STUDY OF METHODS OF CUTTING[1]

YELLOW PINE IN OREGON

Pinus ponderosa

By

Robert H. Weitknecht

April 15, 1916

[1] This document was transcribed from a photocopy of the original, which is located in the Supervisor's Office Silviculture Library Archives. To the greatest extent possible, this version is an exact duplicate of the original text.

TABLE OF CONTENTS

STUDY OF THE METHODS OF CUTTING

YELLOW PINE IN OREGON

In a new forest region, it is commonly necessary for the forester to make the first cutting before he is in a position to determine what method of cutting will be best in the long run. Thus his first method of cutting, which is prescribed by a preliminary knowledge of the habits and requirements of the species with which he has to deal, may not be the method which will prove to be ultimately the best. Under these primitive conditions, the best cutting method is a matter of development. And this development is secured only when a thorough knowledge of the habits and requirements of the species and of its response to regional and site factors is applied to the method of cutting.

In the yellow pine forests of Oregon the first extensive cutting in the National Forests was begun about six years ago. The method then initiated was a form of selection in which about 25 per cent of the stand was reserved. This method was thought the best for the quick removal of the preponderant over-mature trees and for the safeguarding of the reproduction. For six years this method has been in use practically without change and the experience gained and the observations made during this time have revealed to the forester a number of facts which have a very vital and varied bearing on the method of cutting. Among the more important of these revelations have been the alarming loss of heavy windfall in cut-over stands, the existence of an excessive disproportion in age-classes in which mature trees make up nearly the entire stand, the occurrence of accelerated growth in reserved trees to such an extraordinary degree as to greatly increase volume production and the apparent case with which abundant reproduction is secured regardless of the method of cutting practiced.

To thoroughly establish the importance and the bearing of these facts and to ascertain the influence of all factors affecting the method of cutting, the present study was inaugurated two years ago. Since the factors, which affect the method of management are those which prevail under cut-over conditions, the cut-over stand and not the virgin stand was chiefly studied in seeking this information.

Nominally the object of this study is to determine the best silvicultural method of cutting yellow pine. It should be borne in mind, however, that the cutting method which finally will be determined, need not be a new one differing radically from the so-called selection method now in use; much less must it be a conventionalized method.

When the study was initiated such practical questions as the following presented themselves:

(1) Does accelerated growth after selection cutting so materially increase the volume as to become an important factor in the method of cutting; is it possible that it will appreciably shorten the rotation?

(2) How great is the windfall danger in cut-over stands; with such violent and periodic storms as occur in eastern Oregon, is there danger of all the trees in the reserved stand eventually being blown down, or does the loss through wind-throw decrease year by year after cutting as the reserved trees gradually become more wind firm?

(3) Does the dense reproduction which exists after cutting, as reflected by old cut-over areas, start before cutting or subsequent to it; what is the relative abundance, rate of growth and vigor of advance as compared with subsequent reproduction.

(4) What is the effect of fire on cut-over stands; if clear cutting is practiced where there is adequate advance reproduction and a severe fire later destroys all this reproduction, will the scattered little bull pines, if any, which survive the fire be sufficient to restock the ground?

With these questions and many more of less immediate bearing correctly answered the forester will be finally in a position to determine a cutting method which will best conform to the habits of growth of cut-over yellow pine under the climatic influences of eastern Oregon a cutting method which, if it be selection, will indicate the best percentage of trees to be reserved so as to insure the most favorable development of reproduction and reserved trees. There will also be a more definite conception than now exists of the proper rotation.

The fieldwork of this study was conducted almost entirely on cut-over areas wherever such areas were suitable for the study, both on and off the Whitman and Minam National Forests. The procedure followed was that set forth in the working plan for the study dated September 7, 1914. The fieldwork was carried on during the summers of 1914 and 1915. During the 1914 season two months were spent in the field by the writer working alone and a progress report was written summarizing this preliminary work. All the data and finds of this preliminary work and report are incorporated in the present report. In 1915 four months were spent in field work in which two men were engaged for most of the time. Altogether ten man-months were spent in the field work of the study.

In organizing the fieldwork the study was divided broadly according to its four principal phases. Under this subdivision, which has the following headings, the results of the study will now be taken up in this report:

(1) Reserved trees and accelerated growth.

(2) Windfall and other loss in reserved trees.

(3) Reproduction under cutting conditions

(4) Reproduction as affected by fire.

RESERVED TREES AND ACCELERATED GROWTH

The main objects of this phase of the study were to determine whether accelerated volume growth was of sufficient amount and duration to affect in a practical way the method of cutting and if it was, to determine its relative amount when the trees left standing in the cutting made up 10, 15, 20, 25, 35 per cent or more by volume of the original stand.

There are two ways in which these facts can be determined: By the initiation and periodic remeasurement of a number of permanent sample plots on which the timber is cut to leave different percentages standing, which gives results only after a long term of years; and by the analytic growth study of standing trees on temporary sample plots taken on old cut-over areas where the kind and arrangement of trees left standing resemble as nearly as possible those in the selection method of cutting practiced on timber sales. The facts in this report have been determined by the latter method

To one not intimately acquainted with old yellow pine cuttings in a thinly settled region like eastern Oregon, the obvious thought is one of doubt that old private cuttings can be found which even remotely resemble timber sale cuttings. In the course of this study fourteen cut-over areas were visited, which ranged from about a hundred acres to several thousand acres in size. On seven of these cut-over areas suitable spots were found for this sample plot study of the accelerated growth of reserved trees. The reserved trees, or rather the trees left standing, on the plots taken made up from 8 to 53 per cent by volume of the original stand, and on the majority of the plots, they comprised 15 to 20 per cent. In the cutting now being done on timber sales of the Whitman National Forest, about 20 per cent by volume of the trees are reserved. The present timber sale method of cutting and the logger's method of 15 to 40 years ago are both selection methods – in the loose sense in which the term selection is used by the profession today. In the timber sale selection, young thrifty trees (bull pines) and older sound trees with healthy crowns are reserved; in the old time logger's selection many bull pines and older trees slightly crooked, but with sound trunks and healthy crowns were left standing together with the suppressed and defective trees. A rough classification of 112 trees left standing on seven of the sample plots shown that 45% were thrifty and perfect bull pines, 20% were trees of larger size which were crooked or forked but otherwise sound, and 35% were suppressed or defective trees. Trees, the trunks of which may be defective in one way or another, often have vigorous crowns and for the purposes of this study these trees are nearly as good as sound trees. There remain the suppressed trees, and these were avoided or kept in the minority by judiciously and painstakingly locating the plots. Thus, it was possible to find on the old cut-over areas conditions resembling more or less closely those on the timber sales and in any event resembling them closely enough for the practical purposes of the study.

It will be noted in the repot that the trees left standing on the sample plots are often referred to as reserved trees. It was found convenient to use this term in the field work and in the light of the preceding paragraph its use, in a measure, is permissible. But the reader should not get the idea that the reserved tree on the sample plot in the old cut-over area is the carefully selected reserved tree of the forester.

To be suitable for the study of accelerated growth a cut-over area besides having spots containing a sufficient number of satisfactory standing trees, must also meet the requirements of having been cut in one operation, which occurred at least ten years ago but preferably longer, the date of which can be definitely ascertained.

When a suitable cut-over area was found the field procedure was to lay off sample plots of an acre or larger on spots which presented the cutting conditions desired. All the standing trees on these plots were then measured and described, and from each tree over 10 inches d. b. h. a radical core was taken with a 10-inch Mattson increment borer. In the field, the radical growth showing in these cores was analyzed by 5-year periods from the present to at least 50 years before cutting, and later in the office this radial growth was converted into basal area growth. Of the trees which had been logged on the sample plot the necessary measurements were taken to compute the percentage by volume of the trees left standing. In addition, the annual rings on the stumps were counted wherever possible.

Reproduction and windfall investigations were also made on each of these sample acres, but the manner of conducting these operations will be discussed under their proper heads.

Altogether 24 plots aggregating 28 acres were taken. Of these plots, the data from all but two were used very satisfactorily in working up the results of the study. All the plots used were uniformly one acre in size except one three-quarter acre plot, 2, two acre plots, and one four acre plot. The data from these variously sized plots were averaged and reduced to a basis of one acre for the sake of uniformity in the presentation of the results. In the course of the study the field work for all purposes was conducted on 14 cut-over areas, but the accelerated growth sample plots were taken only on 7 widely separated cut-over areas on and off the Whitman and Minam Forests. The series of plots on each area was designated with the name, in most cases, of the town nearest to the area.

In the office compilation of the data gotten on these plots, the chief task was the conversion of the radical growth measurements into basal area growth. For each tree over 10 inches d. b. h. on the plot, basal areas in square feet were secured at 5 year intervals from the present to 60 or 100 years ago. Then the average basal area for the plot was found at 5 year intervals, and from this, the average basal area growth by half decades was obtained. Now if the measurements had covered 80 years and the cutting had been made 20 years ago, the growth for the 12 half decades before cutting and that for the four half decades following cutting were averaged separately. This gave for the plot the average basal area growth before cutting and the average basal area growth after cutting. To show the relation between this growth before and after cutting, it was expressed in the per cent by which it occurred more rapidly after than before. Thus if the average basal area growth before cutting was .020 square feet and that after cutting was .082 square feet, this per cent was obtained as follows:

$$\frac{.082 - .020}{.020} = 310\%$$

Here 310 is the per cent by which the average basal area growth after cutting (the accelerated growth) was more rapid than the average basal area growth before cutting.

It will be noted that all figures for accelerated growth in this report are expressed in basal area. Board foot volume for obvious reasons would have been too crude for this work, and to have used the desirable cubic foot volume would have required stem analyses that would have been impractical to secure. Basal area growth is closely proportional to volume growth, however, and answers the purposes of this study.

When the basal area computations were made for the 22 plots, the per cent of growth faster after cutting than before, together with the other essential facts of each plot, were set down opposite the per cent by volume of the trees left standing when the plot was cut. This information is presented in the form of a complete summary in Table 1. Table 2, which immediately follows, gives for all the plots the average basel area growth by half decades before and after cutting. The facts in these tables are based on accelerated growth measurements of over 400 trees.

TABLE 1

Summary Showing Relation of Accelerated Growth to Per Cent of Trees Reserved, to their Volume, Diameter, Number, Age, Etc.

Plots	Per Cent Left By Volume	Distribution Of Trees Left	Average Basal Area Growth per Tree per Half Decade in Sq. Ft.		Accelerated Growth Faster After Cutting Than Before In Per Cent	Description							
						Stand Per Acre Before Cutting In. Bd. Ft.	Volume Per Acre Time of Cutting	Trees Left Over 12”			Years Since Cutting	Side	Remarks
			Before Cutting	After Cutting				No. per Acre	Av. Diam.	Approx. Ages			
Sanger II	8	Even	.041	.146	256	23,399	1,881	5	21	140-280	22	I	4 Acre plot.
Sumpter I	9	“	.020	.082	310	23,145	2,105	11	17	270	17	II	Dry site.
Granite I	9	“	.031	.128	312	38,900	3,545	17	19	240-270	17	I	
Sumpter IV	10	“	.037	.118	219	28,025	2,800	13	18	200-260	17	I	
North Powder II	10	“	.034	.133	291	28,240	2,785	15	19	200-280	28	I	
North Powder I	11	“	.040	.127	217	31,625	3,615	21	17	170-280	10	I	
Sumpter II	12	“	.040	.137	242	34,505	3,990	17	19	150-270	17	I	
Sumpter V	15	“	.021	.076	262	21,985	3,400	18	16	230-290	15	II	Dry site
Granite II	16	Small groups	.031	.061	97	31,572	5,148	19	19	260-300	16	I	Crowns poor to fair, 2 to 5 trees in
Starkey I	16	Even	.029	.123	324	16,370	2,620	20	17	130-220	19	I	groups.
Starkey III	16	“	.033	.122	270	20,220	3,265	21	17	170-230	19	I	
Starkey IV	17	“	.036	.097	169	20,710	3,455	15	18	200-250	18	I	
Starkey II	18	“	.027	.115	326	29,375	5,425	34	17	200-260	19	II	Rocky site.
Susanville II	20	“	.034	.082	141	20,130	4,135	13	18	200-260	11	I	
Starkey V	28	“	.030	.074	147	16,185	4,485	20	17	200-260	19	II	Rocky site.
Susanville I	32	“	.044	.089	102	23,245	7,515	19	19	200-250	11	I	
Susanville III	32	“	.063	.121	93	30,060	9,785	7	31	350	40	I	Old, big trees.
Sanger I	37	“	.096	.193	101	43,270	16,110	10	32	280-380	25	I	Old, big trees.
Catherine Cr. II	37	“	.060	.131	118	30,708	11,508	12	27	260-330	25	II	Poor crowns: rocky site.
Sanger III	53	“	.082	.141	72	36,515	19,425	15	27	200-300	18	I	Mostly big trees.
Sumpter VI	14	Big intact group	.046	.083	80	26,290	3,740	12	19	180-280	17	I	2 Acre plot - 28 trees in group.
Sumpter III	22	“ “ “	.046	.075	63	21,260	4,585	18	19	140-200	17	I	1 Acre plot - 18 trees in group.

