THE EFFECTS OF PRUNING ON THE GROWTH AND DEVELOPMENT OF A DOUGLAS-FIR PLANTATION

by

JAMES LOUIS LUKERT

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1959

APPROVED:

Redacted for privacy

Associate Professor of Forest Management

In Charge of Major

Redacted for privacy

Head of Department of Forest Management

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Dean of Graduate School

Date thesis is presented May 13, 1959

Typed by Eloise Allison

TABLE OF CONTENTS

INDEX TO TABLES

INDEX TO FIGURES AND GRAPHS

THE EFFECTS OF PRUNING ON THE GROWTH AND DEVELOPMENT OF A DOUGLAS-FIR PLANTATION

INTRODUCTION

Knots are the greatest cause of defect in second-growth wood. Fleischer (14, p. 534) noted that the chief difference between veneer of old growth Douglas-fir and second-growth Douglas-fir was the presence of many knots. If this defect is eliminated, the quality of the products derived from second-growth wood is greatly increased. The means of eliminating this defect is through the use of the silvicultural technique termed pruning.

Pruning not only will increase the quality of the product but also aids in further management of the stand. Cook (9, p. 487) has observed the following management aids derived from pruning operations:

1. Pruning cuts bark peeling costs.
2. Pruning aids logging and administration efficiency.
3. Pruning reduces slash from thinnings and final cuts.
4. Pruning saves lopping branches off at the final cut.

Natural pruning does occur in closed stands of Douglas-fir but the time element prohibits the use of nature as a pruning agent. Paul (25, p. 6) has found that in Douglas-fir stands 100 and 150 years old dead branches protrude along the entire merchantable length of most of the trees. Kachin (19, p. 5), agreeing with Paul, states that no commercially important quantity of clear material develops before a stand is over 150 years old.

Since pruning is an expensive operation and the term of investment is long, it is essential that the trees be pruned to the greatest intensity that is economically feasible without sacrificing growth or endangering the tree's ability to compete.

Study Objectives

The objectives of this study were:

1. To determine whether the intensity of pruning on the area chosen for study significantly reduced the rate of growth of the pruned trees.
2. To determine whether the intensity of pruning on the study area decreased the ability of the trees to compete.
3. To determine whether the pruning operation had any effect on crown class movement and normality[1] relationships.
4. To determine the rate of production of clear wood.
5. To determine whether the rate of form class

---

[1]Based on the normal stand structure in McArdle and Meyer (23).

change was significantly increased by pruning.

6. To determine the effects of pruning on the production of defects in the wood.

Scope of the Study

The study was designed to determine whether pruning under the study area conditions had any detrimental or advantageous effects on stand or tree development.

The study was not designed to test the economics of the pruning operation or to determine the value of clear wood that has been produced.

Two permanent sample plots were established two years after the actual pruning operation in order to make possible the recording of any benefits that may be derived from the pruning treatment. This study involved the remeasurement of these two plots and the analysis of the collected data. The study also included the analysis of the growth and quality factors associated with the individual tree that are responsible for maximum clear wood production.

THE STUDY AREA[2]

The study area, located in the Hebo plantation was established in 1912 on the western slope of Hebo mountain, five miles east of Hebo, Oregon. In December of 1935, six 3-acre plots were established to study methods of pruning in second-growth Douglas-fir.

In April of 1938, two years after the actual pruning operation, two permanent sample plots were established to study the effects of pruning on the stand and were designated P.S.P.[3] no. 23 and P.S.P. no. 24. Each plot is one acre in size with a slope from 35 per cent to 40 per cent on a western aspect. Both plots were classified site IV. The soil is a dark clay loam, moss covered and rocky. P.S.P. no. 23 is located in an original pruned plot with the western boundary running parallel to the bed of an intermittent stream. The average elevation is 2,230 feet and the total number of trees on the plot in 1938 was 335. Ninety-seven trees were pruned. P.S.P. no. 24 is located in the original control plot up the hill and adjacent to P.S.P. no. 23.

---

[2]The history of the study area was compiled from unpublished letters and reports on file at the Willamette Research Center, Corvallis, Oregon.

[3]P.S.P. stands for permanent sample plot.

The average elevation is 2,300 feet and the total number of trees on the plot in 1938 was 352.

The first plot measurements were taken in 1938. Each tree was marked with a metal tag at or as near diameter brest height as possible. The crown position[4] and diameter measurements at the tags were recorded for each tree on both plots. Forty trees from each plot were measured for total height.

The plots were remeasured in 1944 and the results were summarized but not published.[5]

The 1958 remeasurements of these plots were taken by the author and are reported as a part of this thesis.

---

[4]Crown classification adopted by the Society of American Foresters (1944).

[5]Report on the 1938 Establishment and the 1944 Remeasurements of the Siuslaw P.S.P. no. 23 and P.S.P. no. 24 by George H. Barnes - unpublished report.

PROCEDURES

Stand Measurements

The stand measurements in 1958 consisted of the remeasurements of P.S.P. no. 23 and P.S.P. no. 24. These remeasurements were:

1. The crown position of 270 trees on P.S.P. no. 23 and 302 trees on P.S.P. no. 24.
2. The diameter at tag height of 270 trees on P.S.P. no. 23 and 302 trees on P.S.P. no. 24.
3. The total height of the 32 previously selected trees on P.S.P. no. 23 and 39 previously selected trees on P.S.P. no. 24.

Diameter Growth Measurements

A sample comprising nine control trees and nine pruned trees was used to study the effects of pruning on diameter growth. Each of the two permanent sample plots was subdivided into nine equal sectors and from each sector a dominant tree was randomly drawn and an increment core collected. The radial growth in inches was recorded for each year from 1930 to 1958.

Other Measurements

The effects of the pruning operation on the annual height growth, form class and clear wood production were studied from a series of measurements collected from felled trees. Since the trees within the permanent sample plots could not be felled, the sample trees were taken from a one-chain width strip adjacent to the plots. This strip was divided into ten equal segments for each plot and one tree from the codominant or dominant crown position was selected from each segment so as not to create excessive openings in the crown canopy. These twenty trees, ten pruned and ten unpruned, were felled and used in the following measurements.

Height growth was determined by measuring the internodal distances from the growing tip to the year 1930. The total height of the tree was also recorded. The internodal distances were measured to the nearest tenth of a foot.

Cross-sections were cut from the bole at diameter breast height and at 17.5 feet from each tree and sanded for more accurate measurements of form class[6] relationships. The annual growth from 1930 to 1958, measured from an average diameter, was recorded to the nearest one hundredth of an inch.

