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The Testing of Coniferous Tree Seeds at the School of Forestry, Yale University, 1906-1926

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A Second Progress Report of
The Results Secured in Treating

PURE WHITE PINE STANDS

On Experimental Plots at
Keene, New Hampshire

BY

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A Note to Readers
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CONTENTS

A Second Progress Report of The Results Secured in Treating PURE WHITE PINE STANDS 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 cooperation with the Faulkner and Colony Manufacturing Company on lands owned by the latter.[1] 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 1920 the plots were remeasured for the third time, three additional plots were established and six of the original plots were discontinued. A fourth remeasurement was made in 1925. Subsequent to the 1920 remeasurement a first Progress Report was published as Bulletin NO.7 of the Yale School of Forestry. The last remeasurement (1925) of the plots furnishes information covering an additional five-year period. Although twenty years have elapsed since their initiation, the experiments still are only partly completed. Little definite knowledge is available as to the results of thinnings in white pine. For this reason the results and preliminary conclusions secured in the thinning experiments at Keene have been brought up to date and are presented for the information of foresters and landowners engaged in managing white pine lands.

[1] As a result of a gift made in 1923 by the Faulkner and Colony Manufacturing Company, most of the territory within which the principal plots lie is now included within the Park System of the city of Keene. The Park Commissioner of Keene also is cooperating with the University to continue the experiments.

THINNING

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 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 closer 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.[2] Table I shows the comparison.

The average heights of dominant trees, total basal areas and volumes

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

TABLE I

COMPARISON OF HEIGHTS, BASAL AREAS, AND VOLUMES IN CUBIC FEET ON PLOT 604 WITH CORRESPONDING FIGURES FROM THE WHITE PINE YIELD TABLE*

				Values from the white pine yield table for ages given in the first column					
				Quality II			*Quality III*		
Age of stand	*Average height of dominant trees in feet*	*Actual basal area in square feet*	*Actual volume in cubic feet*	*Average height of dominant trees in feet*	*Basal area in square feet*	*Volume in cubic feet*	*Average height of dominant trees in feet*	*Basal area in square feet*	*Volume in cubic feet*
35 yrs. in 1905	42.1	157.07	3,622.0	44.5	193	4,180	36.0	167	3,100
39 yrs. in 1909	48.3	173.51	4,261.6	50.1	206	4,940	41.2	180	3,644
45 yrs. in 1915	52.3	185.09	4,621.2	58.0	221	6,100	48.5	194	4,500
50 yrs. in 1920	55.6	189.9	4,996.4	64.0	232	7,000	54.0	204	5,200
55 yrs. in 1925	60.5	203.94	5,897.6	69.5	241	7,800	58.0	212	5,870

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

TABLE II

COMPARISON OF PLOTS 601, 602, AND 604

Plot number	*Number of trees*	*Volume*		*Mean annual growth*		*Basal area square feet*	*Diameter* of average tree inches*	*Average height of dominant trees feet*	*Age of stand years*
		Board feet	*Cubic feet*	*Board feet*	*Cubic feet*				
		per acre							
601	778	14,664	3,539.0	419	101.0	155.43	6.1	42.9	35
602	920	13,084	3,572.0	374	102.0	151.83	5.5	43.6	35
604	828	14,256	3,622.0	407	103.5	157.07	5.9	42.1	35
Average	842	14,001	3,578.0	400	102.2	154.78	5.8	42.9	35
Range in per cent									
above average 9		5	1	5	1	1	5	1	
below average 8		7	1	6.5	1	2	5	1	

* As a further test the trees on each plot were separated into four diameter groups, starting with the largest trees and progressing downward. Each group contained the same number of trees with the exception of the lowest groups, comprising the trees of smallest diameter. The diameter of the average tree within each group on each plot was computed. When these diameters for the corresponding groups on the three plots were compared they were found to have a maximum variation of 0.6 of an inch.

in cubic feet, computed for the years 1905, 1909, 1915, 1920, and 1925 when the stand was successively 35, 39, 45, 50, and 55 years of age, have been compared to corresponding values for Quality II and III sites taken from the yield tables. It is evident from inspection of these values that plot 604 should be classed as Quality III.

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. 6°5, 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.

In the present Progress Report only plots 601, 602, and 604 from the series are reported upon to show results of thinnings. Chief interest attaches to these three plots because of the marked difference in treatment accorded each plot.