* Note: Figures under this heading refer to the present condition of the trees left standing.

TABLE 2

Average Basal Area Growth in Square Feet per Tree per Half Decade for 60 to 100 Years

(Red Line Indicates Time of Cutting)

Plots	Five Year Periods From the Present to 60 or more Years Ago																	Number of
	85-80	80-75	75-70	70-65	65-60	60-55	55-50	50-45	45-40	40-35	35-30	30-25	25-20	20-15	15-10	10-5	5-0	Trees Averaged
Susanville I						.039	.046	.038	.037	.056	.044	.042	.045	.043	.046	.078	.099	21
Susanville II						.037	.044	.031	.028	.035	.033	.032	.030	.031	.036	.069	.094	13
Sumpter I			.019	.018	.018	.017	.021	.022	.019	.022	.025	.023	.019	.021	.054	.094	.099	23
Sumpter II			.028	.025	.029	.033	.042	.047	.040	.052	.045	.042	.039	.054	.123	.133	.156	17
Sumpter III			.035	.040	.042	.045	.054	.051	.047	.056	.045	.053	.040	.042	.060	.076	.089	18
Sumpter IV			.028	.030	.030	.036	.039	.046	.040	.042	.042	.042	.034	.039	.082	.127	.146	13
Sumpter V			.019	.020	.019	.019	.019	.022	.028	.026	.021	.022	.017	.020	.035	.089	.103	19
Sumpter VI			.040	.036	.046	.044	.048	.048	.045	.053	.054	.048	.043	.045	.067	.091	.091	28
North Powder I			.042	.038	.034	.042	.045	.038	.032	.046	.043	.040	.039	.044	.038	.083	.171	21
North Powder II	.025	.023	.026	.026	.029	.027	.041	.051	.037	.042	.043	.040	.090	.130	.168	.149	.128	15
Granite I	.022	.021	.026	.022	.025	.026	.024	.025	.026	.047	.041	.041	.037	.045	.055	.153	.136	17
Granite II	.036	.033	.032	.031	.038	.028	.034	.031	.027	.032	.032	.031	.038	.024	.034	.063	.085	14
Sanger I	.114	.103	.097	.077	.085	.094	.079	.089	.091	.120	.108	.096	.107	.146	.217	.270	.225	10
Sanger II	.041	.038	.033	.029	.037	.045	.039	.038	.035	.048	.043	.044	.065	.103	.137	.181	.163	19
Sanger III	.089	.082	.079	.082	.078	.089	.066	.080	.077	.084	.087	.090	.073	.091	.110	.154	.160	15
Catherine Creek II	.055	.045	.042	.058	.059	.050	.053	.057	.053	.092	.075	.083	.111	.133	.142	.142	.128	9
Starkey I	.023	.022	.023	.021	.022	.025	.031	.028	.025	.044	.038	.033	.036	.057	.136	.138	.163	20
Starkey II	.020	.024	.023	.021	.020	.024	.024	.022	.021	.034	.059	.033	.040	.057	.110	.135	.158	34
Starkey III	.028	.029	.029	.028	.031	.036	.035	.029	.029	.046	.040	.032	.034	.058	.113	.169	147	21
Starkey IV	.042	.040	.037	.030	.033	.034	.041	.031	.032	.048	.035	.031	.034	.044	.102	115	.128	15
Starkey V	.029	.031	.031	.028	.029	.030	.032	.025	.023	.036	.034	.029	.030	.036	.074	.088	.096.	20
						Older Cuttings – Data Given by Full Decades												
				100-90	90-80	80-70	70-60	60-50	50-40	40-30	30-20	20-10	10-0					
Susanville III				.148	.143	.099	.083	.125	.151	.301	.260	.257	.146					7
Auburn				.205	.156	.128	.101	.113	.269	.379	.317	.258	.183					10

Relation of Accelerated Growth to Per Cent of Trees Reserved

The essential points brought out by these two tables are that accelerated growth does occur to a very striking degree, that it continues through 30 or 40 years following cutting and that, it bears a close relation to the severity of cutting. The heavier the cutting the greater the accelerated growth, or in other words, the lower the per cent by volume left standing the greater the accelerated growth. In the following little tabulation, which illustrates this concretely, the figures were derived from a curve in which the percentages left standing and accelerated growth percentages were used as the ordinates and abscissa. These figures hold for the first 30 years following cutting.

TABLE 3

Per cent Left Standing	Accelerated Growth Faster After Cutting Than Before in Per cent
10	290
15	200
20	145
25	125
30	115
35	105
40	95
45	85
50	75

Table 1 also affords a comparison of the accelerated growth in the big group arrangement of reserved trees with that in the arrangement in which the trees are evenly distributed. As one would expect, the accelerated growth in the big intact groups is much less pronounced than in the even distribution – 72 per cent faster after cutting is the average for the groups as compared with an average of 227 per cent in the evenly distributed plots of the same range in per cent of reserved trees. Only two group plots were taken as compared with twenty plots in even distribution, but these two were such excellent examples of the big intact group arrangement (one group contained 18 trees and the other 28) that it was felt they were sufficient to indicate the relation between the two methods of cutting.

Importance of Accelerated Growth

Now there is available a little knowledge of the behavior of accelerated growth after cutting based on actual investigation. There remains the question of the practical importance of accelerated growth. Several members of the profession in writing more or less at length on the construction of yield tables for many-aged stands in the western United States have given accelerated growth but scant attention. They have made theoretic assumptions with respect to it or have considered it insignificant and negligible and in some cases have even disregarded it entirely. With the actual data in hand, however, it is possible to show by concrete figures the important practical bearing of accelerated growth in the yield of cut-over stands. To bring this out clearly little yield tables of two of the plots are here given, in each of which the yield by decades for 60 years following cutting appears in two columns. The yield figures in one column are based on accelerated growth and those in the other are based, as is the case in the yield tables now in common use, on growth in the virgin forest.

These little tables of comparative yields were made for Starkey Plot III and Catherine Creek Plot II. The former plot with its excellent arrangement of thrifty reserved trees resembled closely timber sale conditions; it was cut 19 years ago, 16 per cent by volume was left standing and the growth after cutting has been 270 per cent faster than before. The latter plot was one of the poorest studied and its reserved trees possessed exceptionally poor crowns; it was cut 25 years ago, 37 per cent was left standing and the growth has been 118 per cent faster after cutting than before.

In making these yield tables Pressler's formula for growth per cent was used with certain limitations to predict the yields based on accelerated growth. In predicting the yields based on growth in the virgin forest the average annual volume growth for the 60 years before cutting was used. The method of making the tables for both plots was the same and will be described for Starkey Plot III only. The average basal areas now and at the time of cutting 20 years ago were used in Pressler's formula as follows:

$$P = \frac{B - b}{B + b} \times \frac{200}{n}$$

$$P = \frac{1.271 - .784}{1.271 + .784} \times \frac{200}{20}$$

$$P = 2.4$$

Here 2.4 is the growth per cent in basal area. But, it was assumed with Pressler that for nearly mature trees of negligible increase in height, the growth per cent in basal area equaled the growth per cent in volume. Thus 2.4 is found to be the growth per cent in volume for the stand on Starkey Plot III. The essential figures for this plot then are:

Present volume of reserved trees per acre	4760 BF
Current annual growth per cent	2.4
Average annual volume growth after cutting	114 BF
Average annual volume growth before cutting	31 BF

Since the accelerated growth in volume is about the same in the third and fourth decades after cutting as it is in the first two decades, it was considered safe to use 2.4 in predicting the yields to the end of the fourth decade. After 40 years from cutting, however, the growth returns nearly too normal and in predicting the yields for the fifth and sixth decades it was assumed that the growth then would occur at the same rate as that of the average annual growth for 60 years before cutting.

It will be noted that these tables give for successive decades after cutting the volume per acre in excess of the volume left standing at the time of cutting. The volume logged on the Starkey plot was 16,955 BF and that on the Catherine Creek plot was 19,200 BF.

TABLE 4

Starkey Plot III

Decades	Yield per Acre Above 3265 B F	
	Based On Accelerated Growth	Based On Growth in Virgin Forest
0	0	9
10	1140	310
20	2280	620
30	3420	930
40	4560	1240
50	4870	1550
60	5180	1860

TABLE 5

Catherine Creek Plot II

Decades After Cutting	Yield per acre above 11,508 BF	
	Based On Accelerated Growth	Based On Growth in Virgin Forest
0	0	0
10	1460	670
20	2920	1340
30	4380	2010
40	5840	2680
50	6510	3350
60	7180	4020

Because of their indirect derivation the figures in these tables can not be accepted as correctly representing the actual volumes, but they do accurately show how great is the difference between accelerated yield and normal yield. It should be mentioned here that neither column in either table has been corrected for loss of trees through accident. Actually the loss on the Starkey plot was 240 BF in 20 years; and if the loss for 60 years would be proportional the total loss would be about 8 per cent by volume. But correction for loss in these tables is unnecessary for, of course, the loss would be the same whether the yield is expressed in increased volume or normal volume and the ratio in the tables would not be disturbed. There was no loss on the Catherine Creek Plot.

The thought occurs at this point that if there are three cuts in a rotation of 180 years, each tree in the stand will experience two periods of accelerated growth. With such an increase in volume, occurring as indicated by the above figures, will not the final yield be produced in a shorter rotation than the one used at present?

Life History of Accelerated Growth.

Thus far only the most important objects of the reserved tree investigation have been considered. Other objects were to determine when accelerated growth begins and when it falls off – to make a study of what might be called its lift history.

To determine how soon after cutting accelerated volume growth occurs, a portion of the Baker White Pine timber sale area was selected for study, the date of cutting of which was known absolutely. Here about 25 per cent or more of the trees has been reserved and four growing seasons had elapsed since cutting. Increment cores were taken from 70 trees of various ages and crown classes. The trees were then classified according to the number of wide rings appearing at the end of the cores; if the tree possessed two wide outside rings it began increased growth two years after cutting, if it possessed three wide outside rings it began increased growth one year after cutting. The final results showed that of these 70 trees 77 per cent began the accelerated growth two years after cutting and 23 per cent began it one year after. The latter were mostly very thrifty young bull pines. This timber sale cutting did not offer for study any badly suppressed trees, but observation on other cut-over areas, the dates of which were determined, showed that such trees often had not begun accelerated growth until three or four years after cutting. Thus it can be stated that the average yellow pine left in cutting requires two years to adjust itself to the new conditions before it lays on increased volume growth.

The duration of accelerated growth and the manner in which it proceeds through its period of activity can not be determined so conclusively as the time of its initiation, and this is so because of the scarcity of cuttings over 40 years old. Of the fourteen cuttings studied only two were 40 and 50 years old, respectively; the others were 28 years old and less, except one which was cut about 40 years ago and had been re-cut extensively some years afterwards, thus rendering it altogether unfit for study. The plots on all the cuttings, however, uniformly show that the basal area growth increases rapidly from the time of cutting to the end of the second decade. And the several 25 years old plots the 40 and 50 year old plots indicate that after this the basal area growth gradually falls off. When it returns to its normal rate cannot definitely be determined from the data in hand, but in any event, it is reasonable to suppose that this would be influenced by such factors as the age of the reserved tree and the strenuous root competition of the younger trees and saplings. The following tabulation, which gives for the two oldest cuttings the average basal area growth before and after cutting, is introduced here to show the falling off the accelerated growth.

TABLE 6

Average Basal Area Growth per Tree in Square Feet

Decades Before Cutting					Decades After Cutting				
5	4	3	2	1	1	2	3	4	5
.143	.099	.083	.125	.151	.301	.260	.257	.146	
.205	.156	.128	.101	.113	.269	.379	.317	.258	.183

In the 40 year old, cutting the accelerated growth fell off gradually until the fourth decade when it took an abrupt drop, but still it has not returned to the average growth (.20 square feet) for the 50 years before cutting. The sudden decrease in growth, which is now taking place on this plot, is probably due, partly to the old age of the trees, 350 years, and partly to the very vigorous root competition of the dense sapling growth, which has crowded up to the very bases of the old trees. This sapling stand has an average height of 20 or 25 feet, is about 40 years old and exceedingly vigorous. It will be particularly noticed in the figures for the 40 year old cutting that the first decade after cutting contains the greatest growth. This is the only plot among the twenty-two taken which presents this inconsistency, the cause of which will shortly be explained.

In the case of the 50 year old cutting the accelerated growth behaved normally, it culminated in the second decade and thereafter fell off slowly and consistently. Now 50 years, after cutting it is still considerably above the average growth, (.104 square feet) for the 50 years proceeding cutting. While the reserved trees in this instance are just as old as in the 40 year old cutting and the young, trees and saplings are offering just as strenuous competition, the greater duration of increased growth here is explained by the exceptional clearance given these trees in the cutting. The data here are based on 10 scattered trees located on an area of about 4 acres making perhaps less than 5 per cent by volume left standing. While in the 40 year-old, cutting seven large trees stood on one acre making a reserved stand of 32 per cent by volume.