---

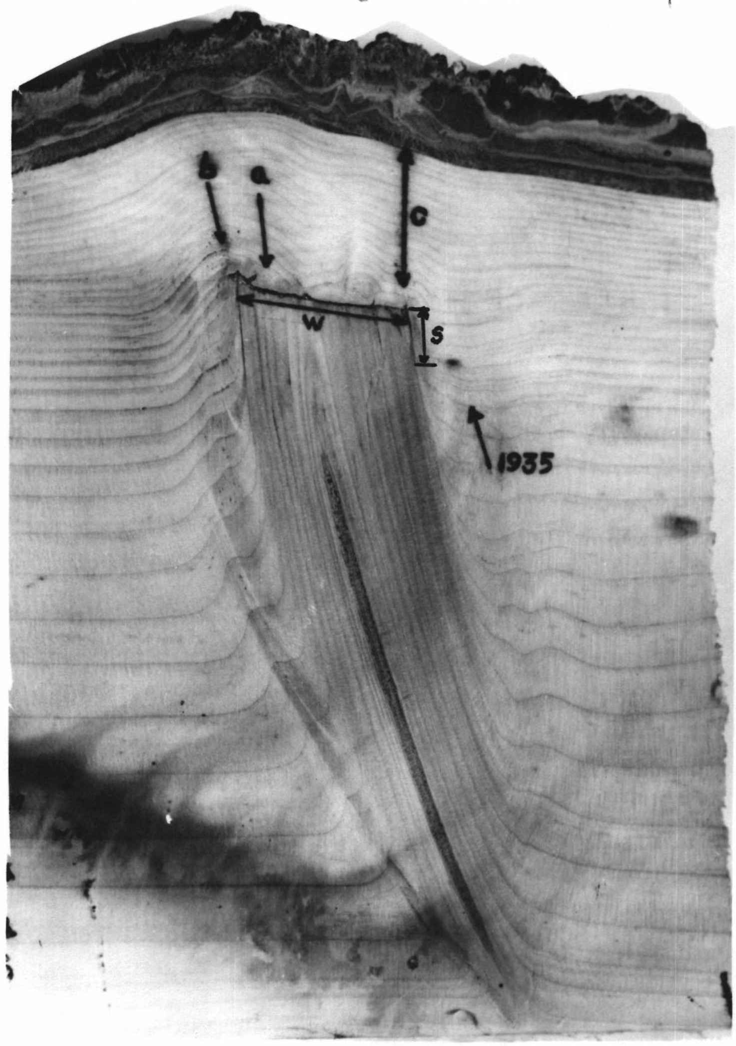
[6]Form class is defined as: $\frac{\text{diameter inside bark at 17.5 feet}}{\text{diameter outside bark at 4.5 feet}}$

Sections containing knot whorls were taken from the bole of each of the ten pruned trees at heights of three, six, nine, twelve, and fifteen feet. This term is referred to as the bole position. The knots were sawn from the whorls exposing the knot as a spike knot. From each knot the following measurements were recorded:

1. The bole position.
2. The major defects causing the additional healing period beyond the normal healing period necessary to grow over the knot stub.
    a. Pitch deposit (natural defect)
    b. Bark deposit (figure 2, a.) (natural defect)
    c. Poor cut (figure 2, b) (pruning operation defect)
3. The presence of stain.
4. The healing period in years if no defect had occurred. (figure 1, year 1935 to a)
5. The healing period in years with the defect added. (figure 1, year 1935 to b)
6. The inches of clear wood produced measured perpendicular to the growth rings at the narrowest point. (figure 1, c)
7. The width of the knot measured parallel to the cut surface. (figure 1, w)

8. The length of the stub measured from the year of pruning to the outer-most point of the knot perpendicular to the growth rings. (figure 1, s)

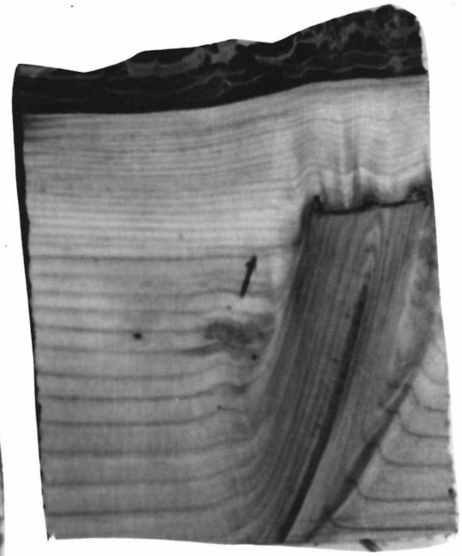
Figure 1. A knot Section Showing the Measurements Recorded from the Sample Knots



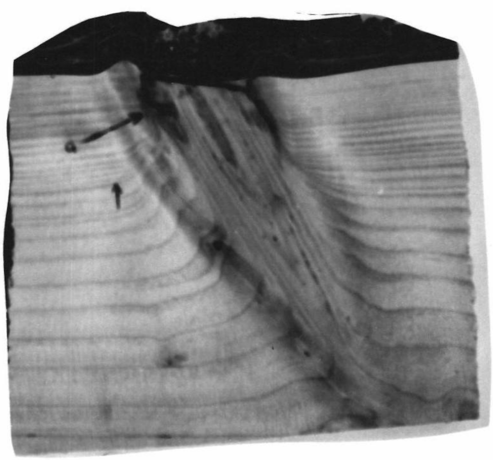
1. Pruning occurred at the year (1935).
2. The amount of clear wood produced is (c).
3. The width of the knot is (w).
4. The growth ring (a) is the first ring that was continuous irrespective of defects.
5. The growth ring (b) is the first ring that is continuous and without defect.
6. The length of stub left after pruning is (s).

Figure 2. Sample Knot Sections Showing the Pruning Defects of Bark Deposit and Poor Cuts. (The arrows indicate the year of pruning)

a



b



b

a. Defect of trapped bark

b. Defect of poor pruning cuts

a. Initial saw contact (in photograph)

ANALYSIS OF DATA AND RESULTS

Research in pruning has fostered several different terms that are used to express pruning intensity. The most common expression is the per cent of live crown removal. The pruning intensity of the Hebo study area based on the per cent of live crown removed is twenty-nine per cent.[7]

The pruning intensity employed in an operation can affect the results of the operation in several ways:

1. The growth of the individually pruned trees may be reduced.
2. The reduction of growth of the pruned trees could, if great enough, change the condition of the stand.
3. The amount and quality of the clear wood produced may be affected.