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. Plots 601, 602, and 604 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 relative condition of the three plots at the time of establishment may be judged from the data in Table II. The small range between the plots in basal area and cubic contents is particularly significant as indicating their similarity.

Table III 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 cqmparison is thus afforded between light and moderately heavy thinnings. Both thinnings have been of the type known as "low" thinnings.

TABLE III

RECORD OF TREATMENT GIVEN THE SAMPLE PLOTS

Plot number	*Treatment in year*					*Established in year*	*Remeasured in years*
	1905	*1909*	*1915*	*1920*	*1925*		
601	Moderately heavy thinning	No cutting	Moderately heavy thinning	Moderately heavy thinning	Moderately heavy thinning	1905	1909, 1915, 1920, and 1925
602	Light thinning	No cutting	Light thinning	Light thinning	Light thinning	1905	1909, 1915, 1920, and 1925
604	Check plot unthinned					1905	1909, 1915, 1920, and 1925

The light thinning removed trees which were completely or nearly overtopped by their neighbors. The moderately heavy thinning took all such trees and in addition removed some of the smaller crowned trees from the main canopy.

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 IV to XII inclusive show the results so far secured as indicated by the measurements in 1909, 1915, 1920, and 1925. The numbers at the left of the lines progress consecutively through all these tables in order to make easy descriptive reference to any column.

Tables of statistical data compiled from the measurements taken on the thinned and unthinned plots:

TABLE IV

NUMBER OF TREES PER ACRE IN THINNED AND UNTHINNED STANDS

		Plot number		
		601	*602*	*604*
		Heavy thinning	*Light thinning*	*Unthinned*
Line No.	*Time*	*Number of trees per acre*		
1	1905 before thinning	778	920	828
2	1905 after thinning	480	556	828
3	1909	480	556	800
4	1915 before thinning	460	540	680
5	1915 after thinning	228	340	680
6	1920 before thinning	228	340	600
7	1920 after thinning	202	308	600
8	1925 before thinning	202	308	560
9	1925 after thinning	148	228	560

TABLE V

BASAL AREA PER ACRE IN THINNED AND UNTHINNED STANDS

		Plot number		
		601	*602*	*604*
		Heavy thinning	*Light thinning*	*Unthinned*
Line No.	*Time*	*Basal area per acre in square feet*		
10	1905 before thinning	155.43	151.83	157.07
11	1905 after thinning	114.05	113.80	157.07
12	1909	128.84	129.73	173.51
13	1915 before thinning	151.30	152.63	184.52
14	1915 after thinning	97.50	119.86	184.52
15	1920 before thinning	113.02	131.41	189.89
16	1920 after thinning	102.45	124.16	189.89
17	1925 before thinning	126.67	151.04	203.94
18	1925 after thinning	100.85	125.71	203.94

TABLE VI

VOLUME PER ACRE IN FEET, BOARD MEASURE, IN THINNED AND UNTHINNED STANDS*

Line No.	*Time*	*Plot number* 601 *Heavy thinning*	602 *Light thinning*	604 *Unthinned*
		Volume per acre in feet, board measure		
19	1905 before thinning	14,664	13,084	14,256
20	1905 after thinning	11,604	10,760	14,256
21	1909	15,032	14,712	18,240
22	1915 before thinning	19,892	19,564	22,272
23	1915 after thinning	13,450	16,488	22,272
24	1920 before thinning	17,148	20,540	25,092
25	1920 after thinning	15,722	19,612	25,092
26	1925 before thinning	21,928	25,336	30,520
27	1925 after thinning	17,562	21,608	30,520
28	Total cut in thinnings	15,294	10,056	
29	Total yield (Lines 27+28=Line 29)	32,856	31,664	30,520
30	Growth between 1905 and 1925 (Lines 29—19=Line 30)	18,192	18,580	16,264

* 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 VII

MEAN ANNUAL AND PERIODIC ANNUAL GROWTH PER ACRE IN FEET, BOARD MEASURE, IN THINNED AND UNTHINNED STANDS

Line No.		*Plot number* 601 *Heavy thinning*	602 *Light thinning*	604 *Unthinned*
		Annual growth in feet, board measure		
31	Mean annual* growth through the year 1905	419	375	407
32	Periodic annual growth for the period 1906 to 1925	910	929	813
33	Periodic annual growth for the period 1906 to 1909	857	988	996
34	Periodic annual growth for the period 1910 to 1915	810	809	672
35	Periodic annual growth for the period 1916 to 1920	740	810	564
36	Periodic annual growth for the period 1921 to 1925	1,241	1,145	1,086