To show graphically the lift history of basal area growth for a period of 100 years – 50 years before and 50 years after cutting – the curve in Figure 1 is given. It should be borne in mind that the ordinates here represent not average basal area growth, but average half decade basal area growth, and the volumes are expressed in thousandths of a square foot. The curve is based on the average figures for six plots. On these plots different per cents were left standing in cutting, from less than 10 per cent to 37 per cent, yet individual lines drawn through the points for each plot all rose steeply after cutting, culminated in the second decade and then gradually descended. The single exception to this rule was offered by the 40 year old plot, the highest point of which fell in the first decade, but as stated above the reason for this will shortly be explained. This uniformity of the plotted points indicates that accelerated growth has a regular life habit unaffected, save in degree, by the severity of cutting.

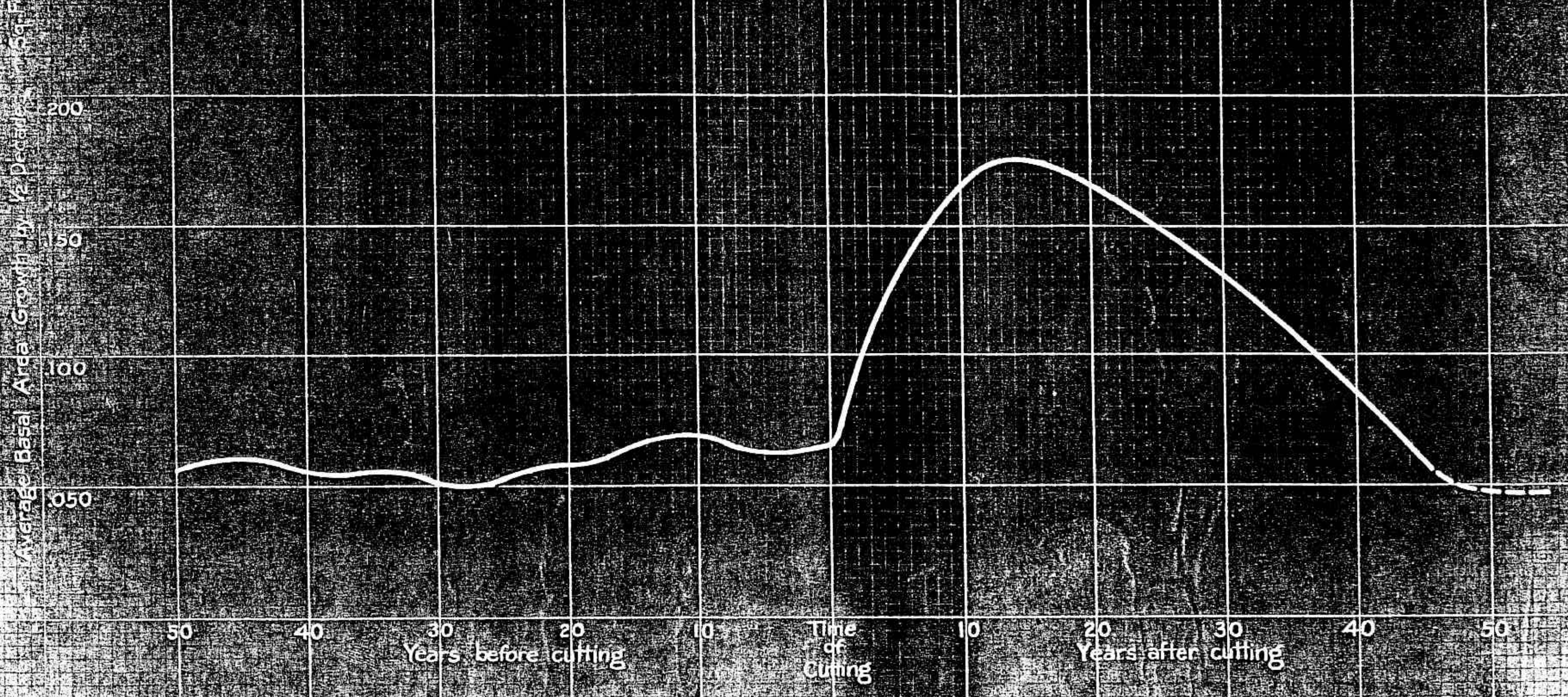
FIGURE I

CURVE SHOWING AVERAGE BASAL AREA GROWTH BY ½ DECADES

BEFORE AND AFTER CUTTING

Basis: 6 Acre-Plots, including 72 Trees, cut 20,25,25,25,40,50 Yrs. ago

Dotted Extension of Curve is interpreted



Effect of Crown Class on Accelerated Growth.

Still another object of the reserved tree study was to determine the effects of the crown class on accelerated growth – to ascertain to what extent accelerated growth occurred in suppressed trees liberated by cutting and how it occurred in trees with thin or unthrifty crowns. The attention of the reader is called to the fine distinction drawn here, namely, that in yellow pine the suppressed crown is very often not identical with the crown of scant foliage and of poor health and it might be added that the suppressed crown in open yellow pine is rarely the overtopped, mechanically inhibited crown which is characteristic of the suppressed tree in stands of more tolerant species. The detailed field descriptions of the individual trees and the basal area figures for each tree afford most excellent material for ascertaining absolutely the information here desired. The working up of this data requires so lengthy and slow operations, however, that in view of the relatively greater importance of other phases of the study, this will not be done at the present time. But this does not preclude setting forth the facts which have been learned by observation, directly and indirectly, in the field and office work. It was observed in the field that even severely suppressed trees liberated by the cutting always exhibited well defined accelerated growth, except in cases where the crowns were unhealthy. It was likewise observed that accelerated growth in trees that had been suppressed started several years later, but then occurred just as abundantly and vigorously as in trees which had been dominant—and this was corroborated in the office by a comparison of the crown descriptions of the trees with their growth figures. All trees with thin, open or very small crowns made very noticeably less accelerated growth than trees with bigger or denser crowns. And all trees with crowns of indifferent health – crowns whose needles were scant, slender and yellow-green in color, as contrasted with the numerous, thick, dark green needles of the thrifty crown – made none or imperceptible accelerated growth. Thrifty young trees, bull pines of say 100 years old, were also observed to show good accelerated growth, but in these, it was apparent that the per cent faster after cutting than before was not nearly as great as in older and mature trees. This is perhaps explainable by the assumption that a tree has a maximum limit of annual volume growth and when the tree is young and in its period of rapid growth it is of course growing at a rate closer to this limit than when it is older. And when the young tree at this period receives such an abnormal stimulation as is offered by a heavy cutting, its growth probably reaches this not very distant limit. The outstanding facts in this little study of the effect of crown classes are that all suppressed trees, so far as they possess healthy crown, produce pronounced accelerated growth and that all trees, whether dominant or suppressed, which have imperfect and unhealthy crowns produce practically no accelerated growth.

Acceleration Due to Climatic Pulsation.

In analyzing the increment cores from which all the volume growth data of this study were obtained, the interesting discovery was made that all the cores uniformly exhibited, 40 years ago, and a very noticeable wide belt of rings covering perhaps 10 years. At no time afterward or for the 40-years before was there a similar belt of wide rings which appeared consistently in all the cores. This fact destroyed the first explanation that this belt of abnormally increased growth was caused by windfalls, insect-killing or other accidental thinning of the stand. And the same fact, together with the universal occurrence of this increased growth on all the widely separated acres studied, led to the belief that it was caused by a period of exceedingly favorable climatic conditions – a climatic pulsation.

To determine whether the belt of rapid growth really occurred as uniformly as appeared to the eye, the cores from four plots on separate cut-over areas were carefully analyzed. This investigation showed that the trees began this rapid growth in 1873, 1874, and 1875 and continued it variously for 8 to 11 years. The average figures resulting from the classification of the date show that the period of rapid growth occurred from 1874 to 1882, inclusive, and covered nine years. To show comparatively the abrupt increase of growth for this period Table 7 is given.

This gives the average basal area growth that occurred in each half decade from 1830 to 1895, and is based on 348 trees standing on five separated cut-over areas. It is exceeding interesting to compare the precipitation curve for the Pacific Northwest* which accompanies the table. It will be noticed that the sustained high points of the curve occur in the half decade 1875 to 1880 and run over slightly into the next half decade and that this coincides exactly with the extraordinarily big increase in growth made at this time. Unfortunately, precipitation records for the Baker City Weather Office, which is the nearest station to the cut-over areas studied, are not available for the years previous to 1889. But it is doubtless a safe inference that the average precipitation curves here given for the Northwest reflects the rainfall history of the Blue Mountain region, in any event it would do so in so striking a pulsation as that which culminated in 1879. In the light of this, it is believed that the belt of unusually wide rings which appears about 1874 and continues about 9 years, represents the increased growth caused by a period of 9 successive years of exceptionally favorable moisture conditions – doubtless heavy summer rains. [*]

[*] From "The Annual Precipitation of the United States for the Years 1872 to 1907," by the U.S. Weather Bureau

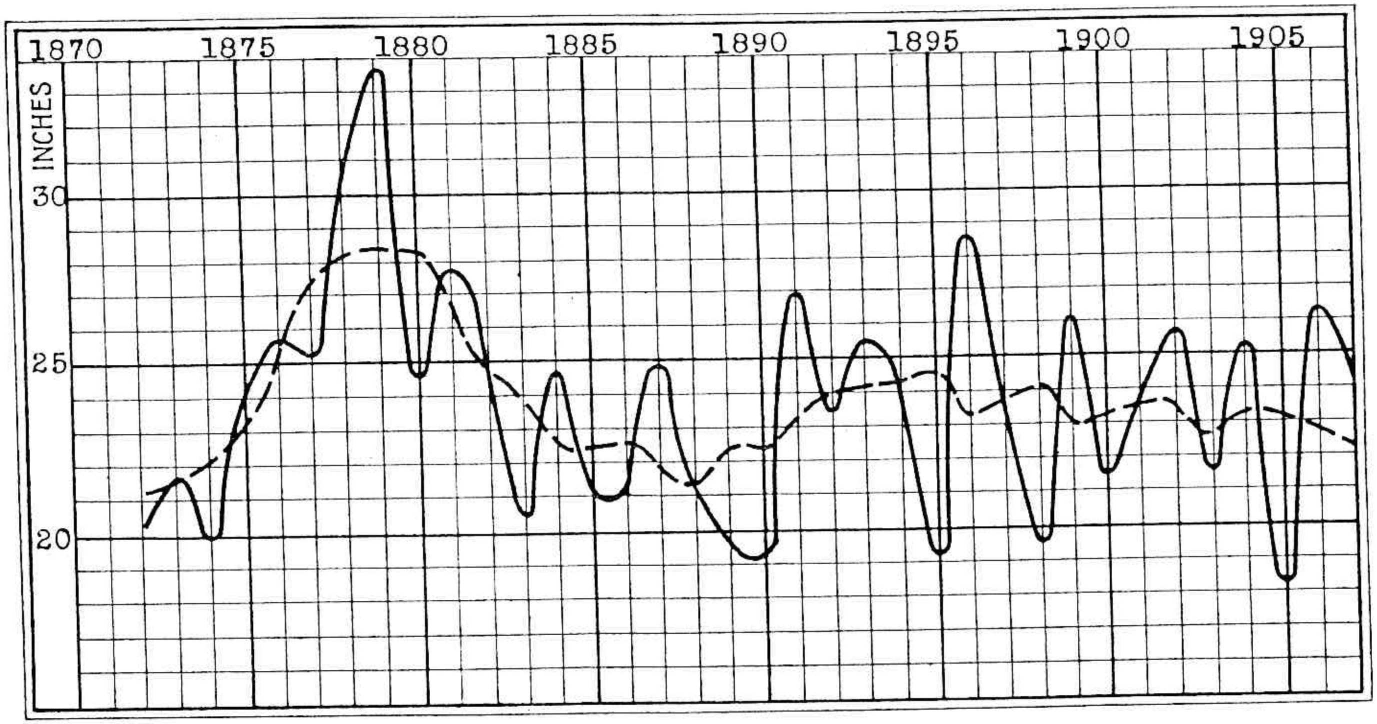
TABLE 7

Average Basal Area Growth per Tree, Half Decades, 1830-1895

1830 -35	1835 -40	1840 -45	1845 -50	1850 -55	1855 -60	1860 -65	1865 -70	1870 -75	1875 -80	1880 -85	1885 -90	1890 -95
.037	.036	.033	.031	.033	.036	.038	.036	.034	.045	.041	.039	.038

Figure 2

Annual Precipitation in North Pacific States and northern Rocky Mt. Plateau.



Full line represents the annual predipitation.
Broken line represents the mean precipitation for successive five-year periods.

In its relation to this study the simulated growth caused by this climatic pulsation does not seriously affect the results. Except for the two 40 or 50 year old plots, it occurred before cutting, for which period the growth was averaged for 50 to 65 years so that its effect in the average figure was hardly recognizable. In the case of the 40 and 50 year old cuttings its influence is not so readily dissipated, but since only two cuttings were old enough to experience this disturbance after cutting it was not thought advisable to correct for it. It will merely be pointed out that it occurred in the second decade after cutting in the 50 year old plot and in the first decade in the 40 year old plot. And this finally explains why the accelerated growth in the last case culminated contrary to rule in the first decade after cutting as shown in Table. 6.

