timber production, mean annual growth was 0.16 inch in, diameter, 0.7 feet in height, and 71 cubic feet per acre.

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