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

TABLE VIII

VOLUME PER ACRE IN CUBIC FEET IN THINNED AND UNTHINNED STANDS*

Line No.	Time	Plot number 601 Heavy thinning	602 Light thinning	604 Unthinned
		Volume per acre in cubic feet		
37	1905 before thinning	3,539.0	3,572.0	3,622.0
38	1905 after thinning	2,538.8	2,590.8	3,622.0
39	1909	3,124.6	3,172.8	4,261.6
40	1915 before thinning	3,973.0	4,028.0	4,621.2
41	1915 after thinning	2,553.0	3,185.6	4,621.2
42	1920 before thinning	3,189.2	3,872.4	4,996.4
43	1920 after thinning	2,912.4	3,668.4	4,996.4
44	1925 before thinning	3,911.8	4,634.8	5,897.6
45	1925 after thinning	3,102.8	3,754.4	5,897.6
46	Total cut in thinnings	3,506.0	2,908.0	
47	Total yield (Lines 45+46=Line 47)	6,608.8	6,662.4	5,897.6
48	Growth between 1905 and 1925 (Lines 47—37=Line 48)	3,069.8	3,090.4	2,275.6

* Based on all trees 2.5 inches and 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 IX

MEAN ANNUAL AND PERIODIC ANNUAL GROWTH PER ACRE IN CUBIC FEET IN THINNED AND UNTHINNED STANDS

Line No.		Plot number 601 Heavy thinning	602 Light thinning	604 Unthinned
		Annual growth in cubic feet		
49	Mean annual* growth through the year 1905	101.1	102.0	103.5
50	Periodic annual growth for the period 1906 to 1925	153.5	154.5	113.8
51	Periodic annual growth for the period 1906 to 1909	146.4	145.5	159.9
52	Periodic annual growth for the period 1910 to 1915	141.4	142.5	59.8
53	Periodic annual growth for the period 1916 to 1920	127.2	137.4	75.0
54	Periodic annual growth for the period 1921 to 1925	199.9	193.3	180.2

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

TABLE X

DIAMETER OF THE AVERAGE TREE IN THINNED AND UNTHINNED STANDS*

Line No.	Time	Plot number 601 Heavy thinning	602 Light thinning	604 Unthinned
		Diameter in inches of the average tree		
55	1905 before thinning	6.1	5.5	5.9
56	1905 after thinning	6.6	6.1	5.9
57	1925 before thinning	10.7	9.5	8.2
58	1925 after thinning	11.2	10.1	8.2

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

TABLE XI

AVERAGE VOLUME PER TREE IN FEET, BOARD MEASURE, IN THINNED AND UNTHINNED STANDS*

Line No.	Time	Plot number 601 Heavy thinning	602 Light thinning	604 Unthinned
		Average volume per tree in feet, board measure		
59	1905 before thinning	18.8	14.2	17.2
60	1905 after thinning	24.2	19.4	17.2
61	1925 before thinning	108.5	82.3	54.6
62	1925 after thinning	118.6	94.8	54.6

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

TABLE XII

AVERAGE HEIGHT OF THE DOMINANT TREES IN THINNED AND UNTHINNED STANDS*

Line No.	Time	Plot number 601 Heavy thinning	602 Light thinning	604 Unthinned
63	1905	42.9	43.6	42.1
64	1909	48.0	47.9	48.3
65	1915	53.7	53.7	52.3
66	1920	59.5	60.2	55.6
67	1925	65.1	65.4	60.5
68	Total height growth for period 1906 to 1925	22.2	21.8	18.4

* 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 and partly from hypsometer measurements of trees standing on the plots.

THINNING

Summary of Conclusions.—The experiments must continue several 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 largely the number of trees per acre.*

In the 20 year period from 1905 to 1925 the heavy thinning removed 81 per cent of the original number of trees. The light thinning caused a similar decrease of 75 per cent. The reduction on the unthinned plot, due solely to death of trees from natural causes, amounted to only 32 per cent of the original number. After the 1925 thinning only 148 trees per acre remain on plot 601, 228 on plot 602 while the unthinned plot 604 still has 560 stems per acre. See Table IV.