The attention of the reader is now called to the following summary of the important facts with regard to accelerated growth, which have been determined by this study:

(1) The trees left standing in a selection cutting experience a very pronounced accelerated growth, which takes place from 100 to 300 per cent faster than the growth before cutting, which continues for 30 to 40 years following cutting.

(2) The rate of accelerated growth bears a close relation to the per cent by volume of the trees reserved; as the reserved stand increases in density the accelerated growth decreases in rapidity.

(3) Accelerated growth is best secured where the reserved trees are evenly distributed; where they are arranged in big groups the increased growth is very slight.

(4) Healthy crowns produce accelerated growth abundantly whether the trees have been dominant or suppressed, but all trees with imperfect and unhealthy crowns produce practically no increased growth.

(5) Accelerated growth normally begins two years after cutting, lasts 30 40 years and has a regular life habit.

To the writer’s mind, the most important fact established by this study is that accelerated growth occurs to such an extraordinary degree in reserved trees in yellow pine that the forester can not afford to disregard it in his plan of management. That this is so is readily apparent upon a comparison of the actual yield of a reserved stand with the yield predicted for it by the type of yield table now in use. The present yield tables are based on growth in the virgin stand and they are not corrected for increased growth and loss through death. In the case of a specific acre which is fairly representative (Table 4) the actual yield 20 years after cutting is found to be 1660 board feet above the predicted yield. This is an increase of 43 per cent in the volume of the predicted yield. The loss on the same acre has been 240 board feet, which amounts to a decrease of 8 per cent of the volume of the stand left at the time of cutting. This is a very slight loss, but even 18 per cent, which is the average loss through death and windfall on 24 sample acres, is considerably less than half of the increase in volume through accelerated growth. And accelerated growth continues through the third and fourth decades while loss, because of increasing windfirmness, becomes decidedly less after 20 years following cutting. Thus it is shown that accelerated growth cannot be disregarded with the simple assertion that it is compensated by loss through death. And in making yield tables for manyaged yellow pine stands the forester must give it as much consideration as he does site and stocking, if his yield tables are to have the highest practical value.

WINDFALL AND OTHER LOSS IN RESERVED TREES.

By far the greatest loss of trees in the reserved stand is caused by windthrow. Two years ago a very detailed windfall investigation was made on two timber sales on the Whitman National Forest.* There 3621 reserved trees on 4000 acres were windthrown in the two severe storms which occurred in the first four years following cutting. On the sale area which suffered the heaviest damage, the windfall amounted to 18 per cent by volume of the reserved stand – a loss which, if continued, would in a few years mean the total loss of the reserved trees. The object of the earlier study was to ascertain the cause of windfall as determined by the crown, height and other characteristics of the thrown tree and by its relation to the soil, topography and the surrounding reserved trees. The object of the present study is to determine whether windfall occurs in heavy as well as light selection cuttings, whether windstorms severe enough to throw trees are of periodic occurrence and whether all the reserved trees are eventually blown down or whether the greater percentage of them gradually become windfirm enough to survive under cutting conditions, to determine these things as they are reflected by the actual windfall history of old cut-over areas.*[*]

The present windfall information is based upon careful field records secured on two large sample plots, 40 and 20 acres in size, and upon the windfall notes taken on 19 of the acre sample plots. On the large plots, where the cutting was done 15 and 19 years ago, the diameter and height of each windfall over 12 inches d. b. h. was recorded and its date of throw carefully determined. When a tree fell later than two years after cutting the year of fall was easily and definitely determined by the number of accelerated rings it exhibited; but the trees which fell in the first two years after cutting and which showed not accelerated rings were somewhat difficult to distinguish from the trees which fell before cutting. Here the state of decay of the tops was compared with that of the tops of the logged trees afforded a fairly accurate means of identification and when there was serious doubt the fallen tree was classified as thrown before cutting.

The 40 acre plot was located near Whitney on a 15 year old cut-over area where only about 8 per cent by volume was left standing evenly distributed at the time of cutting. The cut-over area here occupied a flat or slightly rolling plateau and the sample plot, which was square, lay in a broad, shallow depression where the wind risk if anything was less than on the surrounding ground. On this plot the standing trees as well as the windfalls were cruised and the total stand left in cutting was found to be 41,310 board feet on the 40 acres. Altogether 8995 board feet, or 22 per cent by volume of all the trees left standing over 12 inches in diameter, were wind thrown in the 15 years since cutting. The windthrows by five year periods after cutting occurred as shown in the following little table:

[*] Manuscript Report "Windfall Damage on Cut-over Areas in Whitman National Forest." by R. E. Smith, Forest Examiner, and Robt. H. Weitknecht, Assistant Forest Ranger.

TABLE 8

Whitney Windfall Area – 40 Acres

Years after cutting	0-5	5-10	10-15
Number of Trees Thrown	31	6	3
Per cent by Volume Thrown	94	4	2

The 20 acre plot was located in a 19 year old cutting near Starkey where about 12 per cent by volume was left standing evenly distributed at the time of cutting. This plot was rectangular in shape, 20 x 10 chains, and was situated on a moderately sloping hillside facing west. The situation here was more exposed than on the Whitney cutting, but it did not give evidence of being an exceptionally severe wind risk. The standing trees were not cruised on this area so it is impossible to give the per cent of the total reserved stand which was thrown. Table 9 shows the number of trees and the per cent by volume of the throw by five year periods after cutting. The unusually large volume thrown in the fourth half decade is due to the fall of an especially bad windrisk tree which never should have been reserved under management – a tree 50 inches in diameter with a deep basal fire scar.

TABLE 9

Starkey Windfall Area – 20 Acres

Years After Cutting	0-5	5-10	15-20
Number of Trees Thrown	28	12	1
Per cent by Volume Thrown	54	30	11

Windfall notes were secured also on the numerous acre sample plots which were taken primarily for accelerated growth study of reserved trees. Nineteen of the plots offered windfall data suitable for compilation. These 19 plots made an aggregate of 24 acres and were located on six widely separated areas on the Whitman and Minam Forests. The windfalls occurred quite uniformly on the six areas, but actually took place on only 12 of the plots; there were seven plots unaffected by windfall damage in the same localities, however, and have been included in order to get a true average of the wind throw by area. A total of 34 trees, 12 to 36 inches in diameter, or about 14 per cent by volume, of the reserved stand, were thrown on the 24 acres thus examined. The cutting on sixteen of the plots was done 15, 17 and 19 years ago and on the remainder it was done 26 and 28 years ago. On most of the plots the per cent, left standing at cutting was around 16 per cent by volume. The throw by 5 year periods occurred as shown in Table 10; the high volume in the third half decade is caused by the fall of two big trees 26 and 30 inches d.b.h.

TABLE 10

Wind throws on 24 Separate Acres

Years after Cutting	0-5	5-10	10-15
Number of Trees Thrown	23	7	4
Per cent by Volume Thrown	67	12	21

This study of the windfall history of old cuttings brings out some very interesting and valuable points. While the field data perhaps do not afford an extensive enough basis for drawing definite conclusions, they are strikingly consistent and it is believed that they are sufficient to indicate in a general way the behavior of windfall damage in selection cuttings for the first 20 years following cutting. It should be stated that, in the opinion of the writer, it is reasonably safe to use old private cuttings as a parallel to timber sale cuttings; because he believes that the degree of windfirmness is not appreciably better on the one than on the other. The old private cuttings may contain a number of trees with defective trunks and basal fire scars, but on the timber sale, cuttings are found a greater number of tall and big crowned trees which are equally unwindfirm in a region of so severe winds as the Blue Mountains. The following are the important points, which this study has brought out.

(1) Wind storms severe enough to throw trees in cut-over stands occur periodically, perhaps as frequently as once every 4 or 5 years, and these storms occur universally in the eastern portion of the Blue Mountains. This is conclusive.

(2) Heavy selection cuttings in which only about 8 per cent by volume of the trees are left standing suffer as greatly from windthrow as lighter selection stands in which 25 or 30 per cent are left standing.

(3) A heavy windthrow probably takes place in most selection cuttings in the Blue Mountains, which in 20 years may account to as much as 25 per cent by volume of the entire reserved stand. Of this windthrow the greatest per cent by volume of the trees are blown down by the first severe wind storms which strike the stand immediately after cutting. In this way 60 per cent of all the trees that are blown down in 20 years may be thrown in the first 5 years following cutting, and the remainder thrown in rapidly decreasing percentages year by year, until 15 or 20 years after cutting when the windthrow becomes normal or about what it is in the virgin forest.

This is the most important finding of the present windfall study. It indicates that the alarming loss of 18 per cent by volume – nearly a million board feet – which occurred in the first four years following cutting on the Eccles timber sale is not to be accepted as presaging the total destruction of the reserved stand. It shows that the least windfirm trees in the reserved stand are blown down in a wholesale numbers during the first several years after cutting, and that the more wind firm trees gradually increase their windfirmness and remain permanently in the stand. It indicates that a heavy windthrow is an imminent possibility in most selection cuttings in the Blue Mountains.

The existence of so dangerous a windrisk in eastern Oregon makes the practice of a selection method of cutting exceedingly difficult. But the writer does not believe that it is serious enough to prevent the use of a selection method. He believes that the loss through windthrow can be appreciably reduced by a careful selection of reserved trees with a view to their windfirmness and by a slightly different method of marking on different slopes and in stands of different character. This, however, is a matter of the practical application of the results and will be taken up later.

Loss in the Reserved Stand Other Than Wind Fall.

Windfall causes by far the greater loss among the trees left standing after cutting. On the 19 sample plots 74 per cent of the loss by number was due to windthrow. Other loss results through insects, fungi, lightning, and other causes; the greatest part of it is doubtless due to bark beetles. Of the 12 trees lost on these sample plots through causes other than wind throw, eight were insect-killed and four were killed by unknown causes.

The total loss on the 24 acres amounted to 46 trees or about 18 per cent of the volume of the original reserved stand. The period covered was 17 to 19 years following cutting.

REPRODUCTION UNDER CUTTING CONDITIONS

The subject of reproduction presented the most complex problem in this study. Until now there has been very little knowledge of the many aspects of reproduction in the yellow pine forest of eastern Oregon and no knowledge whatever of the habits and occurrence of reproduction on cuttings. That this lack of knowledge should be of grave concern to the farsighted forester is apparent when the truism is realized that reproduction is the most vital element in perpetuating the stand, and therefore the most important factor in determining the method of cutting. Before now it was known from observation that in the virgin forest there occurred here and there dense little groups of vigorous advance reproduction where a dead tree or wind fall made the necessary clearance, and that in old open stands a dense thicket of stagnating reproduction occassionally occupied the forest floor, and that in most mature stands the forest floor was carpeted with a more or less evenly distributed stand of spindly, undernourished little seedlings. But how these different classes of advance reproduction fared after cutting and what was their importance in regenerating the stand was not known. It was also known that on old cut-over areas there nearly always existed a dense and vigorous stand of excellent reproduction. But it was not known whether this was advance or subsequent or both, nor was it known what was the effect of different severities of cutting on the abundance, vigor and later development of this reproduction. To gain this important knowledge was the object of this phase of the study.

In the field, the reproduction data were gathered in several ways. On each of the 22 reserved-tree sample plots from two to four square rod quadrates were taken on which the reproduction was tallied by age and height, classified into advance and subsequent, and described as to its vigor and distribution. In addition, scattered dominant saplings over the whole acre were cut and examined for age and height. On several of the large cut-over areas straight lines, usually 20 chains long, were run on which square rod quadrates were arbitrarily taken at chain or two chain intervals. And on these quadrates the reproduction was tallied and classified much the same as on the quadrates in the acre sample plots. The main objects of these quadrates were to learn what proportion of the reproduction was advance and what subsequent, and to learn the relative growth and vigor of the two classes. On several of the cuttings suitable for the purpose, an equal number of dominant advance saplings and dominant subsequent saplings were felled and analyzed by age and node heights in order to compare the rate of growth after cutting of the one with the rate of growth of the other. On two suitable cut-over areas a series of arbitrary quadrates were taken on which measurements and descriptions were made to ascertain whether the spindly, malnourished little advance seedlings which commonly cover the forest floor ever recover from their runty condition and make vigorous saplings.

In this way intensive reproduction study was conducted on eleven cut-over areas situated in and about the Whitman and Minam National Forests. These areas were cut from 5 to 28 years ago. They embraced all conditions of site, moist and dry, north slope and south slope; they presented all degrees of cutting from clear cut to selection in which 53 per cent by volume was left standing, though most cases the reserved stand was under 15 per cent. The reproduction studied was from one year to 40 years old and ranged in height from several inches to over 35 feet. It was practically pure yellow pine, only four of the areas having as much as 5 to 20 per cent than other species. Altogether 99 quadrates were used in the office compilation of the data; of these, all were square rods except 16 which were half square rods. In assembling and correlating the data from these quadrates a preliminary tabulation was made giving for each cut-over area the quadrates tallied, the proportion of advance and subsequent reproduction, the number per square rod, ages, aspect, site, stand, vigor, distribution, and all factors which reasonably would affect reproduction. This table is not essential to the reader's understanding of the subject and, therefore, will not be included in the report.