These three basic effects will be analyzed by using the following individual factors:

---

[7]The average height growth in 1938 was 43 feet. Since the mean annual height growth to 1938 was 1.5 feet, the average height in 1936 was 40 feet. At the 3 foot level some dead knots were encountered, thus the lower 4 feet of the tree was assumed to be supporting dead branches. Since the average pruned height was 15.5 feet and 4 feet of this consisted of dead branches, 11.5 feet of live crown was removed. The per cent of live crown removed is 11.5/40 which is equal to 29 per cent.

1. Diameter growth
2. Height growth
3. Form class
4. Clear wood production
5. Crown class movement
6. Normality relationships
7. Incidence of decay

The Effects of Pruning on Diameter Growth

The increment core measurements taken from the eighteen randomly drawn trees within P.S.P. no. 23 and P.S.P. no. 24 were used to study diameter growth. A linear regression between the annual diameter growth of the pruned trees and the annual diameter growth of the unpruned trees was computed for the period since pruning. The regression coefficient, which is the slope of the line in the linear regression equation $y = a + bx$ was found to be 1.025 which indicates that besides the differences in the populations at the beginning of the data period, designated by "a", no significant differences over the data period occurred due to the pruning operation. If a difference had occurred, the slope of the line would have been greater or less than 1.

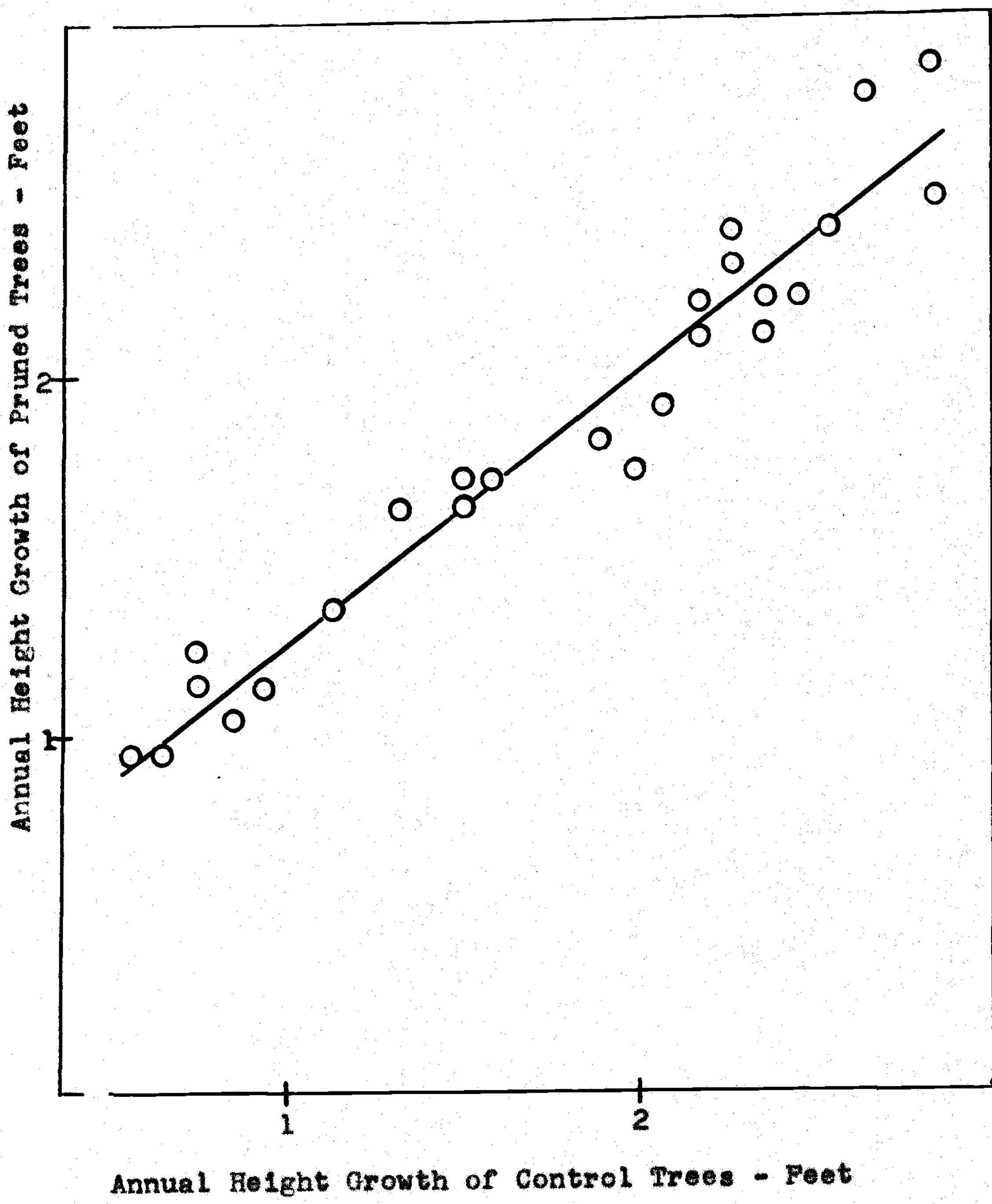
<u>The Effects of Pruning on Height Growth</u>

The reduction in height growth of the pruned trees could easily jeopardize the crown positions of these trees, and thus height growth becomes a critical factor in the position the pruned tree maintains in the stand.