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

This is especially noticeable as a result of the heavy thinnings on plot 601. To illustrate the point the respective values in lines 55, 58, 59, and 62 for plots 601 and 604 are presented side by side.

Line		*Plot* 601	604
55	Diameter of average tree in inches in 1905 before thinning	6.1	5.9
58	Diameter of average tree in inches in 1925 after thinning	11.2	8.2
	Increase in diameter of average tree in inches during the 20 year period	5.1	2.3
59	Average volume per tree in feet board measure in 1905 before thinning	18.8	17.2
62	Average volume per tree in feet board measure in 1925 after thinning	118.6	54.6
	Increase in volume per tree in feet board measure during the 20 year period	99.7	37.3

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 XII.

Starting in 1905 with approximately the same average height of dominant trees (line 63), the two thinned plots now have higher values than the check plot (line 67) and have made greater height growth in the 20 year period (line 68). The heavy and light grades of thinning (represented by plots 601 and 602) as yet show little difference in height growth.

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 eventually may have to be recognized.

4. The actual a1nounts of material secured by the thinnings are considerable.

Using the data contained in Tables VI and VIII, it is evident that the total amount cut in thinnings was on the heavily thinned plot 1S,294 feet, board measure (line 28), or 3,s06 cubic feet (line 46) and on the lightly thinned plot 10,oS6 feet, board measure, or 2,908 cubic feet. These amounts were secured in four thinnings on each plot. Each heavy thinning removed on the average approximately 3,800 feet, board measure, or 87S cubic feet per acre, while each light thinning took out approximately 2,SOO feet, board measure, or, 7So cubic feet per acre. The average percentage of the total volume (standing on the plot before the thinning) removed by the thinnings was for the heavy thinnings 20 per cent of the lumber volume or 23 per cent of the cubic feet volume and for the light thinnings 13.S per cent of the lumber volume or 18.S per cent of the cubic volume.

S. The basal area per acre is considered one of the best indicators of the character of the thinning. Ultimately it may be possible to establish a standard basal area per acre for each degree of thinning, other factors being the same. After and as a result of each thinning the basal area per acre would be reduced to this standard.

Until the thinning in 192S no special effort was made to bring the basal areas on the thinned plots to any fixed standards. The basis for selection of the trees had been the crown relations and relative thrift of the individual trees. Inspection of Table V, lines. 14 and 16, indicates that after the thinnings of 191S and 1920 the basal area of plot 601 (heavy thinning) was brought down to approximately 100 square feet, while that of plot 602 (light thinning) was reduced to approximately 12S square feet.

THINNING

In 1925 the two plots were marked for thinning on the same basis of selection as in the earlier thinnings (namely the crown relatibns and relative thrift of the individual trees). Before the marked trees were felled the total basal area which would be left by the preliminary marking was computed. It was found that very few changes were needed to bring the total basal areas left after the thinnings to approximately 100 square feet per acre for the heavily thinned plot and 125 square feet per acre for the lightly thinned plots. This was done with the result shown in Table V, line 18.

6. The annual growth per acre expressed either in feet} board measure} or cubic feet has been increased as a result of the thinnings. Plots 601 and 602 as contrasted to plot 604 indicate this. See Tables VII and IX, particularly lines 32 and 50.

Results during the first four years after the experiment was started (1906 to 1909) contradict the above statement. See lines 33 and 51. It is probable that the beneficial effect of thinning is not always apparent for a few seasons in a stand previously closed.

The periods 1910 to 1915, 1916 to 1920, and 1921 to 1925 each show faster rates of growth in both board and cubic feet on the thinned plots than on the unthinned plot. (See lines 34, 35, 36, 52, 53, and 54.) 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 lines 52 and 53 are particularly impressive, as indicating the effect of thinning on rate of growth.

A remarkable increase in rate of growth on both the thinned and unthinned plots occurred during the period 1921 to 1925. See lines 36 and 54. This increase was particularly large on the unthinned plot, bringing production for this period up nearly as high as the growth on the thinned plots. Differences in climatic conditions between the period 1921 to 1925 and preceding periods are believed to be the cause for the increased growth. Exceptionally favorable climatic conditions not only might increase the total production but might tend to level off temporarily the differences in growth between thinned and unthinned stands.