Proportion of Advance and Subsequent

Perhaps the first question asked in this study after realizing the remarkable abundance and distribution of natural reproduction on cut-over areas was: What proportion of it is advance and what proportion subsequent? It might be stated parenthetically at this point that the term subsequent reproduction, for which heretofore there has been no adequate designation, originated with this study. And in addition, it seems needless to add that it means reproduction which starts after cutting as contrasted with advance reproduction which starts before cutting. In determining the relative proportion of advance and subsequent reproduction on cuttings the data were used from 99 quadrates representing 11 cut-over areas. A table is here given showing by cut-over areas the proportion in per cent of each class of reproduction and the number of quadrates taken on each area. In this table, most weight should be given to the figures for the Sumpter, Starkey and Austin areas. They were the largest areas on which uniform and suitable conditions prevailed; and on them the greatest number of sample quadrates were taken. The figures for most of the other areas, while they are a fair index, are apt to be less representative of actual conditions because of the fewer quadrates tallied. The least dependence should be placed upon the figures for the North Powder area—for it is possible that light ground fires shortly before cutting considerably disturbed conditions in the advance reproduction.

TABLE 11

Proportion of Advance and Subsequent Reproduction

Existing on Eleven Cut-over Areas

Expressed In Per Cent

Area	Advance	Subsequent	Number of Quadrates
Sumpter N. Slope	22	78	29
Sumpter S. Slope	56	44	35
Granite	57	43	3
Starkey	50	50	8
Catherine Creek	50	50	1
Sanger	81	19	2
Medical Springs	67	33	-
Susanville	96	4	3
North Powder	2	98	2
Austin	91	9	10
White Pine	84	16	4
Whitney	94	6	2
For All Areas	67	33	99

This table shows that the proportions vary quite considerably, but that on most of the areas there is notably more advance than subsequent, and that the average for all the areas is 67 per cent advance and 33 per cent subsequent. The figures in Table 11 give the per cent of each class of reproduction based on the total number of seedlings and saplings occupying the ground. But in reproduction as old as most of this, it is more important to know the proportions in the stand of dominant reproduction than those in the total stand of reproduction. To get an idea what this would be, the data were compiled for three series of quadrates on the Sumpter area and the single series on the Starkey area, an aggregate of 58 separate square rods. The areas were cut 17 to 19 years ago; the advance reproduction started from a year to 20 years before cutting and the subsequent started mostly in the first three years following cutting. It was found that the height of this reproduction was very irregular, that the advance ranged from 2 to 16 feet tall and the subsequent from 1 to 14 feet, and that the average heights were about 5 feet and 3 feet, respectively. It was then assumed that all the reproduction above 4 feet in height was dominant. Of this reproduction, the per cent of advance and the per cent of subsequent were obtained and arranged in Table 12 together with the corresponding percentages based on the total stand of reproduction. The table shows that the proportion of advance in the dominant stand is slightly greater than it is in the total stand.

TABLE 12

Proportion of Advance and Subsequent Reproduction

In the Total Stand and in the Dominant Stand

Area	Total Stand		Stand Over 4 Ft. Tall	
	% Advance	% Subsequent	% Advance	% Subsequent
Sumpter A	22	78	34	66
Sumpter B	74	26	91	9
Sumpter C	97	3	95	5
Starkey	50	50	59	41

This investigation of the proportion of the two classes of reproduction on cut-over areas indicates that advance reproduction is on the whole more abundant than subsequent, and that of all the dominant reproduction the advance makes up a greater part than the subsequent.

Cause for Variation.

An attempt was made to explain the variation in the proportion of the advance and subsequent on the different cut-over areas. But it was not possible to get a consistent correlation of the factors of site, aspect, the presence or absence of an overwood, and other factors which ostensibly might affect the class of reproduction. In general the yellow pine cuttings on north sloped and colder sites contained noticeably more subsequent reproduction than the cuttings on south slopes, or otherwise expressed, the north slopes contained less advance than the south slopes. A plausible theoretic explanation of this would be that the soil temperature on north slopes is much colder because of the north aspect and the dense stand, than that on the south slope where the warmth of soil caused by the south aspect is accentuated by the openness of the stand. And since soil moisture is favorable on both sites in the spring, the soil temperature is the controlling factor in the germination of seed. The deduction is that less favorable germination conditions in the virgin forest exist on the north slope than on the south slope and, therefore, less advance reproduction is found on the north slope. With the opening or the removal of the overwood on the north slope, however, the soil is warmed to a favorable temperature and germination is immediate and abundant. A contributory factor in keeping in subjection advance reproduction on the north slope is perhaps the inhibiting influence of a comparatively dense overwood, an influence so severe in the competition for light and soil moisture which it imposed that the establishment of such seedlings as have germinated is almost impossible. It should be mentioned that the north slopes of this discussion are not those on which the so-called north slope species occur, but the lower north aspects like those in the Sumpter valley where yellow pine is practically pure and in no case makes up less than 80 per cent of the stand.

Transient Seedlings.

In computing the proportions of advance and subsequent which appear in the tables on the preceding pages, seedlings under five years old were not included except for the White Pine and Austin areas. These two areas were cut 5 and 6 years ago, while all the rest of the areas were cut considerably over 10 years ago. The reason for excluding the seedlings under five years old is that it has been found that of the subsequent reproduction that establishes a cover after cutting practically all of it starts in less than five years after cutting. Thus on an area cut 18 years ago, it is typical to find a dense stand of subsequent reproduction 90 per cent of which is 16, 17 and 18 years old and about 10 per cent of which is under five years old. By far the most of these little seedlings are between 1 and 2 years old and among these there seems to prevail a high mortality; this fact leads to the belief that they make up a sort of transient class of reproduction which perpetually starts and dies, and never gets beyond 2 or 3 years old. The cause of this is doubtless to be found in unfavorable conditions of establishment. It is evident from this that it would not give a true index of the proportion of subsequent reproduction as compared with the advance to use these little transient seedlings in computing the percentages. On most of the areas the inclusion of these little seedlings would not materially change the relative proportions as they appear in the table, but on the Granite, Starkey, Sanger and Susanville areas their inclusion would radically increase the per cent of subsequent reproduction.

Abundance and Distribution

Next to the subject of what proportion of advance and subsequent reproduction occupies cut-over areas comes the subject of the abundance of reproduction after cutting. It is not enough to say that reproduction is remarkably abundant on cut-over areas. What should be known is whether, in amount and distribution, it is adequate for regeneration.

The best index of abundance is the number of seedlings per acre. But to be worth anything at all, figures for number per acre should be based on a great number of sample quadrates which should be taken in an arbitrary manner. The figures here given are based on 68 quadrates so taken on the Sumpter, Starkey and Austin areas. The Starkey area is a typical example of the cut-over area, which supports a medium cover of reproduction with scantily covered open patches here and there; the Sumpter and Austin areas are typical of the areas, which support a dense cover of reproduction in which occur very few open patches.

In Table 13 are given the figures for abundance on these areas. The average number per acre was obtained by multiplying the average number per rod by 160 rods. The per cent of dominants was not computed for the Austin area; this area was cut six years ago, the others 17 to 19 years ago.

TABLE 13

Number of Seedlings per Acre

Area	Average No. per Acre	Average No. per Sq. Rod	Per Cent Dominants (Over 4' Tall)	No. of Quadrates Averaged
Sumpter A	4064	25.4	50	20
Sumpter B & C	6464	40.4	36	30
Starkey	2000	12.5	83	8
Austin	8800	55.0	-	10

These are average figures, they are trustworthy and it is believed that they very closely represent the actual conditions on these areas. It will be interesting now to note how specific acres run as to distribution and number per acre. Two plots will be used to illustrate this; both on the same area, cut at the same time, possessing about the same reserved stand and similar site conditions. Sumpter Plot II was described as having a dense cover of reproduction and Sumpter

Plot IV as having a medium cover. In the fieldwork the reproduction on the acre plots was classified as dense, medium and scant, and was so outlined on the sketch maps made for each plot on cross-section paper. One or more representative square rod quadrates were taken in each cover class. In the case of Sumpter Plot II, the reproduction on 35 per cent of the acre was dense, on 44 per cent it was medium and on 21 per cent it was scant; with 162, 99 and 4 seedlings to the square rod respectively. The total stand of reproduction on this specific acre was 13,705 seedlings. In the case of Sumpter Plot IV, the reproduction on 80 per cent of the acre was medium with 20 seedlings to the square rod, and on 20 per cent it was scant with about 2 seedlings to the square rod; and the total stand of reproduction on this acre was 2624 seedlings. On both plots the reproduction is mostly over 16 years old and ranges in height from 2 to 12 feet. The condition of the reproduction on both plots is vigorous, but it is noticeably more so on the plot with the fewer number per acre.

In the field the reproduction was also described as to its occurrence in even distribution and in groups. It was found that on the cut-over areas as a whole the ground was covered with a remarkably even distribution of reproduction. This does not mean that over an entire quarter-section the ground would be 100 per cent shaded by an intact stand of reproduction as would be the case in Douglas fir. It means that for large units of area the reproduction was much more evenly distributed than group wise, and that where openings occurred they were, as a rule, negligible so far as reforestation was concerned. This applies more particularly to the large cut-over areas such as those near Sumpter, Whitney, Medical Springs and Pleasant Valley, where these areas have not been affected by fire or other injury. It should be stated that in many cases subsequent reproduction, by filling in between the patches of advance, in the most influential factor in bringing about an evenly distributed cover.

The essential points brought out by this study of the abundance and distributions of reproduction on cut-over areas are:

(a) From 200 to 8800 seedlings are an average number per acre over large areas.

(b) Over 13,000 seedlings per acre, 16 to 18 years old occur on specific plots and are growing vigorously.

(c) On specific plots 2000 seedlings per acre which are evenly distributed, 16 to 18 years old, make an adequate stocking for natural reforestation.

(d) On the large cut-over areas the reproduction as a whole is evenly distributed and amply sufficient in amount for reforestation.

In connection with the abundance of reproduction on cuttings should be mentioned the opinion commonly held among non-technical men in eastern Oregon that these vast “thickets” of young growth (through which these men can no longer ride on horseback) are worthless because they are too dense to make a mature forest, they can only choke to death. In the study it was observed that actual stagnation was very restricted and insignificant, and in all cases, it existed long before the overwood was removed in cutting. It was also observed that, aside from this negligible stagnation, the vast cover of reproduction on all the areas nowhere exhibited a sickly condition due to density. Even in the densest reproduction the leaders were never even-topped, everywhere the dominants stood well above their neighbors and were surviving vigorously, and gave every indication that they would so survive to make a mature stand. This was particularly observed on the three oldest cuttings where the subsequent reproduction was 30, 40 and 50 years old, respectively, and where it was very dense and vigorous.

Comparative Rate of Growth

The growth and vigor of reproduction under cut-over conditions is radically different from what it is under virgin forest conditions. The height growth of subsequent reproduction is much more rapid than that of advance reproduction which remains under the intact virgin stand. And the advance which is liberated by cutting grows at an accelerated rate which greatly exceeds its rate of height growth before cutting. The figures in Table 14 show how much faster is the height growth of subsequent than of un-liberated advance. In this table, the average height at various ages on three cut-over areas is compared with that for unliberated advance. The heights of the subsequent are based on node-height measurements from 41 seedlings. The height growth figures for the advance are based on about 60 seedlings measured in 1910 in the same region in which the present study was conducted. * All seedlings upon which these figures are based were representative dominants. The subsequent reproduction occurred under a reserved stand of from 8 to 12 per cent by volume.*

TABLE 14

Height Growth of Subsequent Reproduction

Compared with Unliberated Advance.

Age In Years	Total Height in Feet and Tenths			
	In the Virgin Forest	In the Cut-over Forest		
		North Powder	Sumpter	Starkey
1	.2	.1	.2	.2
2	.3	.2	.3	.3
3	.5	.3	.5	.5
4	.6	.4	.7	.7
5	.8	.5	1.0	.9
6	1.0	.7	1.3	1.1
7	1.1	.9	1.6	1.3
8	1.3	1.1	2.0	1.6
9	1.5	1.4	2.5	2.0
10	1.7	1.7	3.0	2.5
11	1.9	2.1	3.6	3.0
12	2.1	2.6	4.2	3.6
13	2.3	3.2	4.8	4.3
14	2.5	3.9	5.5	5.0
15	2.7	4.6	6.1	5.8
16	3.0	5.6	6.8	6.8
17	3.2	6.4	7.5	7.9
18	3.5	7.3	8.2	9.0
19	3.7	8.2		10.1
20	4.0	9.2		
21	4.3	10.2		
22	4.6	11.3		

* See manuscript report "A Study of the Growth of Yellow Pine in Oregon," by G. A. Bright, Forest Examiner.

