YALE UNIVERSITY · SCHOOL OF FORESTRY

BULLETIN No. 7

A PROGRESS REPORT OF THE RESULTS SECURED IN TREATING PURE WHITE PINE STANDS ON EXPERIMENTAL PLOTS AT KEENE, NEW HAMPSHIRE

BY

RALPH C. HAWLEY

Professor of Forestry, and Forester in Charge of the School Forests

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ON EXPERIMENTAL PLOTS AT
KEENE, NEW HAMPSHIRE

PURPOSE OF THE REPORT

IN October, 1905, nineteen permanent sample plots were established in the white pine type near Keene, New Hampshire, by the United States Forest Service in coöperation with the Faulkner and Colony Manufacturing Company on lands owned by the latter. The plots were remeasured in 1909 and again in 1915 by representatives of the United States Forest Service. After the 1915 measurement the plots were turned over to the Yale School of Forestry. In September, 1920, the plots were remeasured for the third time, three additional plots were established and six of the original plots were discontinued. Fifteen years have elapsed since the beginning of the experiments. While the experiments are only partly completed, information of value in reference to the management of white pine has been acquired. The purpose of this publication is to make the information available for foresters and landowners engaged in managing white pine lands.

LOCATION OF THE PLOTS

Keene, New Hampshire, is located in Cheshire County in the southeastern part of the state, approximately 16 miles north of the Massachusetts state line and 13 miles east from the Connecticut River. It is an important New England center of the white pine box and woodworking industries. The area is within the New England white pine region.

Character of the soil.—Within the New England white pine region at least two distinct classes of upland (or well-drained) sites can be distinguished. One consists of the heavier, more fertile soils, the other comprises the lighter, sandier, and more sterile soils. Pure stands of second growth white pine are found on both classes of site, principally on areas cleared for pasture or cultivation and later allowed to grow up to forest. Upon the heavier, more fertile soils the pine meets severe competition from many hardwoods, several of them faster growing in height and more shade

enduring than the white pine. On the lighter, sandier soils fewer hardwoods compete with the pine, and those which do, offer a weaker competition against the white pine than do the same species on the more fertile soils. This difference in character of competition between the pine and hardwoods has important bearing upon the management of the white pine type. Treatment which may be successful upon one class of site will not necessarily be satisfactory upon the other.

The Keene plots are located upon the river plain of the Ashuelot about 50 feet above the level of the river. The soil is a fine, deep sand, droughty in summer. Although level and free from stones the land is considered rather light for agricultural use.

The area may be considered as typical of the second class of upland sites, just described, upon which hardwood competition with pine is weak.

Hence the information contained in this report is applicable primarily to this class of upland sites. It should apply to such sites where found throughout the New England white pine region.

The site quality.—The site may be further classified as lying between Quality II and Quality III and closest to the latter.

This statement is based on comparison of values secured in the unthinned plot, number 604, with corresponding values given in the best existing yield table for white pine.[1] Table 1 shows the comparison.

The average heights of dominant trees, total basal areas and volumes in cubic feet, computed for the years 1905, 1909, 1915, and 1920 when the stand was successively 35, 39, 45, and 50 years of age, have been compared to corresponding values for Quality II and III sites taken from the yield table.

Height was assumed to be the best criterion of site quality, hence this factor was used first in comparing plot 604 with the yield table.

The results of this comparison show that in 1905, when 35 years of age, plot 604 had an average height four per cent above Quality II site values; in 1909, at the age of 39 years, its height was less than one per cent above the Quality II values; in 1915, when 45 years old, the height was midway between Quality II and III; and in 1920, at the age of 50 years, the height was about three per cent above the Quality III site values in the yield table.

If the figures are taken literally the plot has changed during the 15 year period from site II to site III. This anomalous situation must be due to discrepancies in the data. Since plot 604 has remained unthinned the

[1] *White Pine under Forest Management,* by E. H. Frothingham, Bull. 13, United States Department of Agriculture, pp. 21 to 23.

TABLE 1.