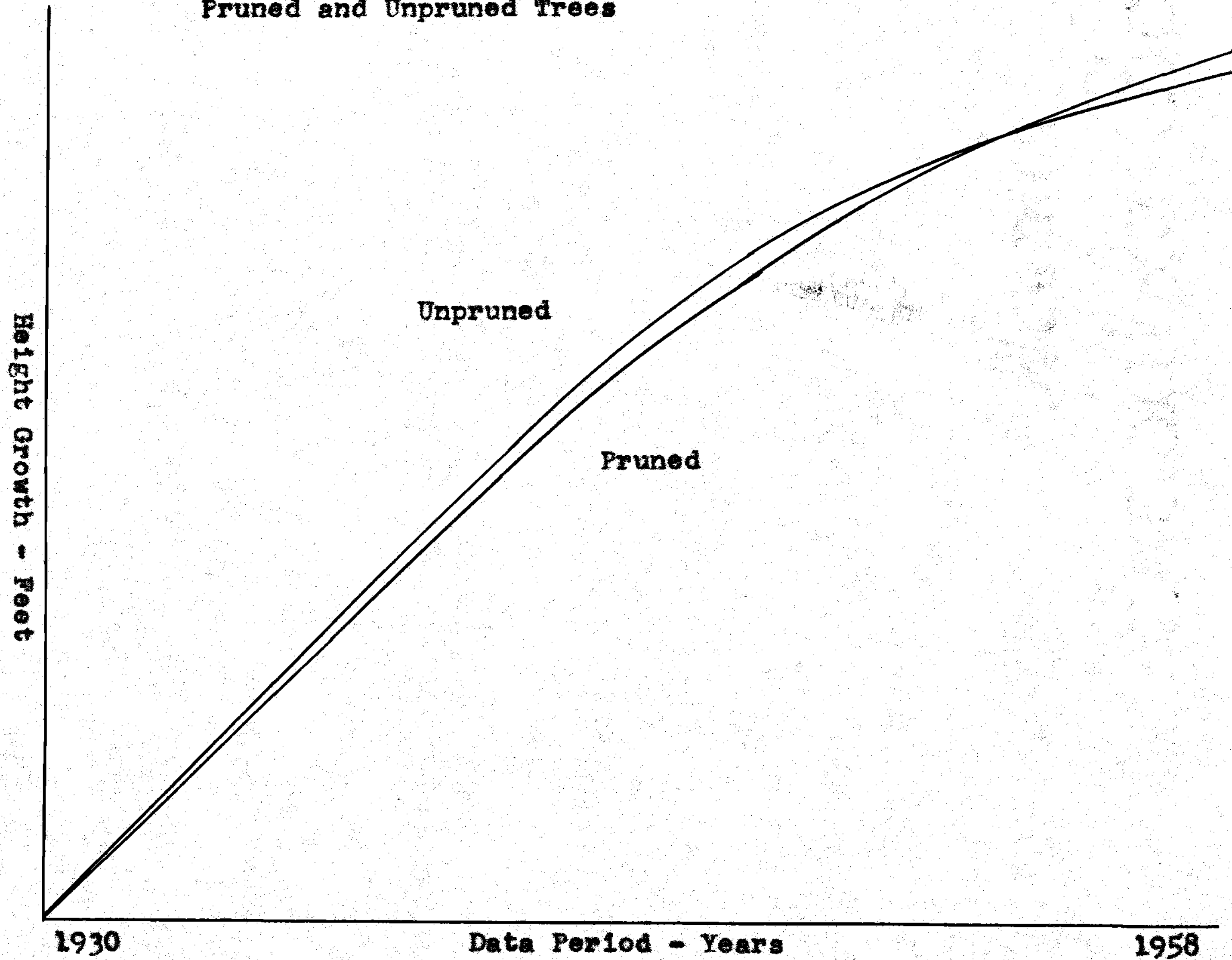
The height growth data collected from the twenty felled trees selectively picked along the outer edge of P.S.P. no. 23 and P.S.P. no. 24 were used for the analysis of height growth. The average height of the unpruned trees was 75.8 feet; for the pruned trees it was 80.4 feet. A linear regression between the annual height growth of the pruned and control trees was determined. Graph 1 represents the linear regression for height growth.

A "b" value of 0.737 was obtained which would indicate an appreciable difference between the two populations. The difference develops from a change occurring in the later stage of growth. The two populations are the same at first but change during a period from about 1946 to present. This assumption is substantiated by the accumulative height growth curves (graph 2), which shows the pruned and unpruned trees following essentially the same trend throughout the data period, except for the increase in height growth, since 1946, in the pruned trees.

Graph 1. A Linear Regression of Annual Height Growth of Pruned Versus Unpruned Trees



Graph 2. Accumulative Height Growth During the Data Period for the Pruned and Unpruned Trees



It can be concluded that no loss or gain in height growth occurred due to the pruning operation.

<u>The Effects of Pruning on the Form Class</u>

The reduction of log taper signifies an increase in form class and consequently an increase in the quality of the product. Several investigators have suggested that pruning increases the form class at a faster rate than the normal increase in unpruned trees. Cline and Fletcher (8, p. 10) and Smith (32, p. 262) suggest that improvement in form class is likely to be accelerated slightly by pruning. Young and Kramer (36, p. 477) have shown that in loblolly pine the distribution of growth on the bole after pruning tends to make the shape of the bole below the crown approach that of a cylinder. Marts (21, p. 206) reports that taper is reduced with pruning in longleaf pine.

Form class ratios were derived from the sections cut from the twenty felled trees taken from the edges of P.S.P. no. 23 and P.S.P. no. 24. The direct measurements included the average diameter inside bark at 17.5 feet for each tree and the average diameter inside bark at 4.5 feet for each tree.

To change the expression diameter inside bark at 4.5 feet to diameter outside bark at 4.5 feet the equations developed by Johnson (17, p. 1-3) were employed. The basic equations are:

(trees 10" and larger)

Diameter growth outside bark = wood growth x 1.182

(trees 9.9" and smaller)

Diameter growth outside bark = wood growth x 1.104

The form class ratio was then computed for each year from 1930 to present. Linear regressions were computed for the relationships of form class against years for the pruned and unpruned trees.

Table I. A Comparison of the Change in Form Class from 1930 to 1958 for Pruned and Unpruned Trees

Class	Regression Coefficient[1] ("b" values)
Form Class of Pruned sample	.01039
Form Class of Unpruned sample	.00947

[1]Regression coefficients computed for annual form class for the 1930 to 1958 period.

By analysis of covariance it was shown that the regression coefficient of the form classes of pruned trees was not significantly different from the regression coefficient of the form classes of the unpruned trees.

It is therefore concluded that for the period between 1930 and 1958 pruning did not improve the form class of the trees.

The Effects of Pruning on Clear Wood Production

Log quality is dependent upon the amount of knot free wood produced. Factors affecting the quality include the growth rate, length of pruning stubs, knot defects, and the bole position of the knots.

The growth rate of the pruned trees must be maintained at the maximum rate to receive the maximum return. This cannot be at the sacrifice of quality, however. Paul (24, p. 682) states that one of the silvicultural objectives in improving the quality of second-growth Douglas-fir is the maintenance of a uniform growth rate. Paul (27, p. 17) further states that ten rings per inch is the minimum number for old growth quality. Fleisher (14, p. 537) agrees with Paul. According to Dilworth (11, p. 69, 71a, 71c) eight rings per inch is the minimum number allowed for no. 1 and no. 2 peeler logs and no. 1 saw logs in Douglas-fir.