Table 15 shows the increased height growth of liberated advance on three cut-over areas as compared with advance in the virgin forest. The advance which was freed by the partial cutting of the overwood uniformly shows, except for that on the Starkey area, a very appreciable acceleration of height growth. The Starkey reproduction, moreover, showed the least acceleration of any on five areas.

The increased growth would be still more pronounced if the figures for the un-liberated advance, secured by Forest Examiner Bright in 1910, had been based on representative dominants instead of on the best dominants. In this study only the thrifty average dominants, which gave promise of reaching the pole stage were used. This is evident from a comparison of heights before cutting of the advance measured in this study with those of the advance measured in the earlier study. The latter, it is believed, slightly overstate the rate of height growth of dominant advance in the virgin forest.

Table 15

Accelerated Height Growth of Advance Reproduction

After Cutting Compared With Unliberated Advance.

Broken Lines Indicate Time of Cutting.

Age In Years	Total Height in Feet and Tenths			
	Unliberated Advance	Liberated Advance		
		North Powder	Sumpter	Starkey
1	.2	.1	.1	
2	.3	.2	.2	
3	.5	.3	.3	
4	.6	.4	.4	
5	.8	.5	.5	
6	1.0	.6	.6	
7	1.1	.7	.7	
8	1.3	.8	.8	
9	1.5	.9	.9	
10	1.7	1.1	1.0	
11	1.9	1.3	1.1	1.2
12	2.1	1.6	1.3	1.4
13	2.3	1.9	1.5	1.6
14	2.5	2.2	1.8	1.8
15	2.7	2.5	2.1	2.1
16	3.0	2.9	2.5	2.4
17	3.2	3.4	3.0	2.7
18	3.5	4.0	3.5	3.0
19	3.7	4.6	4.0	3.3
20	4.0	5.2	4.5	3.6
21	4.3	5.9	5.0	3.9
22	4.6	6.6	5.5	4.2
23		7.4	6.1	4.6
24		8.2	6.7	5.1
25		9.0	7.3	5.6
30		14.4		9.0
35		21.0		14.0

The important question now is what is the practical difference between the growth of subsequent reproduction and accelerated advance? A correlation of the total heights for the two classes of reproduction on the several areas gives the figures shown in Table 16. The age of the subsequent here is also the age of the cutting.

Table 16

Area	Advance		Subsequent	
	Age	Total Height In Feet	Total Height In Feet	Age
Whitney	30	7.5	4.2	15
Starkey	35	14.0	10.1	19
Sumpter	26	7.9	8.2	18
North Powder	36	22.4	15.7	25

On these areas the dominant advance increased its height growth after cutting and now more than maintains its lead over the rapid-growing subsequent, except in the case of the Sumpter area. On the latter area the subsequent has passed the advance, probably because the advance had a start of only 8 years with an average height of but 8 tenths of a foot at the time of cutting. The increased height growth of the advance on the North Powder area is exceptionally fast. On all the areas the annual height growth for the last 3 or 4 years has been about the same in both classes of reproduction.

All this indicates that dominant advance reproduction increases its height growth after cutting and in most cases maintains a considerable lead over the rapid growing subsequent. And the deduction is that this quality together with the greater abundance of advance should make this class of reproduction extremely important in securing a rapid regeneration of the stand and in bringing about a perfect balance of the age classes.

The attention of the reader should be called here to the fact that on none of the cut-over areas studied was advance reproduction found as a recognizable age class beyond 40 years of age. Isolated saplings over this age were occasionally found but never in any considerable number per unit of area. On the Sumpter and Starkey areas 40 year old saplings were the oldest which existed as an age class; and on the Sumpter area, which was most intensively studied, the preponderant ages of the advance were between 20 and 34 years. On the Whitney and Austin areas the oldest reproduction as a class was between 25 and 35 years. On the cut-over areas as a whole there existed practically no age classes, except in rare isolated cases, between the sapling growth 40 years old and the big bull pines and mature trees 200 years old and older – a condition due doubtless to repeated fires before the settlement of the country. This great interruption in the gradation of age classes is very noticeable to the observer on the ground who has in mind yellow pine as a many-aged forest which is cut ostensibly by a selection method. It is evident that this disproportion of age classes, this overbalance of mature trees and young reproduction, will present the most serious problem in the future regulation of the cut.

Recovery of Malnourished Advance.

Closely related to the subject of increased height growth of advance reproduction after cutting is the recovery after cutting of what has been termed in this study, malnourished advance reproduction. It will be recalled that in the virgin yellow pine forest in eastern Oregon there are now two more or less definite classes of advance reproduction. One of these classes is made up of dense groups of vigorous seedlings growing in openings in the mature stand. In the other class the forest floor under the mature trees is plentifully and evenly covered with thin-stemmed, weak looking little seedlings. It is believed that the latter class comprises by far the greatest proportion of the advance reproduction, and that its importance in regeneration under the present conditions of age classes and cutting method is much greater than is that of the more conspicuous reproduction which occurs in groups. Malnourished advance reproduction occurs evenly distributed and is made up of characteristically of spindly-stemmed little seedlings with the merest tufts of needles at the end of their leaders and branches – their height may be 12 inches and their age 20 years. In the one sided struggle for light and soil moisture which is waged between these small seedlings and the big trees of the overwood, the little seedlings suffer extreme malnourishment – often to the point of extinction. With this malnourished reproduction existing so plentifully, it is of great importance to the forester to know whether, upon the partial cutting of the overwood, it will recover and make thrifty seedlings or whether it will never recover, but will live in a stagnated condition and thus become a serious hindrance to the establishment of subsequent reproduction.

In the investigation of this problem, two neighboring cut-over areas were studied: One a private cutting near Austin which was logged 6 years ago with less than 5 per cent by volume left standing; the other a timber sale cutting two miles away in the Whitman National Forest, which was logged 5 years ago with about 30 per cent left standing.

On the practically clear cut private area 10 half-square rods were taken at equal intervals was recommended by Forest on two parallel lines arbitrarily located in a section of the cutting. The particular section selected Forest Examiner Munger who had been on the area when it was cut six years ago and observed it then as a typical area of malnourished reproduction. When the present data were collected the reproduction here was practically pure yellow pine and a fairly complete stocking; 90 per cent of it was advance, most of which at the time of cutting was 10 to 18 years old and about 10 inches high. On the 10 quadrates all the seedlings were tallied by heights and 65 per cent was analyzed in detail for age, total height, height grown since cutting, vigor, and degree of recovery. In this study a seedling was described as recovered if in 5 or 6 years after cutting it had begun effectively to increase its height growth and to increase perceptibly its vigor and the amount of its foliage. Of the 167 seedlings here, analyzed 65 per cent recovered from the malnourished condition and are now making vigorous growth. The average annual height growth of this reproduction before cutting was less than 1 inch; of that which has recovered, the average annual growth in height for the period since cutting was 3 inches. It was noted that the recovered seedlings had not begun increased height growth until the third, fourth and often the fifth year after cutting; which shows that recovery may not begin until five years after cutting and that the time when it begins depends doubtless on the degree of malnourishment. Thus, though the average yearly height growth since cutting was 3 inches, the actual yearly growth since the initiation of increased height growth was from 4 to 12 inches. The growth in diameter and the increase in foliage was consistent with the growth in height, so that the thriftiness of the dominant seedlings now gives a general appearance of vigor to the whole stand of reproduction.

On the timber sale areas, 4 half-square rods were located in the 4 quarters of a 2 acre plot and the field data were taken in the same way as on the private area. The timber sale area was studied chiefly to see how the recovery of malnourished reproduction under a reserved stand of 30 per cent by volume compared with the recovery under a very scant reserved stand.

Here over 75 per cent of the reproduction was advance, the condition of which before cutting was probably very similar to that on the private area which was less than 2 miles distant. Of the 139 advance seedlings analyzed only 32 per cent had recovered. The average annual height growth of these before cutting was about 1 inch; after cutting it was 1.8 inches. Recovery was very slight here; where it existed at all it was evident only in the greater length of internodes for the last year or two. The reproduction had not greatly increased in vigor since cutting.

The essential points brought out by this little study are: (1) The spindly, undernourished advance seedlings which often thickly carpet the ground under the mature stand are able to recover and make vigorous seedlings; (2) The percentage of such reproduction which recovers is in relation to the density of the stand reserved in cutting; where there was practically nothing reserved 65 per cent of it recovered, where a stand of 30 per cent by volume was reserved 32 per cent recovered. These figures are based on cuttings 5 and 6 years old; it is not likely, however, that an appreciable number of seedlings will recover after the sixth year following cutting.

Supplementary to the above study consideration was given to the hindering effect on recovery caused by logging injury and slash. Logging injury resulted chiefly in the form of scars at the bases of the stems and less frequently as crooked stems due to a breaking-off of the leaders or the first whorl of branches at the time of logging. Slash injury to reproduction which was less serious than the preceding which took the form of crooked and twisted stems caused by the seedlings having to grow through and around the criss-crossed branches of the slash. The percentage of seedlings which is prevented from recovering as a result of logging and slash injury is probably insignificant compared with that which actually does recover. In this connection it was interesting to note that there was markedly less evidence of logging injury to reproduction on the timber sale area than on the private land, and of course no injury from slash, because the latter had been burned on the sale area.

<u>Exceptional Growth Adjacent to Stumps.</u>

Before the subject of the growth of reproduction after cutting is left, the exceptional height growth and vigor of seedlings adjacent to stumps should be mentioned. It is common on cut-over areas to find strikingly tall and thrifty reproduction clustered densely about a stump, often completely hiding the stump. These exceedingly vigorous seedlings occur mostly beside big stumps, and usually within a radius of 5 feet from the center of the stump. The tallest seedlings of the cluster are those immediately adjacent to the stump and these are frequently three times as tall as the surrounding reproduction of the same age. This thrifty reproduction occurs on all side of the stump, the south as well as the north; it is usually subsequent reproduction, but sometimes advance is found occurring in this way. The writer believes that this exceptional growth is explained by the presence close to stumps of more soil moisture than exists farther away. And the greater soil moisture is present here chiefly because of the mulching effect of the accumulated litter and humus at the base of the stump, and partly because of the effect of the stump's shade in helping to conserve this moisture. It is possible, however, that there are several contributing causes for this unusual condition of reproduction. One such may be a tilled condition of the soil due to the former activity of the stump's roots, a tilth holding an increased supply of soil moisture which becomes readily available to the roots of the seedling.

A parallel to stump occurrence is found in the virgin forest in the presence of thrifty reproduction adjacent to dead trees and snags. Here, it is believed, the cause is not chiefly the admittance of light to the forest floor upon the death of the tree, for in the immediate vicinity one may find open spots which contain no reproduction, but the admittance of light to a particular part of the forest floor where there exists a favorable condition of soil moisture. Favorable soil moisture necessarily existed here during the life of the tree and after its death it is reasonable to suppose that it was maintained by the accumulated mulch at the base of the tree. The traditional explanation for occurrence of reproduction next to dead trees and stumps is that the dead trunk or the stump offers physical protection against the inhibiting influences of frost and drought. While such protection is undoubtedly a factor in the establishment of little seedlings 2 or 3 years old, it certainly is not the cause of rapid annual height growth in saplings 15 years old, which, in the case of the stumps, are much taller than the height of the stumps.

The recorded observations on a number of cut-over areas show that exceptionally fast growing and vigorous reproduction is commonly found clustered immediately around stumps. And knowledge of the conditions leads to the conviction that his unusual growth is caused chiefly by the presence of very favorable soil moisture conditions at the base of the stumps.

Effect of Reserved Stand on Reproduction.

Thus far the reproduction after cutting has been considered subjectively. Now it will be considered as to how it is affected by the reserved stand – partial overwood which is left after a selection cutting.

There seems to be no pronounced effect of the reserved stand on the abundance of reproduction. For the practical purposes of reforestation the number of seedlings per acre on the plots which supported a reserved stand of 30 per cent by volume was not radically different from that on the plots with a reserved stand of 10 per cent. The former plots contained perhaps 2,000 or 3,000 seedlings per acre, the latter 6,000 to 10,000. However, 2,000 seedlings evenly distributed over an acre are quite probably more effective for reforestation than 10,000. The reserved stand, of course, does not affect the abundance of advance reproduction; that is governed by conditions before cutting, perhaps mainly by the site and the character of the overwood. And it is the opinion of the writer that the abundance of subsequent under a reserved stand of from 5 to 30 per cent is influenced chiefly by the site and the amount of advance reproduction already on the ground. A reserved stand of less than 5 per cent is not likely to afford enough seed trees for prompt reforestation, and a reserved stand of over 30 per cent is apt to provide an overhead cover not open enough for optimum germination and establishment conditions.