*Comparison of heights, basal areas, and volumes in cubic feet on Plot 604 with corresponding figures from the white pine yield table.**

Age of stand	Average height of dominant trees in feet	Actual basal area in square feet	Actual volume in cubic feet	VALUES FROM THE WHITE PINE YIELD TABLE FOR AGES GIVEN IN THE FIRST COLUMN								
				QUALITY I			QUALITY II			QUALITY III		
				Average height of dominant trees in feet	Basal area in sq. feet	Volume in cubic feet	Average height of dominant trees in feet	Basal area in sq. feet	Volume in cubic feet	Average height of dominant trees in feet	Basal area in sq. feet	Volume in cubic feet
35 yrs. in 1905	46.3	161.88	3,823.6	53.0	218	5,200	44.5	193	4,180			
39 " " 1909	50.5	175.88	4,343.6	59.5	232	6,240	50.1	206	4,940			
45 " " 1915	53.4	186.52	4,709.6				58.0	221	6,100	48.5	194	4,500
50 " " 1920	55.8	194.76	5,014.8				64.0	232	7,000	54.0	204	5,200

* *White Pine under Forest Management*, by E. H. Frothingham, Bulletin 13, United States Department of Agriculture, Washington, 1914.

figures, upon which "average heights of dominant trees" are based, had to be secured from hypsometer measurements of standing trees. There may be small errors made in securing the average height of dominant trees under this method but hardly enough to affect the comparison.

Basal area and volume as factors for measuring quality of site usually are considered less reliable than height, because the total basal area or volume depends upon the density of stocking as well as upon the quality of site. It is only in fully stocked stands or in those whose per cent of stocking, as compared to the fully stocked, is known that either basal area or volume can be employed to fix site quality.

When once the quality of site is determined for a given plot the basal area may be used as an indicator of the degree to which the plot is fully stocked.

Taking the height as the indicator of site class and basal area as indicator of degree of stocking the following result is secured when comparing plot 604 with the yield table already used. In securing these figures interpolation has been made between printed values in the yield table.

Plot 604	*Was at age in years*	*Stocked in per cent of a fully stocked stand*
	35	82
	39	85
	45	90
	50	93

In order to check with the yield table the volumes in cubic feet actually measured on the plot at the different ages should be only those proportions of the volumes in the yield table which the basal areas bear to the basal areas of a fully stocked stand. Compared in this way the actual volumes show only slight differences as indicated below from those in the yield table.

THE ACTUAL CUBIC FOOT VOLUMES ON PLOT 604

At age in years	*Differ from the volumes in the yield table by only*
35	6 per cent
39	2 " "
45	2 " "
50	2 " "

In conclusion, height, basal area, and volume as actually measured on plot 604 at intervals for the last fifteen years are in harmony with one

TABLE 2.

Statistics indicating the condition of Plots 601, 602, 603, *and* 604 *in October,* 1905, *when the thinning experiment was initiated.*

Plot numbers	*Number of trees*	*Volume* — *Board feet* (Per Acre)	*Volume* — *Cubic feet* (Per Acre)	*Mean annual growth* — *Board feet* (Per Acre)	*Mean annual growth* — *Cubic feet* (Per Acre)	*Basal area square feet* (Per Acre)	*Diameter of average tree inches*	*Average height of dominant trees feet*	*Age of stand years*
601	778	16,226	3,719.4	464	106	157.17	6.1	46	35
602	902	12,984	3,716.0	371	106	152.76	5.5	45.8	35
603	1,032	14,856	4,056.0	424	116	167.20	5.5	46	35
604	828	15,512	3,823.6	443	109	161.88	6.0	46.3	35
Average	889.5	14,895	3,828.75	425.5	109.25	159.75	5.775	46	
Range in per cent above average	14	9	5½	9	6	5	6	6½	
Range in per cent below average	12½	13	3	13	3	4	5	4	

another and when one is secured from the yield table the others will be found to check closely. But, during the 15 year period the three sets of values run across the yield table from the Quality II to the Quality III columns.

Judging then from the course of development of plot 604 over a 15 year period it would seem that the values in the yield table at different ages and on different qualities of site are not in complete harmony with the natural development of pine stands.

CLASSIFICATION OF THE PLOTS

The permanent sample plots are arranged as follows in two series:

A series to show the results of thinnings; consisting of main plots numbered 601, 602, 603, and 604 ranging in size from 0.25 to 0.5 acres and reproduction plots 601-A, 602-A, and 604-A, each one square rod in area.

A series to show the results of reproducing white pine under shelterwood (the shelterwood method) consisting of main plots Nos. 605, 612, and 614, ranging in size from 0.25 acre to 0.5 acre and reproduction plots Nos. 606-610, 613, and 615-619, covering one square rod each.

THE THINNING EXPERIMENTS

Description of the experiments.—The purpose is to bring out the differences in growth and development resulting from different methods of thinning as compared to unthinned stands. Four plots were established in 1905 in the pure white pine type on a level, sandy area of uniform site quality and with fairly uniform density of stocking and silvicultural condition. The location of the plots with reference to each other is shown on the accompanying diagram.

The relative condition of the four plots at the time of establishment may be judged from the data in Table 2. The small range between the plots in basal area and cubic contents is particularly significant as indicating their similarity.