The average amount of clearwood produced based on the measurements of 113 knot sections was .67 inches (Table II). Since the average healing time with defect added was 9.5 years (Table II), .67 inches of clear wood

Table II. Analysis of 113 Sectioned Knots in Relation to Bole Position

Bole Position[1]		Average Length of Stub	Average Healing Period of Stub	Average Amount of Clear Wood Grown	Average Healing Time Plus Defect	Average[2] Knot Size	Defects[3]							
							Poor Cut		Stain		Bark		Pitch	
Feet from Base	Number of Knots	Inches	Years	Inches	Years	Inches	(No.)	(W)	(No.)	(W)	(No.)	(W)	(No.)	(W)
3	31	.36	9.1	.62	10.6	.62	3	10	15	54	5	18	6	22
6	35	.29	7.3	.62	8.5	.78	7	23	19	61	6	19	9	29
9	24	.21	5.8	.73	7.6	.81	8	38	11	52	4	19	5	24
12	18	.26	8.0	.65	10.5	.99	1	6	13	82	3	19	2	13
15	5	.26	8.4	.75	10.2	.68	2	45	4	91	1	23	1	23
Average:		.27	7.7	.67	9.5	.78								

[1] The bole position is the point on the bole measured in feet from the base of the tree.
[2] Fourteen knots were not recorded due to mis-judgments in cutting sections.
[3] Twenty-four knots of the total contained two defects, the rest only one.

The (W) weighted values were determined by:

$$\frac{\text{Actual number of defects per bole position}}{\text{Number of knots sampled per bole position}} \times \text{Total No. of Knots Sectioned.}$$

was produced in 13.5 years. This is a rate of twenty rings per inch.

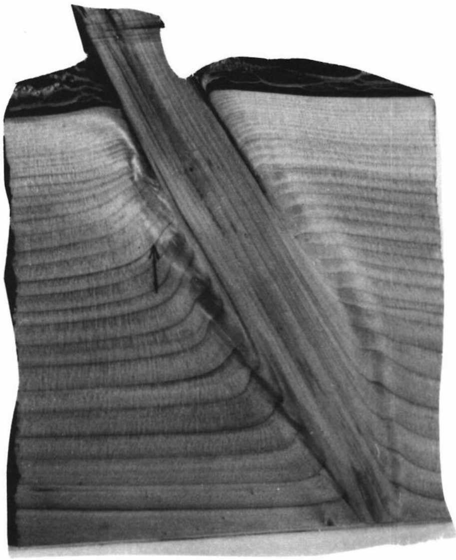
Figure 3 shows a section with an average growth of twenty rings per inch and a section from an unpruned tree.

The growth of the sample trees could then be two and one-half times as great and still meet the ring per inch requirements for no. 1 and no. 2 peeler logs or no. 1 saw logs. The growth rate could be increased three and one-third times and still meet the requirements for no. 3 peeler which is six rings per inch. At a growth rate of six rings per inch since pruning the section in Figure 4 would have added radial increment growth equal to (b) rather than its actual growth equal to (a).

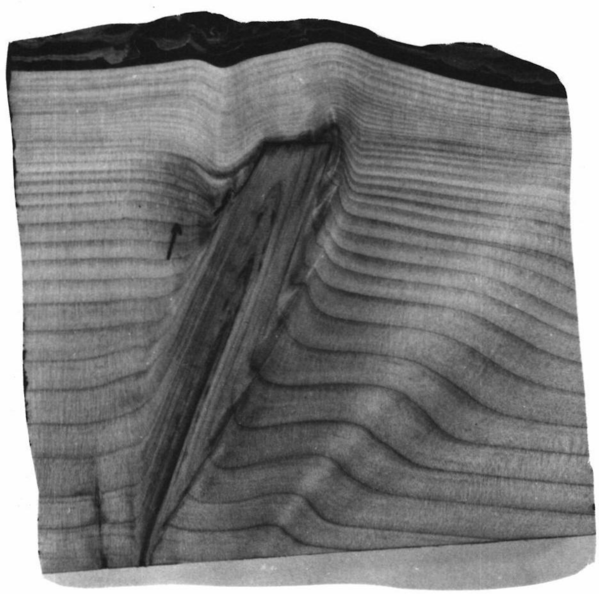
The stub left after pruning has a direct effect on healing time. The longer the stub the longer it takes to produce clear wood. Table II indicates this. The knots from bole position 6 are inconsistent with this statement. It would seem unlikely that growth would be accelerated at this position and not at the higher positions.

The bole position of the knot is important when comparing it to the knot size or the incidence of pruning defects. The knot diameter increases with the increase in height on the bole. Data at bole position fifteen is