The effect of the reserved stand on the growth of reproduction, however, is more evident. Reproduction under a reserved stand does not grow as fast as that under no overwood whatever. On the sample plots the height growth of reproduction, and this applies particularly to the increased growth of advance reproduction, was not nearly so great in the cases where 30 per cent by volume of the trees was left standing as where 15 per cent was left. Thus, the retarding effect on height growth of reproduction increases in direct proportion with the increase in the per cent of trees reserved. Below 15 per cent, however, if the reserved trees are not too small and thus too many in number, the effect is not material, i.e., reproduction will grow just as vigorously under a stand of 5 per cent as under one of 10 or 15 per cent by volume. Perhaps the best example of the retarding influence of the heavy reserved stand as compared with a lighter is afforded by the recovery of undernourished advance reproduction. Under the subject of malnourished reproduction it was shown that where there was a reserved stand of 5 per cent by volume, 65 per cent of the reproduction recovered and made vigorous increased height growth; where there occurred a reserved stand of 30 per cent, only 32 per cent recovered. Thus it can be stated that the growth and vigor of reproduction after cutting is less favorable under a heavy reserved stand than under a light one and that the retarding effect increases directly with the increase in reserved stand. Up to 30 per cent it seems that this retardation of growth is not serious, but in reserved stand of much over 30 per cent by volume, especially where the trees are small, it is possible that the rate of growth of the reproduction will be only slightly better than it is in the virgin stand.

The nursing or sheltering effect of the reserved stand on the reproduction in the Blue Mountains is important only when the seedlings are under 4 or 5 years old. There is every reason to believe that in this region drought is the cause of a high mortality of 1 and 2 year old seedlings. The reserved stand undoubtedly protects these little seedlings against drought, possibly also against frost, and thus it helps in the establishment of subsequent reproduction. But after the stand of reproduction is 4 or 5 years old it does not require overhead protection of any sort. This is vividly shown by the exceedingly thrifty reproduction, which exists over a vast acreage of cut-over areas on much of which there are very few standing trees.

Of the effect of the severity of cutting in securing subsequent reproduction little can be said definitely at this time, because so little is known of the productivity of seed, the frequency of seed years and the germination conditions in the yellow pine forest. The sample plots indicate that where the cutting left from 30 down to 10 per cent by volume of the trees standing, subsequent reproduction occurred more plentifully than it did where the reserved stand was less than 10 or more than 30 per cent. These limits frequently did not hold because of the influence of site or number of trees left standing. The comparative scarcity of subsequent in reserved stands of over 30 per cent is probably due as much to the greater competition here, which retards germination and establishment as to a less prolific seed production. And the cause of the scarcity in the reserved stands below 10 per cent is found doubtless in a lack of sufficient seed trees. But subsequent reproduction in some amount was always found even where less than 5 per cent of the trees were left standing. On several of the larger cut-over areas, the heavily logged south slopes on which only runty culls stood every 5 or 6 chains, contained an exceedingly scant amount of subsequent reproduction. No larger areas of north slope with equally few seed trees were found, but on such north slopes as were studied, the subsequent was always more plentiful than on the south slopes. This seems to indicate that after cutting better conditions of germination exist on the north slope than on the south.

It was one of the objects of this study to investigate the source of the seed which gives rise to subsequent reproduction; to learn something of the abundance of seed and of the distance from the seed tree at which it effectively covers the ground, and to ascertain if possible whether the accumulated seed for several seasons does not remain in a stored condition in the ground until cutting and then germinate. Suitable conditions for making this investigation require cuttings between 5 and 10 years old on which there are large areas with very scattered seed trees to absolutely no seed trees at all. Such conditions were not found. In some cases the areas had been recut for cordwood, but mostly they had been too severely burned over as a result of the slash burning required by state law.

The effect of the reproduction on the reserved trees should be mentioned. This does not become important until about 30 years after cutting when the reproduction is in the thrifty sapling stage and begins to compete strenuously with the reserved trees for the available soil moisture. The effect of the reproduction on the reserved trees was shown by the data secured in the 40 and 50 year old cuttings where the reproduction was dense and of about the same age as the cutting. Here the accelerated growth in the fourth and fifth decades after cutting fell off gradually but very decidedly. If the reserved trees are old and overmature the effect of the reproduction in curtailing accelerated growth is doubtless accentuated.

In concluding the subject of reproduction, it may be stated that this study has made a number of valuable findings. And it has also called attention to that still remains to be investigated—much which was observed in the field and discussed speculatively in this report. The following summary points out the important results of the study with regard to reproduction.

The practical value of these results will be taken up later in the discussion on the practical application of the findings of the study as a whole.

(1) Yellow pine reproduction on cut-over areas in the Blue Mountains is remarkably abundant and well distributed, and is amply sufficient for adequate reforestation.

(2) On cut-over areas as a whole advance reproduction is more plentiful than subsequent both in total number and number of dominants.

(3) Subsequent reproduction grows 2 or 3 times as fast as advance reproduction in the virgin forest; but advance after cutting increases its height growth and in most cases maintains its lead over the rapidly growing subsequent.

(4) Malnourished or suppressed advance reproduction recovers after cutting and, where the cutting is heavy enough, a high percentage of it makes thrifty reproduction.

(5) The reserved stand seems to have very little effect on the abundance of reproduction; and its effect on the growth and vigor of reproduction does not appear to be serious when the stand is below 30 per cent, but under a heavier reserved stand the reproduction grows much less rapidly.

(6) When reproduction reaches the thrifty sapling stage about 30 years after cutting, it is believed that, through its vigorous competition with the reserved trees, it is the cause of the falling off of the accelerated volume growth of these trees.

(7) The writer is convinced from this study of reproduction that, in the arid Blue Mountains, different sites, nominally north and south slopes in the yellow pine type, possess sufficiently different conditions of soil temperature and soil moisture to influence radically germination and establishment conditions, and he believes that this is chiefly the cause for the great variation in the occurrence of advance and subsequent reproduction.

REPRODUCTION AS AFFECTED BY FIRE

The objects of this phase of the study were to ascertain, if possible, how extensively fires occur on cut-over areas in eastern Oregon, how destructive they are to reproduction, and to what extent natural replacement is secured when a severe fire absolutely destroys all the reproduction on an area. Five burned areas on the cutting near Whitney, Sumpter, Austin and Cove were studied. The method of study was by extensive examination, except in the case of the Cove burn where a series of quadrates was taken. In order to compare the actual conditions on the burned area with the condition of the reproduction and reserved trees which would now exist on it, if it had not been burned, critical examination was made of adjoining unburned portions of the cutting in each case.

At Whitney two separate burned-over cuttings were examined, one cut 5 years ago and the other 12 years ago. Both are situated adjacent to the Sumpter Valley Railroad and the fire on each was set without doubt by sparks from a locomotive. The burned area in the 12 year old cutting, which will be described first, comprises over 300 acres. The unburned portion of this cutting contains a cover of reproduction which is amply adequate for natural reforestation. Two thirds of this reproduction is advance which occurs in groups and is fairly vigorous. The remaining third is vigorous subsequent reproduction, 8 to 10 years old, which is clustered about stumps and scattered between the groups of advance. The cutting here was very heavy, only about 2 or 3 trees of seed bearing ability to the acre were left standing. The fire which swept over this area occurred about 5 years after cutting. It was exceedingly severe and apparently occurred in the dry season, for the ground was burned absolutely clear of all debris – the slash was entirely consumed and the stumps were unusually charred and blackened. Here and there a small bull pine was killed, but the thick barked old culls escaped injury. As would be expected in so devastating a fire, absolutely all of the reproduction was killed and consumed. The burned area 7 years after the fire is estimated to have an average of perhaps 4 or 5 seedlings to the acre with many acres containing no reproduction whatever. These seedlings are 2 to 6 years old and have been started by the isolated seed trees that escaped destruction by the fire. From the standpoint of forest management this area is denuded and the few, poor, scattered seed trees which remain, an average of perhaps one to the acre, are entirely inadequate to ever effectively restock the area.

The burn in the 5 year old cutting at Whitney covers about 250 acres. Here the reproduction on the neighboring unburned area is also sufficient for natural reforestation; it is mostly advance in dense groups and is more patch than that in the 12 year old just described. On this area practically clear cutting was practiced so that only about one seed-producing tree to every 3 or 4 acres was left standing. Here the fire occurred 2 years after cutting; but evidently it burned under favorable conditions, for the slash was not entirely consumed and in many places the fire did not run in the grass. Where tops lay in groups of advance they burned and killed the reproduction, but many groups not so situated did not suffer injury. On this area, about 50 per cent of the reproduction was destroyed by the fire. While that which is left is perhaps sufficient as a natural stocking, it is extremely uneven in distribution, the fire having accentuated the original patchiness of the reproduction. Large openings occur everywhere and it does not seem possible that these openings can be filled by the doubtful seeding from the little cull trees scattered 5 to 10 chains apart over the area.

The burned area examined near Sumpter, while it is only 60 acres in extent, furnishes an excellent example of the maximum damage a fire can do in a yellow pine cutting. On this area, the cutting was done 15-years-ago. The fire, the origin of which is known, occurred within 2 years after cutting. Before the fire, there were 5 or 6 seed trees to the acre. The adjoining unburned area has a satisfactory cover of reproduction. The fire here swept the ground clean of all debris. Practically all the seed trees were killed, even the largest ones 16 inches or more in diameter. The few that were not directly killed by the fire were later wind thrown, so that now there is not a living tree above seedling size on the whole area. The reproduction was completely destroyed except for a little isolated group of advance which will be described later. Aside from this insignificant bit of advance the only reproduction on the burned area is made up of widely scattered clumps of seedlings which have been started by chipmunks or squirrels. These isolated clumps contain from 5 to 15 seedlings, which are even aged and from 10 to 12 years old. Here and there over the area are a very few solitary seedlings 4 to 13 years old which have evidently started from seeds that were wind-blown 10 to 15 chains from trees on the edge of the burn. Thus 13 years after the fire this area is still unstocked, and since all the seed trees upon it were destroyed, it never will be able to restock itself. Ultimately, yellow pine will recover the ground by migration from the edges, but this is an age-long process and is not restocking from the standpoint of forest management.

An interesting feature of this burn is the little group of advance seedlings which escaped the common destruction of the rest of the reproduction on the area. This little group stands out strikingly as an island of tree growth in the middle of the burned waste. It is an open group of about 40 seedlings, 3 to 10 feet tall, which occupies a space of less than a square chain. Examination showed that this space was originally an opening in the stand before cutting and also that it was used as a log landing. As a result of the latter use, the ground evidently must have been absolutely clear of all litter and debris at the time of the fire. Thus, although the fire burned intensely all around this spot, it was not able to reach the reproduction across the loose mineral soil surrounding the log landing. The writer has observed several instances of groups of reproduction which have escaped the general destruction in the burns where they occurred, in fact, their occurrence is not uncommon in yellow pine burns, but never has he examined a case where the fire was as so severe as here.

The burned area studied near Austin differs very little from those already described, but there are available actual figures of abundance of reproduction on the adjacent unburned area which afford so excellent a contrast to conditions on the burn, that this area will be treated also. The burn examined is only about 30 acres in size, but it is a component part of the irregularly burned-over cuttings to the north of Austin. Like elsewhere the burned areas here were destructively burned in some places and less so in others, this according to the dryness or dampness of the ground cover at the time of the fire. These burns, it is believed, were chiefly caused by the careless brush burning practiced by private operators in their perfunctory compliance with the state forest fire laws. It might be mentioned that the slash on private cuttings in eastern Oregon is now commonly burned with astonishingly little regard for the condition of the weather and, of course, with no provision whatever for the protection of the reproduction, for the burning is practically always broadcast. The cutting on the burn under question was done 6 years ago, and the fire ran over area within a year after cutting. Intensive reproduction study was made, for another purpose, of 20 acres of unburned cutting immediately adjoining the burn, and the average stand of seedlings was found to be 7920 per acre. This reproduction was advance which was evenly distributed and from 10 to 18 years old at the time of cutting. Practically clear cutting was practiced in that only about one small cull tree to the acre was left standing. The fire here killed all the seed trees on the area and destroyed over 90 per cent of the reproduction. The burned area is now covered with a dense stand of snowbrush dotted here and there with a little group of advance reproduction which escaped the fire. And scattered throughout the burn are a few subsequent seedlings mostly 5 years old, which probably started from seeds, dropped from the dead cull trees immediately after the fire. No seedlings 1 or 5-years-old were found. It is estimated that there are about 500 seedlings to the acre irregularly distributed on this area, and there is not possibility of this stand being increased by natural seeding. While this is a stocking which will eventually insure a timber cover, provided a second fire does not run over the area, it is the writer’s opinion that it is not the most desirable one for natural regeneration in yellow pine.