Table 3 indicates the treatment given the sample plots after their establishment in 1905. It will be noted that plots 601 and 602 have been thinned in the same manner each time; the former with a moderately heavy (C grade) thinning and the latter with a light (B grade) thinning. A direct comparison is thus afforded between light and moderately heavy thinnings.

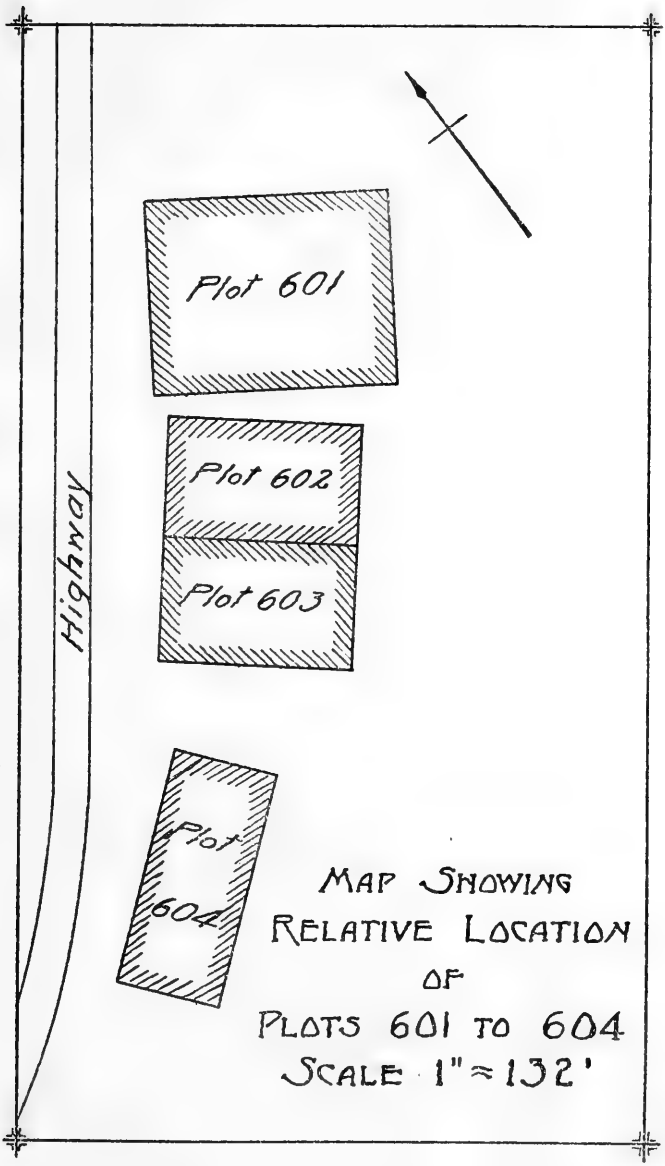
Highway
Plot 601
Plot 602
Plot 603
Plot 604
MAP SHOWING
RELATIVE LOCATION
OF
PLOTS 601 TO 604
SCALE 1" = 132'

TABLE 3.

Record of treatment given the sample plots.

Plot number	*Treatment in year*				*Established in year*	*Remeasured in years*
	1905	1909	1915	1920		
601	Ordinary thinning C grade	No cutting	Ordinary thinning C grade	Ordinary thinning C grade	1905	1909, 1915, and 1920
602	Ordinary thinning B grade	No cutting	Ordinary thinning B grade	Ordinary thinning B grade	1905	1909, 1915, and 1920
603	Thinning Borggreve's method	No cutting	Ordinary thinning C grade	Ordinary thinning C grade	1905	1909, 1915, and 1920
604	Check Plot Unthinned				1905	1909, 1915, and 1920

Plot 603 received in 1905 a heavy selection thinning (Borggreve's method). A number of relatively poorly formed and large crowned dominant trees were removed. To partially cover the openings created by this cutting most of the intermediate and overtopped trees were left standing. Unfortunately the presence of these trees made the removal of the large dominant trees a difficult task. In the logging many of the unmarked lower class trees were destroyed. After the cutting gaps were left, where the large trees stood, which have not closed in the succeeding fifteen years. In 1915 it was decided that to continue thinning among the biggest, dominant trees (Borggreve's method) was unwise, since the portions of the plot from which dominant trees had been taken in 1905 still showed wide gaps in the crown cover, while other portions of the plot were too densely stocked. Many intermediate and overtopped trees were in poor condition. The method of thinning was therefore changed in 1915. In that year and in 1920 plot 603 received C grade thinnings.

A comparison can eventually be drawn between plots 601 and 603 to indicate the results of C grade thinnings when applied with and without a first thinning according to Borggreve's method.

Plot 604 from which no trees have been cut serves as a basis for comparison with the plots which have received thinnings.