Figure 3. A Comparison of Knot Characteristics in Pruned and Unpruned Sections



Unpruned section



Pruned section with the growth of 20 rings/inch

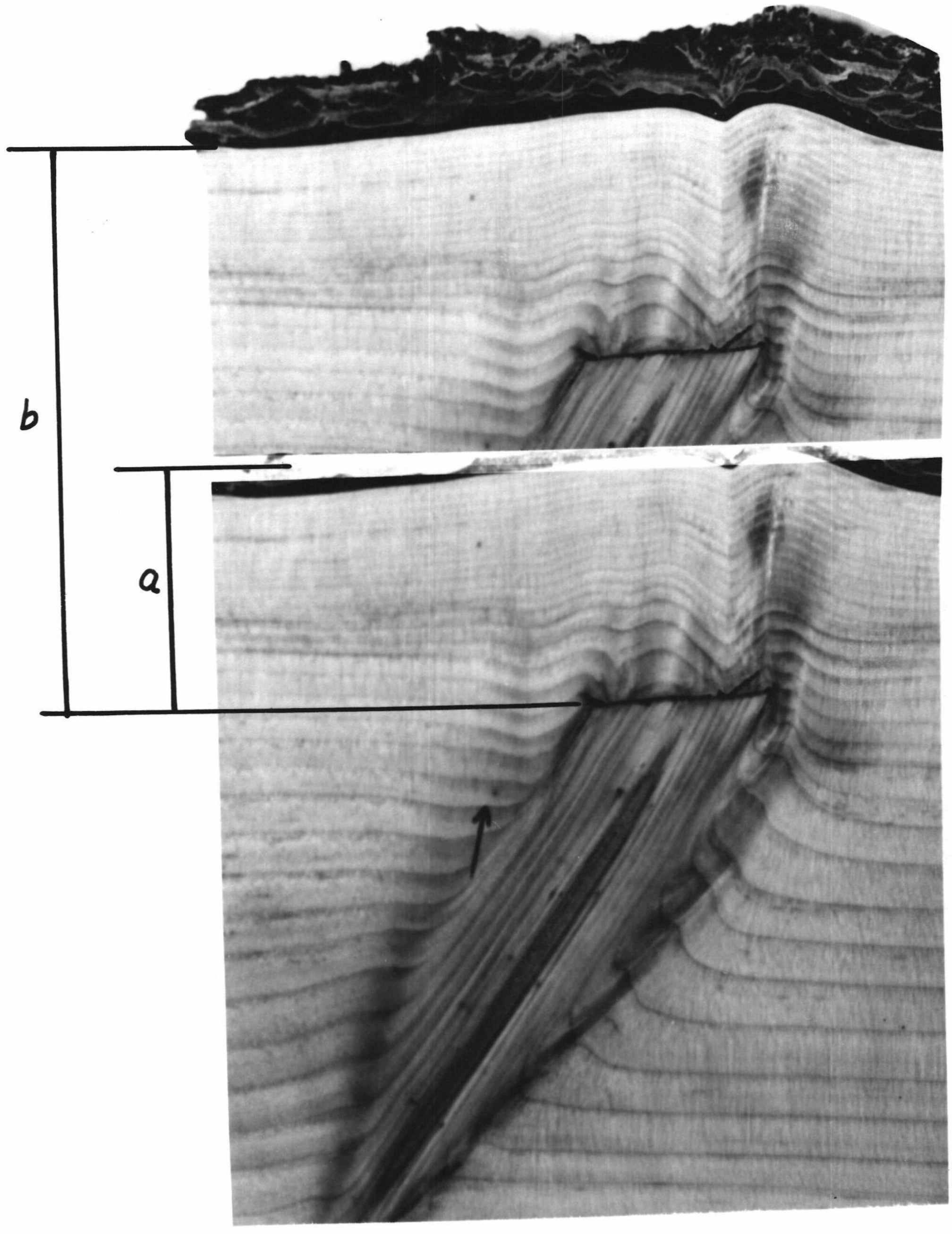


Figure 4. A Section Showing the Present Rate of Growth and the Projected Growth That Could Have Been Attained without a Reduction in Quality

a = The present growth rate

b = The growth that would have been obtained at a rate of six rings per inch since pruning.

not in accord with the above statement probably due to the lack of insufficient data. Paul (25, p. 6) states that the diameter of branches at the time of death averages from about one-half inch near the ground on sites II and III to 1.6 and 1.2 inches, respectively, in the upper portions of the tree. Although most of the limbs removed from the study trees were alive, the figures from Paul's study and Table II compare favorably. Even though knot size increases as height increases, there is no effect on the healing period or occurrence of natural defect (Table II). This conclusion agrees with Anderson (1, p. 11) who found that the diameter of the pruned branch has less effect upon healing time than the stub length and rate of diameter growth of the pruned trees.

The defects of stain, bark and pitch are reasonably constant throughout the range of bole positions (Table II). The defects caused by poor pruning consistently rise with the increasing bole position except in the instance of bole position twelve. This figure may be in error due to sample size. This result would be expected since the higher the pruning operation, the more difficult the performance of the operation. The size of knot also becomes larger with increasing height which would increase the possibility of a poor pruning job.

Defects add to the healing period. Table II shows that an average of 1.8 years additional growth was required before clear wood was produced due to defects. The defect of stain occurred three times as often as the defect of trapped bark or pitch. The defects were not large and many of them would become insignificant if the maximum growth rate was achieved.

<u>The Effects of Pruning on the Crown Class Movement</u>

Crown class movements are an indication of the effects of pruning on the stand condition. Slaubaugh (30, p. 905) found that the point red pine lost dominance corresponded to the point at which height and diameter growth were reduced. Stein (34, p. 354) reports that when 25 per cent of the live crown was removed from Douglas-fir, only the normal number of trees dropped in crown class. No trees, however, dropped into the suppressed or dead classifications in thirteen years.

At the end of twenty years, seven more years than reported by Stein, the pruned trees in P.S.P. no. 23 show that at least 6.3 per cent (Table III) of the pruned trees dropped below the codominant crown position. The one dead pruned tree appeared to have lost its top during a wind storm. At the normal rate reported by Stein (34, p. 354) an additional eighteen per cent of the dominant trees could have dropped into the codominant class and still be normal. Thirty-three per cent of the trees dropped to the codominant position which would not appear to be excessive if the additional seven years is considered.

It would appear from this reasoning that no excessive crown movement occurred due to pruning.[8]

Table III. Crown Class Movement of the Pruned Trees in Permanent Sample Plot no. 23

Crown Class	Pruned Trees			
	1938		1958	
	Number	Per Cent	Number	Per Cent
Dominant	97	100	59	60.7
Codominant	-	-	32	33.0
Intermediate	-	-	3	3.1
Suppressed	-	-	2	2.1
Dead	-	-	1	1.1

The Effects of Pruning on the Normality Relationships

If pruning affected the stand development, the pruned stand's relationship with normality should vary from the relationship of the control stand to normality.

The height of the pruned plot (Table IV) shows a greater increase than the height of the unpruned plot.

---

[8]It was impossible to set up a normal rate of crown movement for the control stand due to insufficient crown position data for the year 1938.

Table IV. Normality Relationships of Permanent Sample Plot no. 23 and Permanent Sample Plot no. 24[1]

Plot	Year	Age	Site Index	No. Trees	Basal Area	Volumes		
						Cubic	International	Scribner
		(Yr)	(Ft)	(Pct)	(Pct)	(Pct)	(Pct)	(Pct)
(Pruned) 23	1938	28	111	18	89	100	339	-
	1944	34	110	27	112	134	310	2,582
	1958	48	120	44	126	138	160	457
(Unpruned) 24	1938	28	109	19	81	90	287	-
	1944	34	110	27	107	129	304	2,379
	1958	48	111	42	122	138	176	537

[1]The (Pct) are the percentages of the actual figures to the normal values taken from McArdle and Meyer (23).

The effect of the increase in height growth in plot no. 23 is not evident in the normal volume relationships (Table IV). The basal area increased the same percentage in both plots. The volumes have reacted similarly for both plots. The high percentages in the volume groups and low percentages in the number of trees is due to the planted nature of the stand.

The increase in height growth can most likely be attributed to one of two things; either the slight increase in height growth due to the removal of 25 per cent of the crown as reported by Isaac (17, p. 12) and Stein (34, p. 354) occurred, or the local site condition on P.S.P. no. 23, which is located adjacent to an intermittent stream bed, was better for growth than the local site condition on P.S.P. no. 24.

The Effect of Pruning on the Incidence of Decay

In a study of decay in Douglas-fir, Boyce (4, p. 6) found that 83 per cent of Fomes pini entered the trees through knots. The elimination of knots, therefore, should decrease the likelihood of Fomes pini entering the tree. Pruning eliminates the knots. The fear that pruning itself may induce rot was challenged by Childs (7, p. 2) who found extensive decay developing in only three out of 253 dissected pruned trees. He further found that 45 of the 253 trees contained signs of slight decay or discoloration, but that evidence suggests that rot generally dies when the pruning wound is completely closed. In the trees he studied Anderson, (1, p. 18) found no evidence that pruning induces infection by decay fungi.