The burned area near Cove is about 400 acres in extent and roughly a mile long and a half mile wide. As nearly as could be determined the fire occurred 10 years ago. The date of cutting is unknown. The stand was about 60 per cent yellow pine and the remainder north slope species. Only a portion of the burn comprising 160 acres was studied. Two sides of this area about half a mile apart are flanked by uncut timber and scattered widely over the area are only 11 seed trees, 7 of which are big yellow pines of good seed bearing ability. This burned area was studied intensively by running 5 parallel lines across it 10 chains apart and taking square-rod quadrates every 5 chains on these lines. Thirty quadrates were tallied and an average of 3 seedlings to the square rod was obtained. Seven quadrates contained nothing, but in all cases seedlings were seen near these blank quadrates. The fire here was exceedingly severe both from report of settlers and evidence on the ground. Practically all the seed trees were killed, though bigger trees and a larger number were left standing here than on any burned area studied. Only the 11 big thick-barked yellow pines and Douglas firs were able to survive this fire. All the reproduction was killed and consumed, and judging from the unusually dense cover of reproduction on the cuttings around Cove, this was very good here. At present the area is covered with a dense stand of willow and snowbrush. Three seedlings to the rod gives an average of 480 to the acre. This reproduction is 55 per cent yellow pine and ranges from 3 to 10 years old, about two thrids of it being from 7 to 10 years old. In this case, it has taken 10 years to scantily stock a complete waste with 480 seedlings to the acre. This reproduction is remarkably well distributed and from the standpoint of artificial reforestation it would doubtless be considered a sufficient stocking.

In the study of these five, burned-over cuttings the essential points are:

(1) On three of the areas the fire was so severe that it wiped out absolutely all of the reproduction and on the other two it killed 50 and 90 per cent, respectively.

(2) On two areas all the seed trees were killed by the fire, on two the greater per cent of them were destroyed and on one area the seed trees were not injured.

(3) Natural replacement is slowly taking place on all of the areas, but only by the slow process of incidental seeding from such inferior cull trees as escaped the fire, and from trees on the edges of the burn from which a seed now and then is carried great distances by storm winds.

(4) Stocking adequate for reforestation is doubtfully present on only three of the areas, and on two of these this stocking is made up chiefly of advance reproduction which survived the fire. The Cove burn is the only one which from a complete waste has been able to restock itself, and here the stocking is so scant that it is a question whether it is really adequate. The Sumpter burn and one of those at Whitney are now 14 and 7 years old, respectively, and are still practically denuded.

These results indicate, in a measure, what would happen if in yellow pine timber sales clear cutting were practiced and fire should accidentally follow cutting. There is the gravest danger that such a fire would kill not only the reproduction, but also the un-merchantable bull pines upon which dependence would be placed for restocking the area. It is true that the fire on a timber sale cutting would be less destructive than one on a private cutting, because of the un-disposed and highly inflammable slash existing on the latter. But slash is not the only destructive carrier of fire. The writer knows of a number of instances on timber sales and railroad rights of way where considerable yellow pine reproduction up to 5 feet tall, has been killed by the heat from grass fires. A grass fire would rarely kill the small bull pines left in clear cutting, but this study shows that these are not effective seeders and such little seeding as they accomplish would require about 15 to 20 years to bring about satisfactory replacement.

Another destructive effect of fire is that in which crowns of young bull are partially killed. The damage caused in this way is especially pertinent, because it occurs on timber sales where the brush is piled and the burning is done with more than common care and judgment. This damage is ordinarily inconspicuous; even a careful observer on an inspection of a cutting will not be impressed with it. The writer had an excellent opportunity to observe this minutely on a 40-acre plot laid out on the Eccles timber sale for the purpose of securing detailed windfall data. On this plot he made careful records of the crowns of all the standing and thrown trees and incidentally was so struck with the extent of this inconspicuous fire damage to small trees that he made notes with regard to it. These are not adequate to furnish actual figures, but they indicate that a very appreciable proportion of the little bull pines (up to 50 feet tall and with foliage to within 10 or 15 feet of the ground) and had their crowns partially killed by fire. In some cases as much as the lower two thirds of the crown and in most cases the lower half or quarter of the crown had been killed. This injury was done by the flames and heat from the burning brush piles close to the little trees. The seriousness of this damage is apparent when it is realized that the volume growth of a tree depends largely on its crown. When a tree is deprived of a half or a third of its crown, its volume production is proportionately reduced. While probably no permanent physiological injury results from this partial fire killing, it is the opinion of the writer that the retardation of growth is very appreciable

One of the indirect points brought out by this investigation is the terrible destructive effect of heat (not flames) in killing needles and the cambium of the smaller branches. In many instances the killed needles were unconsumed and the branches unblackened by flames. This killing power of heat in the destruction of young reproduction and the crowns of young trees is very little realized or appreciated by Forest officers.

A word might be added here on how extensively fires occur on yellow pine cut-over areas in the Blue Mountains. Of the older cuttings the proportion which has been burned, is surprisingly small. The Sumpter Valley cuttings serve as an illustration. It is estimated that there are approximately 8,000 acres of cut-over land in this valley. The cut-over area occupies both sides of the valley and borders closely on the ranches lying in the valley bottom. The Sumpter Valley Railroad runs along the edge of the cutting on the north side and directly through the cutting on the south side of the valley. The proportion of these 8,000 acres of cutting which has been burned is estimated at less than 15 per cent. The burned areas occur in six or seven different spots mostly on the south side of the valley. About half of the fires were very evidently set by the railroad and the origin of the others is unknown. The Sumpter Valley cuttings are 15 to 25 years old and on the vast unburned portion of them there is almost a continuous cover of thrifty, dense reproduction from 4 to 15 feet tall. It is interesting to contrast with this the large areas near Whitney and Austin which were cut within the last 5 or 6 years. Here the slash has been disposed of in accordance with state law. The slash burning has been done carelessly and as a result these recent cuttings are characterized by big stretches of burned-over ground on which most of the reproduction has been destroyed.

CONCLUSION

When this study was initiated the nominal object was to determine the best silvicultural method of cutting yellow pine in Oregon. Its purpose also was to establish the importance of certain facts with regard to accelerated growth, windfall, reproduction and fire, and to ascertain the influence of all factors affecting the cutting of yellow pine.

Most of the specific objects of the study have been quite satisfactorily attained for the Blue Mountain region in Oregon, but even here there is still a lack of complete knowledge with regard to some of the factors which influence cutting, particularly regarding windfall and the disproportion in age classes. And in other parts of the yellow pine range in Oregon the study has not been carried on at all. Until a complete knowledge of the subject is gained, it will be obviously premature to make a final statement of the best silvicultural method of cutting.

Tentative Correlation of Data.

It is interesting, however, to correlate in a broad way the available data which a view to ascertaining what is tentatively indicated as the proper cutting method. In doing this the writer starts with the premise that the method will be either one which will produce a many-ages stand or one which will produce an even-aged stand. Reproduction is as a rule one of the important determinants of the cutting method, but is believed that in eastern Oregon the common abundance of advance reproduction will permit either method. The heavy windfall loss in this region, of course, would be obviated by a method leading to an even-aged condition. On the other hand, the accelerated growth in the reserved trees of the many-aged stand produces a volume increase which is greater than the loss by windthrow. And the possibility is always present of the reproduction being destroyed by fire after clear cutting with the subsequent idleness of the ground for 15 years or more before natural replacement slowly brings about an adequate stocking.

While the yellow pine forest in eastern Oregon appears to be roughly even-aged because of the overbalance of mature trees, it is believed that the manyaged stand is the true habit of yellow pine. This is reflected by the occasional instances of almost perfect distribution of age classes found where fire has not molested the stand. The present mature yellow pine forest (apparently even-aged) exhibits a decidedly open stand; this indicates that under the real even-aged condition, the trees in middle life and at maturity would require the same excessive ground space. Under the protected many-aged stand, these interspaces would be occupied by the younger age classes, and the available ground would be more intensively used. And only in the many-aged stand is it possible to secure the big volume increase due to accelerated growth. These two elements in the many-aged stand – complete use of the ground and periodic volume accelerations – make for a much shorter rotation than is possible in the even-aged stand. For instance, if the even-aged method will produce the final yield in 200 years, it is believed that the many-aged method will produce the same aggregate yield in about 175 years.

From the results of this study and from extended observation in the yellow pine forest, the writer tentatively believes that a cutting method producing a many-aged stand is the proper one for this species. In this discussion the method of cutting purposely had been considered only in its broadest and fundamental aspects.

It should be added that as yet the study has conclusively revealed nothing that shows the method now in practice to be radically out of harmony with the habits and requirements of yellow pine, nor has it revealed anything that shows it to be in need of immediate and revolutionary change.

Immediate Application of the Findings

Although the study has not completely covered the field, the data obtained are comprehensive and fruitful of findings, which have immediate application in the present timber sale practice. These findings which are summarized under four headings in this report, will now be considered briefly in the light of their practical bearing.

With regard to accelerated growth the important practical value lies in the knowledge that its occurrence produces a yield at the end of the cutting cycle, which is greatly in excess of that predicted by the present yield tables. Another point is that accelerated growth is best secured when the reserved trees are evenly distributed, and it is abundantly secured when they make up from 20 to 30 per cent by volume of the original stand – as is the present practice in eastern Oregon. The maximum accelerated growth can be obtained under these conditions if the marker selects for reserved trees only those with thrifty crowns and those which will receive the greatest liberation when their neighbors are cut.

With regard to windfall the study shows that a heavy windfall loss – as much as 25 per cent of the reserved stand – is an imminent possibility in the Blue Mountains. This is a very severe loss, but one which it is reassuring to note, is more than offset by the accelerated volume growth.

To reduce the wind risk as much as is in his power, the marker should exercise the greatest care in the choice of reserved trees, and in no event should he leave very tall trees or trees with excessively large crowns. [1] Since the study also indicates that the bulk of the heavy loss occurs in the first 5 years after cutting, it might be possible to provide tentatively in the timber sale plans for the removal of the wind thrown timber at the end of 4 or 5 years. Also as the present knowledge of windfall is enlarged, it may be found that excessive windthrow is confined to certain areas. In such a case, a special adaptation of the cutting method might be practiced – a method in which only the smallest trees and young bull pines are reserved.

In the case of reproduction, the most valuable finding from a practical standpoint is that advance is as a rule more abundant after cutting than subsequent and that it increases its growth and vigor, and even the poorest of it recovers from suppression. Advance should therefore be protected with the greatest care in logging and particularly in brush burning. Because of the increase in height growth and in vigor stimulated by liberation, advance reproduction should be favored as much as possible in marking.

The conclusions with regard to fire find their chief application in connection with slash disposal. They indicate that reproduction is very easily killed by fire running in the grass as well as fire running slash. They show that the heat as well as the flames from intensely burning brush piles kills the reproduction within a considerable radius surrounding the pile, and also kills the lower parts of the crowns of small bull pines close to the pile.

Brush piles should not be made close to young bull pines. Brush burning should not be started too early in the fall before conditions are sufficiently safe to prevent the running of fire. Piles should not be burned so rapidly and intensely that the surrounding reproduction and the crowns of young trees nearby are killed by the heat. The caution with which brush should be burned can not be too much emphasized. The value of the living reproduction on the ground is worth a great deal more than the few cents per M board feet saved by early, hasty and careless brush burning.

Present Status of the Study.

The study thus far has been conducted only in the eastern portion of the Blue Mountains. Here the phases dealing with accelerated growth and fire have been quite completely covered and the data are comprehensive and conclusive. The data on reproduction are complete, but there is still much to be understood regarding the variation in its occurrence and the influence of site factors upon it. The wind fall data are a little too scant, and it is felt that more data should be collected before the present drastic conclusions be accepted as final for the whole Blue Mountain region.

The phases of the study which as yet have not been investigated at all are the following:

(1) The great disproportion in age classes. Apparently the virgin yellow pine forest in eastern Oregon is made up mostly of mature trees and young reproduction with very few intermediate poles and young trees. In the present cutting practice the whole of the reserved stand will be cut at the end of the first cycle 60 years hence. And 120 years hence at the end of the second cycle there will be practically no ripe trees 180 years old; there will exist in the stand only 60 and 120 year old trees, with a few scattered older trees. In other words, there will be no timber to furnish the expected periodic cut at that time. This problem should be studied and it is possible that this can be done in the form of an age survey of cut-over areas. The big timber sale areas on the Whitman Forest with their comparatively fresh stumps should afford an excellent field for this investigation.

[1] See Conclusion in report on "The Windfall Damage on Cut-over Areas – Whitman National Forest." By R. E. Smith and Robt. H. Weitknecht.

(2) The subject of the adaptation of the present yield tables based on virgin growth to the vastly different growth which takes place under cut-over conditions.

(3) The silvicultural aspect of the north slope problem

It is recommended that these phases of the study be investigated next in the same section of the Blue Mountains already studied. It is also recommended that all phases of the study be carried on in the western part of the Blue Mountain region, especially on the Ochoco Forest and perhaps on the Umatilla and Malheur Forests. Here accelerated growth and fire need to be given very little attention, but reproduction and particularly wind fall should be intensively studied, as should also the subject of the distribution of age classes.

Since the yellow pine region of the east slope of the Cascades is known to differ quite considerably from the Blue Mountains with regard to reproduction and windfall, and possibly with regard to age classes, it is recommended that the study be conducted in this region also. But because of the greater economic importance of the timber in the Blue Mountains, it is advisable to complete the study there before undertaking elaborate work elsewhere. It might be well, however, to do a little preliminary work in the Cascades, probably in the region of the Crater Forest where old cuttings are available.

Specifically it is recommended that during the field season of 1916 the study be carried on in the Blue Mountains as suggested, and if there is a little time in the fall, to do some preliminary work on the Crater Forest.

- o 0 o -