On all plots the slash resulting from each thinning, after close utilization of merchantable material, has been left on the ground to decay.

Tables 4 to 12 inclusive show the results so far secured as indicated by the measurements in 1909, 1915, and 1920. The numbers at the head of the columns progress consecutively through all these tables in order to make easy descriptive reference to any column.

Results for the period 1905 to 1909 are less reliable than for the periods 1910 to 1915 and 1916 to 1920 and should be given small weight in drawing conclusions. The reason for this is that many unmarked trees were cut or destroyed by the lumbermen in making the thinnings in 1905 without an adequate record being kept of such losses to the unmarked stand. For further explanation see page 23.

Tables[2] *of statistical data compiled from the measurements taken on the thinned and unthinned plots.*

TABLE 4.

Number of trees per acre in thinned and unthinned stands.

	1	2	3	4	5	6	7
	Number of trees per acre in						
	1905		1909	1915		1920	
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning*
601	778	562	474	460	228	228	202
602	920	744	556	540	352	340	308
603	1,032	928	784	676	276	260	236
604	828	828	804	684	684	600	600

[2] Tables 4 to 12 were compiled from the original measurements by Mr. W. H. Meyer.

TABLE 5.

*Volume per acre in board feet in thinned and unthinned stands.**

	8	9	10	11	12	13	14	15	16	17
	Volume per acre in board feet in†									
	1905		1909	1915		1920				
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning (present stand) Oct. 1, 1920*	*Removed in thinnings in 1905, 1915, and 1920*	*Total yield (14+15=16)*	*Increase between 1905 and 1920 (16–8=17)*
601	16,226	13,766	15,318	20,194	13,588	17,154	15,722	10,498	26,220	9,994
602	12,984	12,192	13,512	17,452	14,460	17,780	16,852	4,712	21,564	8,580
603	14,856	9,620	11,360	16,124	11,152	14,384	13,652	10,940	24,592	9,736
604	15,512	15,512	19,096	22,232	22,232	25,096	25,096		25,096	9,484

*The values in this table are secured by use of Volume Table 24 in *White Pine under Forest Management*, Bulletin 13, United States Department of Agriculture.

† Includes trees 4.6 inches and over in diameter breast high.

TABLE 6.

Mean and periodic annual growth per acre in board feet in thinned and unthinned stands.

	18	19	20	21
	Growth in board feet			
	*Mean annual**	*Periodic annual*		
Plot number	*through the year* 1905	1906 *to* 1909	1910 *to* 1915	1916 *to* 1920
601	464	388	813	713
602	371	330	657	664
603	424	435	794	646
604	443	896	523	573

* Age of stand for all plots was 35 years in 1905.

TABLE 7.

*Volume per acre in cubic feet in thinned and unthinned stands.**

	22	23	24	25	26	27	28	29	30	31
	Volume per acre in cubic feet in									
	1905		1909	1915		1920				
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning (present stand) Oct. 1, 1920*	*Removed in thinnings in 1905, 1915, and 1920*	*Total yield 28+29=30*	*Increase between 1905 and 1920 30–22=31*
601	3,719.4	2,986.0	3,263.0	4,038.8	2,587.8	3,230.6	2,752.6	2,662.4	5,415	1,695.6
602	3,716.0	3,272.0	3,268.0	4,109.2	3,272.8	3,912.0	3,709.6	1,482.8	5,192.4	1,476.4
603	4,056.0	3,044.4	3,144.0	3,759.6	2,213.2	2,765.2	2,654.0	2,669.2	5,323.2	1,267.2
604	3,823.6		4,343.6	4,709.6		5,014.8	5,014.8		5,014.8	1,191.2

*Based on all trees 2.5 inches or over in diameter breast high. The values in this table are secured by use of Volume Table 26 in *White Pine under Forest Management*, Bulletin 13, United States Department of Agriculture.

TABLE 8.

Mean annual and periodic annual growth per acre in cubic feet in thinned and unthinned stands.

	32	33	34	35
	Growth in cubic feet			
Plot number	*Mean annual through the year* 1905	*Periodic annual* 1906 *to* 1909	1910 *to* 1915	1916 *to* 1920
601	106	69.2	129.3	128.6
602	106	—1.0 (loss)	140.2	127.8
603	116	24.9	102.6	110.4
604	109	130	61.0	61.0

TABLE 9.

Basal area per acre in square feet in thinned and unthinned stands.