In not one of the 113 knots dissected in this study was a sign of decay detected. This finding substantiates previous studies indicating that pruning will not increase the incidence of decay.

DISCUSSION

Diameter growth appears to have not been affected by the removal of 29 per cent of the live crown. This agrees with the literature which indicates that diameter growth is only slightly, if at all, affected by the removal of 29 per cent of the live crown.

Barrett and Downs (2, p. 508) reported a slight loss in growth in eastern white pine. Slash pine, according to Bennett (3, p. 638) was not affected. Slaubaugh (30, p. 906) found no decrease in diameter growth in red pine. Western white pine, as reported by Helmers (16, p. 674), was not affected, but Buchanan (6, p. 365) shows a slight loss in growth, but not significant. Hallin (15, p. 2) and Mowat (22, p. 3) found no significant loss of growth in ponderosa pine. Douglas-fir does not seem to be affected at this intensity. Stein (34, p. 354) and Finnis (13, p. 18) showed no loss of growth, but Isaac (17, p. 7) found a slight increase due to the removal of 25 per cent of the live crown.

Height growth also has not been affected by the removal of 29 per cent of the live crown. Other studies have produced similar results. A slight loss with a quick recovery was noted in eastern white pine by Barrett and Downs (12, p. 598). Bennett (3, p. 638) in slash pine, Young and Kramer (36, p. 476) in Loblolly pine, Hallin (15, p. 3) and Mowat (22, p. 3) in ponderosa pine all reported no loss in height growth. Slabaugh (30, p. 906) found height growth in red pine slightly reduced by this pruning intensity as did Buchanan (6, p. 366) in western white pine and Dahms (10, p. 444) in ponderosa pine. Conversely Helmers (16, p, 676) found western white pine slightly stimulated by the removal of 25 per cent of the live crown. This slight stimulation is also reported in Douglas-fir by Stein (34, p. 354) and Isaac (17, p. 8). Finnis (13, p. 18) found no loss or increase in height growth in Douglas-fir.

The idea that an increase in height growth may occur with a small reduction in the crown as reported by Isaac and Stein is based on the theory that the lower branches in a dense stand do not synthesize enough nutritional products to sustain themselves, and thus they must borrow nutrients from other parts of the tree. If these limbs are removed, the excess nutrients can be used in other parts of the plant to accelerate growth.

Although the form class computations indicate that there is no acceleration of the normal form class range in the pruned trees, the acceleration may be present at a lower point on the bole. Young and Kramer (36, p. 478) state that the diameter growth at any place in the crown is not affected by the amount of crown below that place and the distribution of growth on the bole tends to make the shape of the bole below the crown approach that of a cylinder. Since the average pruned height is 15.5 feet, the measurement at 17.5 feet is actually located in the crown on the average tree and is not affected by the degree of pruning. The diameter growth, according to Young and Kramer above, would be greater at fifteen feet or right below the crown, becoming progressively less moving down the bole. This may explain the finding that as the poor pruning cuts increased in the weighted number progressing up the bole (Table II), the healing time in years (Table II) tended to decrease while progressing up the bole.

The average diameter growth in the past two decades has been around twenty rings per inch. The most important factor in determining final pruning profit, state Shaw and Staebler (29, p. 3), is generally the average rate of diameter growth on the pruned section. The minimum profitable growth rate they suggest is fifteen rings per inch. This points out the real necessity for following the pruning operation with other cultural operations in order to maintain adequate and uniform growth. Uniformity of growth, states Paul (24, p. 682), can hardly be expected in second-growth stands without recourse to thinnings. He also states that pruning should be done early and allow thinning to control growth.

Site quality has an important bearing on wood quality. Paul (25, p. 12) found that trees on site quality IV contained about one and one-half times more knot whorls per unit of tree length than on site quality II. Pruning then, could be considered more essential, from the standpoint of quality, on sites of lower quality such as the site IV in this study.

Pruning is a silvicultural technique that is destined to play a big role in the new era of second-growth management. Cook (9, p. 487) very clearly illustrates the need for pruning in this statement: "If our managed forests yield nothing better," (meaning no. 2 and no. 3 common lumber), "our silvicultural efforts will have in some part at least, failed of their proper objective, which should be to grow quality as well as volume."

SUMMARY AND CONCLUSIONS

A forty-six year old pruned Douglas-fir plantation near Hebo, Oregon was used to study the effects of pruning on the growth and development of the stand. The field measurements included the remeasurement of the permanent sample plots and sample tree measurements involving height growth, diameter growth, form class relationships, and clear wood production.

The reduction of the crown by 29 per cent does not appear to have affected the stand to any measurable extent. The growth of the stand has been slow and clear wood production is far below optimum, but this slow growth does not seem to be due to pruning in any respect. Defects caused an increase in the healing period, but if maximum growth were realized the healing period would not be greatly affected.

The following general conclusions that can be drawn about the trees in this study are:

1. The removal of 29 per cent of the live crown does not significantly increase or decrease the height or diameter growth of Douglas-fir.
2. The form class measured at 17.5 feet is not accelerated in relation to the normal increase when the pruned height is 15.5 feet.

3. The poor cuts due to the pruning operation increase as the operation moves up the bole.
4. The removal of 29 per cent of the live crown does not affect the crown class positions of the pruned trees.
5. The entrance of wood rotting fungi into the pruning wound is not a serious problem in second-growth Douglas-fir.
6. The length of stub left after pruning has a direct effect on the length of time before clear wood production begins.

BIBLIOGRAPHY

1. Anderson, E.A. Healing time for pruned Douglas-fir. 1951. 22 p. (U.S. Dept. of Agriculture. Forest service. Forest Products Laboratory. Madison. Report R1907).

2. Barrett, L.I. and A.A. Downs. Growth response of white pine in the southern Appalachians to green pruning. Journal of Forestry 41:507-510. 1943.

3. Bennett, F.A. The effect of pruning on height and diameter growth of planted slash pine. Journal of Forestry 53:636-638. 1955.

4. Boyce, J.S. A study of decay in Douglas-fir in the Pacific Northwest. Washington, D.C., 1923. 20 p. (U.S. Dept. of Agriculture. Bulletin 1163).

5. Boyce, J.S. Forest pathology. New York, McGraw-Hill, 1948. 550 p.

6. Buchanan, T.S. Pruning western white pine. Journal of Forestry 42:365-366. 1944.

7. Childs, T.W. Pruning and occurrence of heart rot in young Douglas-fir. 1956. 3 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station, Portland, Ore. Research Note 132).