7. Thinned stands have a smaller wood capital per acre than the unthinned. Hence even though the growth in amount were no greater yet figured as a percentage on invested wood capital the growth in thinned stands would be far greater. Where} as is usually the case} the growth in amount in thinned stands exceeds that in unthinned stands the above relation of growth to invested capital becomes even more striking.

PURE WHITE PINE

Table XIII has been compiled from the original data in Tables VI and VIII to bring out the per cent of increase on invested wood capital in plots 601, 602, and 604.

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 is well brought out in Table XIII, particularly line 72, for the period 1921 to 1925.

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.

TABLE XIII

THE PER CENT OF INCREASE ON INVESTED WOOD CAPITAL IN THINNED AND UNTHINNED STANDS

		Plot number					
		601		602		604	
		Heavy thinning		*Light thinning*		*Unthinned*	
		Per cent of increase on the wood capital present at beginning of the period					
		Capital and increase reckoned in terms of					
Line No.	*Period*	*Feet bd. m.*	*Cubic feet*	*Feet bd. m.*	*Cubic feet*	*Feet bd. m.*	*Cubic feet*
69	1906 to 1909*	29.5	23	37	22	28	18
70	1910 to 1915	32	27	33	27	22	8
71	1916 to 1920	27	25	25	21.5	13	8
72	1921 to 1925	39	34	29	26	22	18

* In this initial period the effect of the thinnings had not yet become apparent.

8. *The decrease in wood capital resulting from thinnings should be of importance in lessening taxable values.* If the volumes in feet, board measure, 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 ratio shown in Table XIV. (Computed from data in Table VI.)

TABLE XIV

VOLUME IN FEET, BOARD MEASURE, EXPRESSED AS A PROPORTION OF THE VOLUME OF THE UNTHINNED PLOT ASSUMED AS 100

Period	*Plot number* 601 *Heavy thinning*	602 *Light thinning*	604 *Unthinned*
	Volumes expressed as percentages		
1905 after thinning	81	75	100
1915 after thinning	60	74	100
1920 after thinning	63	78	100
1925 after thinning	58	70	100

Thus the wood capital invested in the thinned stand ranges from less than 60 to approximately 80 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 relative number of dead and dying trees in the various plots. No such trees are found in the thinned plots while they are numerous on the unthinned plot. The trees on the heavily thinned plot appear to be in better condition than on the other two plots. Every tree has an opportunity to expand its crown. In the unthinned plot the large number of living trees prevents all but the best dominant trees in the stand from securing adequate room for crown expansion.

11. *Pine reproduction is encouraged by heavy thinnings.* When the plots were first established in 1905 and for a number of years thereafter, no figures were taken as respects reproduction. In 1920 such records were started. In the spring following each seed year pine seedlings appear in all the plots, both thinned and unthinned. The pine seedlings in the unthinned plot 604 die within a few years and most of them within one or two years.

In the heavily thinned plot the pine seedlings live on much longer and

are more thrifty and vigorous. The number of older seedlings living on the two plots is one indication of the fact. On plot 601 (heavily thinned) there were in 1925 pine seedlings, five years or older in age, to the number of approximately 6,000 per acre, while on plot 604 (unthinned) there was not a single living pine seedling as old as five years. This is more striking since the number of pine seedlings less than five years of age was practically the same (approximately 6,500 per acre) on each of the two plots.

Whether the present crop of older pine seedlings can continue to live indefinitely under the heavily thinned stand remains to be proven. In any case it appears evident that a crop of pine seedlings adequate in quantity and character to establish a new forest will be always on hand in heavily thinned areas; but in the unthinned area the younger, feebler and less numerous pine seedlings cannot be depended upon to accomplish a similar result.

The lightly thinned plot (602) contains fully as many five-year and older pine seedlings as the heavily thinned plot. The seedlings on the former plot are less vigorous than on the latter and cannot be expected to live many years longer.

12. *Weighing all factors the heavy thinning is considered superior to the light thinning.* An inspection of the two thinned plots is of value in reaching this conclusion. The healthy condition of the stand, the thrifty character and excellent spacing of the individual trees point to the relative desirability of the heavy thinning.

The financial advantages of the heavy thinning as contrasted to the light thinning have been brought out in the preceding pages. They may be summarized by saying that the heavy thinning gives larger returns at each cutting, leaves less wood capital tied up in the forest, thus lessening taxable values, while at the same time producing wood at an equal or greater rate than the lightly thinned stand.

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