	36	37	38	39	40	41	42
	Basal area per acre in square feet in						
	1905		1909	1915		1920	
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning*
601	157.17	127.06	128.68	153.28	98.10	113.70	103.70
602	152.76	136.28	127.36	153.80	122.36	138.68	131.64
603	167.20	124.12	124.96	142.40	90.41	98.08	91.88
604	161.88	161.88	175.88	186.52	186.52	194.76	194.76

TABLE 10.

Diameter of the average tree in thinned and unthinned stands.

	43	44	45	46	47	48	49
	*Diameter of average tree in inches in**						
	1905		1909	1915		1920	
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning*
601	6.1	6.4	7.1	7.8	8.9	9.6	9.7
602	5.5	5.8	6.5	7.2	8.0	8.6	8.9
603	5.5	5.0	5.4	6.2	7.8	8.3	8.4
604	6.0	6.0	6.3	7.1	7.1	7.7	7.7

*Secured by dividing the total basal area by the number of trees and finding the diameter corresponding to this average basal area.

TABLE 11.

*Average volume per tree in board feet in thinned and unthinned stands.**

	50	51	52	53	54	55	56
	Average volume per tree in board feet in						
	1905		1909	1915		1920	
Plot number	*Before thinning*	*After thinning*		*Before thinning*	*After thinning*	*Before thinning*	*After thinning*
601	20.9	24.5	32.3	43.9	59.6	75.2	77.8
602	14.1	16.4	24.3	32.3	41.1	52.3	54.7
603	14.4	10.4	14.5	23.9	40.4	55.3	57.8
604	18.7	18.7	23.7	32.5	32.5	41.8	41.8

*Secured by dividing the total volume per acre by the number of trees per acre.

TABLE 12.

Average height of the dominant trees in feet in thinned and unthinned stands.

	57	58	59	60
	*Average height of dominant trees in feet in**			
Plot number	1905	1909	1915	1920
601	46	50	54.7	59.7
602	45.8	49.7	54.7	60.2
603	46	48.3	53	57.7
604	46.3	50.5	53.4	55.8

*Secured by averaging the heights, taken from height curves for each diameter, of all the dominant trees. The height curves used were constructed partly from measurements of the total heights of trees cut on the plots in thinnings, but principally from hypsometer measurements of trees standing on the plots.

Summary of results.—The experiments must continue one to two decades longer before final conclusions can be drawn. Careful study of the figures in these tables should indicate the general effects of the thinnings. Tentative conclusions based on the data now on hand are presented in the following paragraphs.

1. *The thinnings have reduced the number of trees per acre by percentages of the original numbers ranging from 67 to 77.* During the 15 year period from 1905 to 1920 the number of trees per acre on the plot thinned C grade has dropped 74 per cent; on the plot thinned B grade 67 per cent; on the plot first thinned according to Borggreve's method 77 per cent. The decrease on the unthinned plot due solely to natural causes amounts to only 28 per cent.

Starting with 778 to 1,032 trees per acre in 1905 the thinned plots (601, 602, and 603) now contain 202 to 308 trees per acre. The number of trees on the check plot (604) has been reduced by natural causes from 828 to 600. See Table 4.

A comparison of columns 2 and 3 for plots 601, 602, and 603 would seem to indicate a large decrease from natural causes between 1905 and 1909. Most of this decrease is accounted for by injuries to unmarked trees caused by the lumbermen in making the 1905 thinning. The figures in column 2 were compiled before the thinning from tally of the trees to be left rather than from an actual count of the trees left standing by the lumbermen. Many small trees were destroyed.

2. *The reduction in number of trees per acre has concentrated growth on fewer stems of larger average diameter and volume.* See Tables 4, 10, and 11.

This is especially noticeable as a result of the C grade thinnings on plot 601. To illustrate the point the respective values in columns 43, 49, 50, and 56 for plots 601 and 604 are presented side by side.

Column		*Plot* 601	604
43	Diameter of average tree in inches in 1905 before thinning	6.1	6.0
49	Diameter of average tree in inches in 1920 after thinning	9.7	7.7
	Increase in diameter of average tree in inches during the 15 year period	3.6	1.7
50	Average volume per tree in board feet in 1905 before thinning	20.9	18.7
56	Average volume per tree in board feet in 1920 after thinning	77.8	41.8
	Increase in volume per tree in board feet during the 15 year period	56.9	23.1

The advantage is obvious. Fewer but bigger trees on the area tend to lower logging costs and permit the manufacture of larger sized and often better quality material.

3. *Height growth has been stimulated as a result of the thinnings.* See Table 12.

Starting in 1905 with approximately the same average height of dominant trees (column 57), the three thinned plots now have higher values than the check plot (column 60).

The C and B grades of thinning (represented by plots 601 and 602) as yet show little variation in height growth, but are both ahead of the Borggreve thinning (plot 603). This is brought out in the following table:

Table 13.