8. Cline, A.C. and E.D. Fletcher. Pruning for profit. Boston, Harvard Forest and Massachusetts Forestry Association, 1928. 23 p.

9. Cook, D.B. Justifications for forest pruning in the northeast. Journal of Forestry 49:487-489. 1951.

10. Dahms, W.G. Growth of pruned ponderosa pine. Journal of Forestry 42:598. 1944.

11. Dilworth, J.R. Log scaling and timber cruising. Corvallis, O.S.C. Cooperative Association, 1958. 300 p.

12. Downs, A.A. Growth of pruned eastern white pine. Journal of Forestry 42:598. 1944.

13. Finnis, M.J. Experimental pruning of Douglas-fir in British Columbia. Vancouver, British Columbia Forest Service, 1953. 23 p. (Research Note 24).

14. Fleisher, H.O. The suitability of second-growth Douglas-fir logs for veneer. Journal of Forestry 17:533-539. 1949.

15. Hallin, W.E. Pruning ponderosa and Jeffrey pine. 1956. 4 p. (U.S. Dept. of Agriculture. Forest service. California Forest and Range Experiment Station. Berkeley. Research Note 115).

16. Helmers, A.E. Effect of pruning on the growth of western white pine. Journal of Forestry 44:673-676. 1946.

17. Isaac, L.A. Results of pruning to different heights in young Douglas-fir. 1945. 16 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station. Portland, Ore. Research Note 33).

18. Johnson, F.A. Estimating past diameter of Douglas-fir trees. 1955. 3 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station. Portland, Ore. Research note 112).

19. Kachin, Theodore. Natural pruning in second-growth Douglas-fir. 1940. 14 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station. Portland, Ore. Research Note 31).

20. Lehtpere, R. The influence of high pruning on the growth of Douglas-fir. Forestry 30:9-20. 1957.

21. Marts, R.O. Effect of crown reduction on taper and density of longleaf pine. Southern Lumberman 179: 206-209. No. 2249. 1949.

22. Mowat, E.L. Effect of pruning on growth of ponderosa pine. 1947. 3 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station. Portland, Ore. Research Note 38).

23. McArdle, E. and W.H. Meyer. The yield of Douglas-fir in the Pacific Northwest. Washington, Govt. printing office, 1949. 37 p. (U.S. Dept. of Agriculture. Technical Bulletin 201).

24. Paul, B.H. Improving the quality of second-growth. Journal of Forestry 30:682-686. 1932.

25. Paul, B.H. Knots in second-growth Douglas-fir. 1947. 19 p. (U.S. Dept. of Agriculture. Forest service. Forest Products Laboratory, Madison. Report 1690).

26. Paul, B.H. Pruning forest trees. Journal of Forestry 31:563-566. 1933.

27. Paul, B.H. Quality of second-growth Douglas-fir and suggested means of improvement. Forest Products Research Society Proceedings 4:16-20. 1956.

28. Shaw, E.W. and G.R. Staebler. An analysis of investments pruning. Journal of Forestry 50:819-823. 1952.

29. Shaw, E.W. and G.R. Staebler. Financial aspects of pruning. 1950. 45 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station, Portland, Ore.).

30. Slaubaugh, P.E. Effects of live crown removal on the growth of red pine. Journal of Forestry 55:904-906. 1957.

31. Slaubaugh, P.E. Do pruned red pine trees remain dominant? 1957. 2 p. (U.S. Dept. of Agriculture. Forest service. Lake States Forest Experiment Station, St. Paul, Minn. Technical Note 476).

32. Smith, J.H.G. An example of the importance of change in form class to calculations of clear wood growth. Forest Chronicle 32:260-262. 1956.

33. U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station. Volume tables for permanent sample plots - for use in western Washington. Portland, Ore., 1954. 28 p.

34. Stein, W.I. Pruning to different heights in young Douglas-fir. Journal of Forestry 53:352-355. 1955.

35. Advisory committee, the Puget Sound research center. Volume tables for permanent sample plots - for use in western Washington. 1954. 28 p. (U.S. Dept. of Agriculture. Forest service. Pacific Northwest Forest and Range Experiment Station, Portland, Ore.)

36. Young, H. and P.J. Kramer. The effect of pruning on the height and diameter growth of loblolly pine. Journal of Forestry 50:474-479. 1952.

A P P E N D I X

Table V. Statistics of the Live Stand in Permanent Sample Plot no. 23 and Permanent Sample Plot no. 24.

								Dominant and Co-dominant Trees	
Plot	Date Measured	Age Year	Growth Period	Site Index	Site Quality	Number of Trees	Basal Area in Sq.Ft.	Average d.b.h. inches	Average height feet
23	1938	28	-	111	IV	321	101.9[1]	8.2	44
	1944	34	6	110	IV	331	152.0	10.0	58
	1958	48	14	120	IV	270	217.1	12.1	81
24	1938	28	-	109	IV	348	91.7[1]	7.3	42
	1944	34	6	110	IV	350	142.8	9.1	57
	1958	48	14	111	IV	302	212.5	11.4	76

[1]The increase from 1938 to 1944 is due to failure to tag a few small trees.

Table VI. Periodic and Mean Annual Increments and Volumes on Permanent Sample Plot no. 23 and Permanent Sample Plot no. 24.

Periodic Annual Increments

Plot	Period	Basal Area Sq.Ft.	Cubic Feet	Volume: Board Feet International ¼"	Volume: Board Feet Scribner
23	1938-1944	8.4	297	1,621	481
	1944-1958	3.8	171	1,350	1,292
24	1938-1944	8.5	294	1,635	286
	1944-1958	5.0	216	1,190	272

Mean Annual Increments

Plot	Date Measured	Basal Area Sq.Ft.	Cubic Feet	Volume: Board Feet International ¼"	Volume: Board Feet Scribner
23	1938	3.6	72	251	8
	1944	4.5	112	493	91
	1958	4.5	146	742	324
24	1938	3.3	63	185	0
	1944	4.2	104	441	50
	1958	4.4	140	661	320

Table VI. Periodic and Mean Annual Increments and Volumes on Permanent Sample Plot no. 23 and Permanent Sample Plot no. 24. (Continued)

Board Feet and Cubic Feet

Plot	Date Measured	Volume Cu.Ft.	Stand 6.6" and Greater International ¼" Bd.Ft.	Stand 11.6" and Greater Scribner Bd.Ft.
23	1938	2,018	7,021	210
	1944	3,802	16,747	3,098
	1958	7,027	35,665	21,163
24	1938	1,762	5,184	0
	1944	3,527	14,993	1,713
	1958	6,572	31,727	15,480