Showing the effect of thinning upon height growth.

	Average height of dominant trees		*Height growth for period* 1905-20	
Plot number	(*Column* 57) *in* 1905 *feet*	(*Column* 60) *in* 1920 *feet*	*in feet*	*in percentages based on growth on check plot taken as* 100
601	46	59.7	13.7	144
602	45.8	60.2	14.4	152
603	46	57.7	11.7	123
604	46.3	55.8	9.5	100

These figures indicate that height growth may be influenced by the silvicultural treatment of the stand. As a consequence, within the same site class different standards of height growth may have to be recognized.

4. *The actual amounts removed in each of the thinnings are shown for each plot in board feet, cubic feet, and on a percentage basis in Table* 14.

It will be seen that the plot thinned C grade (plot 601) and the one thinned in 1905 according to Borggreve's method (plot 603) and subsequently C grade, are close together in the total amounts removed; though differing as to the percentages taken out in the individual thinnings.

The 1905 thinning on plots 601 and 603 furnishes a good illustration of the difference between the C grade and Borggreve style of thinning.

TABLE 14.

Showing amounts (expressed in board feet and in cubic feet) and percentages removed in thinnings.

Plot no.	Amounts and percentages removed in thinnings in 1905 — Board feet — Amt. per acre	1905 — Board feet — Percentage of total volume	1905 — Cubic feet — Amt. per acre	1905 — Cubic feet — Percentage of total volume	1915 — Board feet — Amt. per acre	1915 — Board feet — Percentage of total volume	1915 — Cubic feet — Amt. per acre	1915 — Cubic feet — Percentage of total volume	1920 — Board feet — Amt. per acre	1920 — Board feet — Percentage of total volume	1920 — Cubic feet — Amt. per acre	1920 — Cubic feet — Percentage of total volume	Column 15 — Total amount per acre removed in all thinnings — Board feet	Column 29 — Total amount per acre removed in all thinnings — Cubic feet
601	2,460	15	733.4	20	6,606	32	1,451	36	1,432	8	478.0	15	10,498	2,662.4
602	792	6	444.0	12	2,992	17	836.4	20	928	5	202.4	5	4,712	1,482.8
603	5,236	35	1,011.6	25	4,972	31	1,546.4	41	732	5	111.2	4	10,940	2,669.2

The former removed 15 per cent of the board foot contents of the stand or 20 per cent of the cubic contents, while the Borggreve cutting took out 35 per cent of the board foot volume but only 25 per cent of the cubic contents. The large percentage of the board foot volume cut is due to the removal of the largest trees which yielded a relatively high content in board feet as contrasted to cubic feet, whereas many of the smaller trees cut in the C grade thinning gave no yield at all in board feet.

The B grade thinnings (plot 602) produced approximately half the volume of the other cuttings.

5. *The basal area per acre is considered one of the best indicators of the character of the thinning. Ultimately a standard basal area per acre can be established for each degree of thinning. After and as a result of each thinning the basal area per acre would be reduced to this standard.*

So far in this experiment no special effort has been made to bring the basal areas to any fixed standard. The basis for selection of the trees has been the crown relations and relative thrift of the individual trees. Inspection of Table 9, particularly columns 40 and 42, indicates that after each of the last two thinnings the basal area of plot 601 (thinned C grade) has been brought down to approximately 100 square feet, while that of plot 602 (thinned B grade) has been reduced to 125 square feet.

In future thinnings on the plots these standards will be used.

A record of the changes in basal area per acre since 1905 is given in Table 9. The discrepancies between corresponding values in columns 37 and 38 are due to the same cause explained under Conclusion 1, page 23.

6. *The annual growth per acre expressed either in board feet or cubic feet has been increased as a result of the thinnings.* Plots 601, 602, and 603, as contrasted to plot 604 indicate this. See Tables 6 and 8.

Results during the first four years after the experiment was started (1906 to 1909) contradict the above statement. See Columns 19 and 33. There may be two reasons for this. First, it may be possible that the beneficial effect of thinning is not always apparent for a few seasons in a stand previously closed. Second and most important in this instance, the large decrease in number of trees on plots 601, 602, and 603 between 1905 and 1909, resulting from injuries to unmarked trees caused by the lumbermen in making the 1905 thinning, greatly reduces or in the case of growth in cubic feet on plot 602 (column 33) completely offsets the growth during the period 1906 to 1909.

The periods 1910 to 1915 and 1916 to 1920 each show large increases in

rate of growth on the thinned plots in both board and cubic feet. (See columns 20, 21, 34, and 35.) As is well recognized measurement in cubic feet affords a better expression of the relative wood producing power of the different stands than does the board foot unit. Consequently the values in columns 34 and 35 are particularly impressive, as indicating the effect of thinning on rate of growth.

The slackening of growth in the unthinned plot (604) is striking as contrasted to the increase in plots 601, 602, and 603.

7. *With a wood capital smaller than in the unthinned stand, a thinned plot gives a higher rate of increase on the invested capital.*

It was shown under the preceding caption that the amount of material actually produced per acre per year was increased. Since the thinnings tend to reduce the total amount of wood capital remaining in the stand at any given age as contrasted to the unthinned stand, it follows that the rate of increase on invested wood capital should in theory be higher in thinned stands.

This theory is borne out by the results of the experiment as shown in Table 15.

TABLE 15.

Showing the per cent of increase on invested wood capital in thinned and unthinned stands.

		Per cent of increase on wood capital present at beginning of period			
		1910 *to* 1915		1916 *to* 1920	
Plot number	*Treatment*	*Capital and increase reckoned in terms of* Board feet	Cubic feet	Board feet	Cubic feet
601	*Thinned*	32	24	26	25
602	"	29	26	23	20
603	"	42	20	29	25
604	*Unthinned*	16	8	13	6

Table 15 has been compiled from the figures in Tables 5 and 7. The period 1906 to 1909 was not considered because of the inaccuracy of the

data relating to the thinned plots after the 1905 thinning. For further explanation see page 23.

The per cent of increase on invested wood capital is from two to four times greater in thinned as compared to unthinned stands. The use of thinnings thus affords not only an opportunity for reduction of the capital invested in the timber, but at the same time increases the amount of growth and its per cent in relation to wood capital.

8. *The decrease in wood capital resulting from thinnings would be of importance in lessening taxable values.* If the volumes in board feet on the unthinned plot at any given time are taken as 100, then the volumes on the thinned plots at the same time are in the following ratio. (Computed from data in Table 5.)

Plot number	*Treatment*	*Volumes expressed as a proportion of the volume of the unthinned plot assumed as* 100	
		After thinning in 1915	*After thinning in* 1920
601	*Thinned*	61	63
602	"	65	67
603	"	50	54
604	*Unthinned*	100	100

Thus the wood capital invested in the thinned stand ranges from 50 to 67 per cent of that in the unthinned stand and ought to carry a correspondingly lower valuation.

9. *The comparatively early financial return secured from sale of material removed in thinnings has a most favorable effect upon reducing the cost of growing a crop of timber as compared to the unthinned stand.* This relation is too well understood to require further elaboration here.

10. *The thinned plots are in more vigorous and healthier condition than the unthinned plot.* This is evidenced by the relatively large number of dead and dying trees in the various plots. Very few dead or dying trees are found in the thinned plots and nearly all the standing trees have opportunity to expand their crowns. In the unthinned plot the large number of living trees prevents even the best dominant trees in the stand from securing adequate room for crown expansion.

11. *Pine reproduction, mixed with some hardwood becomes permanently established as a result of heavy thinnings.* In 1905 when the plots were first established and for a number of years thereafter no figures were taken as respects reproduction. Recently such records have been started, but the

results so far secured do not warrant more than the statement given above. Reproduction starting too early in a rotation may readily become a nuisance and be something to prevent rather than to encourage. How heavy thinnings can be used and still keep out reproduction remains yet to be determined.

12. *Weighing all factors the C grade thinning is considered superior to the B grade or Borggreve thinning.* An inspection of the three thinned plots is of value in reaching this conclusion. The appearance of the stand, and the character and spacing of the individual trees points to the relative desirability of the C grade thinning.

THE EXPERIMENTS IN REPRODUCING WHITE PINE UNDER THE SHELTERWOOD METHOD

As stated on page 10 three main plots and eleven reproduction plots are included in the series. These may be further subdivided into three groups consisting of:

a. Main plot 605 and reproduction plots 606, 607, 608, 609, and 610, illustrating the final stages of the shelterwood method.

b. Main plots 612 and 614 and reproduction plots 613 and 615 illustrating the early stages of the shelterwood method.

c. Reproduction plots 616, 617, 618, and 619 established to show reproduction following shelterwood cuttings, but about which insufficient data were secured at time of establishment to make the plots instructive.

This report will deal primarily with Group a.

Plot 605 of one-half acre in size was established in 1905 in a stand of close-grown pine, which had been lightly thinned in 1900 by the Faulkner and Colony Manufacturing Company, and so heavily thinned by the same company in 1904, as to leave the crowns of the trees barely touching or in the widest gaps 10 feet apart. Following the cuttings an abundant reproduction started under the shelter of the remaining timber. Enough survived the final cuttings to fully stock the area.

The plot was remeasured in 1909. In the winter of 1912-13 the stand was cut clear.

At the time of the first thinning in 1900 the age of the stand was 48 years.

No detailed reports are available to show what was removed at each cutting, further than to indicate that the shelterwood method of reproduction was employed.

To trace the development of the reproduction resulting from these cut-

TABLE 16.

Showing the amount of reproduction following cuttings under the shelterwood method.

A. White pine seedlings.

Plot number	Number of white pine seedlings per acre										Remarks
	Present before the final cutting of 1912–13 and counted in year				Present after the final cutting of 1912–13 and counted in year						
	1905	1909			1915			1920			
	Seedlings originating from seed crop of										
	1904	1904	1907	Total	1904	1907–14	Total	1904	1907–14	Total	
606	88	17	7	24	10		10	10	2	12	
607	87	16		16	12		12	4	9	13	
608	48	22	8	30	7	3	10	1	5	6	*Max. amount of slash in* 1905
609	556	310	57	367	205	3	208	125		125	*Min. amount of slash and max. reproduction*
610	188	118	24	142	102	9	111	86		86	
Average per plot	193	97	19	116	67	3	70	45	3	48	
Total per acre	30,880	15,520	3,040	18,560	10,720	480	11,200	7,200	480	7,680	

B. Species other than white pine.

Plot number	*Amount per acre of reproduction other than white pine* — *Present before the final cutting of 1912–13 and counted in year* 1905	1909	*Present after the final cutting of 1912–13 and counted in year* 1915	1920	*Remarks*
606	1	3	2	4	
607	2	1	3	2	
608					*Max. amount of slash*
609	7	6	3	4	*Min. amount of slash*
610	3	13	1	1	
Average per plot	2.6	4.6	1.8	2.2	
Total per acre	416	736	288	352*	

*Composition: Birch 46 per cent
Cherry 27 " "
Hemlock 9 " "
Basswood 9 " "
Apple 9 " "

tings plots 606, 607, 608, 609, and 610 were laid off on or close to plot 605.

The figures secured from these plots are presented in Table 16.

White pine seedlings at the rate of 30,880 per acre were on the ground when the plot was established in 1905. These seedlings came in after the first thinning made in 1910 and originated from the heavy seed crop of 1904.

In 1920 of these seedlings 7,200 per acre were still alive and together with 480 pine seedlings which started from seed crops subsequent to 1904, formed dense thickets of reproduction averaging 7 to 9 feet in height with some individuals as high as 15 feet.

The causes which resulted in this large decrease in number of seedlings during the fifteen years from 1905 to 1920 can only be surmised, as detailed records of the seedlings which died were not kept in the early stages of the experiments. It seems likely that the beetle Hylobius[3] Pales, known to be in the region, was instrumental in reducing the number of seedlings.

A small amount of hardwood reproduction came in with the pine. In 1905 other reproduction than pine totaled 416 per acre. In 1920, 352 hardwoods (including a few hemlock) per acre, principally birch and cherry, were present.

At the time of each remeasurement the hardwoods which were overtopping pine were cut back to the ground. Very little of this work was needed. Now the pine is free. Hardwood competition with pine has not been a serious factor on these plots.

The small amount of hardwood reproduction and its inability to compete strongly with the pine is attributed to the dry, sandy nature of the site.

The pine tops remaining after the various cuttings were left on the ground as they chanced to fall. Utilization was close and the slash consisted mainly of the pine branches. The effect of this slash in controlling the local distribution of pine reproduction is marked. A comparison in Table 16 of plots 608 and 609 will bring out this point.

Plot 608 represented areas having in 1905 the maximum amount of slash. Plot 609 represented areas having in 1905 the minimum amount of slash cover. This condition is reflected in the pine reproduction on the two plots. Plot 609 had the maximum reproduction of pine, 556 seedlings per square rod, while plot 608 contained only 48 seedlings per square rod.

The following conclusions appear justified from the results secured on plot 605 and its accompanying reproduction plots.

[3] *The Life History and Control of the Pales Weevil* (Hylobius Pales) by H. B. Peirson. Harvard Forest, Bulletin No. 3, Petersham, 1921.

PURE WHITE PINE STANDS

1. *Pine reproduction can be successfully obtained by cuttings under the shelterwood method.*

2. *Hardwood reproduction starts in smaller amounts than pine reproduction but will overtop a portion of the pine seedlings. One or two cleanings to free the pine may be necessary, but should not prove so expensive as on more moist and heavier soils.*

3. *The slash left after thinnings in white pine stands is not abundant enough to prevent reproduction stocking the area, but may lie thick enough over small patches to greatly reduce the amount of reproduction on such spots.*

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