THINNING PLANTED RED PINE BY THE PERCENT-OF-HEIGHT METHOD

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

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1962

THINNING PLANTED RED PINE BY THE PERCENT-OF-HEIGHT METHOD

A Thesis

Presented to

the Faculty of the Department of Forestry

Michigan State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Forestry

by

George Edward Dissmeyer

March 1962

G 20829
3/24/62

ACKNOWLEDGEMENTS

The author extends sincere appreciation to Dr. V. J. Rudolph, who, as major professor, supervised the study.

Appreciation is extended to Dr. T. D. Stevens, Head, Department of Forestry, and Dr. D. P. White for their advice and assistance given throughout the author's course of study.

Grateful acknowledgement is also due Mr. M. W. Day, Research Forester, Dunbar Experimental Forest, for his field assistance during the course of the study.

Sincere appreciation is extended to the Department of Forestry, Michigan State University, for making this study available to the author.

ABSTRACT

Because of its growth characteristics, red pine is difficult to thin by methods based either on evidence of stagnation in diameter growth at breast height, or decline in basal area growth. These bases may be misleading, because with increased stand density and stand closure, diameter growth at breast height and basal area growth decline, while diameter growth higher up on the tree continues at a high rate.

Height, which is easily estimated, combines the two factors of site and age into one measurement. This study tests the use of height as the criterion for regulating stand density in making thinnings. The number of trees per acre to leave after thinning is computed so that the average spacing between trees is a desired percent of the height of average dominant trees.

Five thinning treatments differing by 2-percent intervals from 16-percent through 24-percent of the height, plus an unthinned control, were replicated four times in two red pine stands in the Dunbar Forest near Sault Ste. Marie, Michigan. The plantations were established in 1927 and 1928, and were thinned in 1953, 1956, and 1959. Stand changes and growth were computed for the 5-year period 1956-1961. It was found that an average spacing in red

pine equal to 20-percent of the height of the average dominant tree, resulted in the largest basal area and cubic-volume growth over the 5-year period.

It was also found that in closed, even-aged stands, crown position and diameter class at breast height of individual trees could be used to evaluate diameter growth. This relationship can be used as an aid in determining which trees to favor in thinning. Trees of larger diameters at breast height and stronger crown positions should be favored in thinning red pine.

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INTRODUCTION

Red pine, because of its great commercial importance, has had its distribution extended beyond its natural range by plantings during the 1900's. Many of these plantations were made on sites normally not associated with red pine. Today, these plantations are in various stages of development depending upon their ages and sites. Many plantations, because of their high density, need to be thinned. Under these unnatural conditions of wider distribution, and variation in site, the question is presented as to the best thinning method for these plantations.

Red pine growth characteristics create problems in determining the proper time and degree of thinning. Wilson (1955) stated that in plantations with spacings greater than 6 X 6 feet, the young trees, because of a large live-crown ratio, will develop considerable bole taper until the crowns close. At the time of crown closure, there is a high basal area, and diameter growth at breast height decreases, which suggests stagnation and a need for thinning. Actually, the excessive taper reflects an inflated basal area value, and the growth at breast height decreases as the amount of bole taper is reduced in response to crown closure and increased stand density. This change occurs as diameter growth decreases at breast height, while diameter growth higher up on the bole continues at approximately its former rate, as evidenced by the annual rings being wider higher on the bole than at breast height. This growth characteristic reduces the bole taper and increases the merchantable volume of the stem. Therefore, if basal area or diameter growth at breast height is used in programming red pine thinnings, it could result in premature and excessive thinning.

There is need for a better criterion than basal area for governing red pine thinnings that will result in desired levels of growing stock. Wilson (1946) believes that height is such a measure. He has stated that:

> Height, within reasonable limits of stocking is negligibly affected by spacing. It is as suitable for the purpose of simple numerical expression of stocking as it is for determination of site quality. Height has the virtue of combining the components of age and site in one measurement.

The objectives of this study were to test height as the basis upon which red pine thinning should be governed, and to determine the relationships between crown position and diameter at breast height, and diameter growth obtained following several degrees of thinning. Specifically, basal area and volume growth following thinning to several stand densities was investigated. The density, or average spacing between trees was equal to a percent of the average height of the dominant trees.

In marking for thinning, it is important that a forester know which trees to favor and which to cut. If he can recognize some basic tree characteristics indicative of future growth, he can use these in his choice of final crop trees. Crown position and diameter at breast height are two easily recognized characteristics which might be used as indicators of expected growth. The relationships between these two tree characteristics and diameter growth at breast height are determined in this study.

LITERATURE REVIEW

The present knowledge and practices in red pine thinnings are based upon results from basal area, spacing, or volume regulation studies. Only until recently has any work been done with the percent-of-height method of thinning red pine, and, as yet no definite recommendations are available. European literature presents some recommendations for native species based upon the percent-of-height method. Hummel's (1954) density index system, as cited by Braathe (1957), called the average spacing equal to 20-percent of the average height of the dominant trees the standard density, based on square arrangement of the trees. This standard spacing is given the index value of 1.0, and corresponds closely to the general thinning grade adopted in practice for conifers in Great Britain (except for larch). Hummel's density-index system was developed for even-aged stands treated with low thinnings or with free thinnings, but Hummel implied also that the system could be used in crown thinning of stands.

At the same Congress in 1954 where Hummel presented his paper, Becking (1954), as cited by Braathe, (1957), also put forward a proposal nearly identical to Hummel's. The main difference was that Becking calculated the number of trees on a triangular arrangement and expressed the spacing as a percent of height. He also implied that thinning grades should be separated by 3-percent intervals.

American literature on the percent-of-height thinning method describes work done by Wilson (1946, 1955). However, Wilson merely discussed the theory of the method and its use on red pine. He describes growth characteristics of red pine where it develops excessive bole taper before crown closure, which results in an inflated basal area value. At crown closure, red pine "corrects its form," which results in decreased growth in basal area and diameter at breast height. Wilson states that the use of basal area or diameter growth in programming red pine thinnings could result in premature and excessive thinning.

Wilson proposed the used of height for programming red pine thinnings. Height has the virtue of combining age and site into one measurement, and is suitable as a base for a numerical expression of spacing. The spacing is based upon a percent of the average height of dominant trees. For example, if the average dominant height is 60 feet, and the spacing is equal to 20-percent of that height, the average spacing equals 12 x 12 feet.

Wilson makes the following general statements about the percent of height to be used in thinning, which he calls the _f_ factor:

1. The _f_ factor decreases with increased tolerance.
2. Site has no effect on the _f_ factor.
3. The _f_ factor definitely increases where suppressed trees are eliminated from the stand.

4. The f factor varies with the natural ability of species to thin out with age.

However, Wilson's study has not reached the point where he can draw definite conclusions and make specific recommendations, for thinning red pine. In discussing red pine stands Engle and Smith (1952) stated that:

> Spacing, when given as a percentage of height, appears to provide a good indication of the degree of stocking in the stand. From the data, it seems that red pine stands need thinning when spacing of the trees is less than 20% of total height.

This statement was not supported by statistical analyses, but was derived from empirical observation of data.

Diameter growth relationship to crown position was studied by Rudolph (1959). For Scotch pine planted in Michigan, he found that:

> Dominant trees in the thinned areas grew significantly more in diameter than dominant trees in the control areas. Dominant trees favored by thinning grew more in diameter than codominant trees in both thinned and unthinned areas. In the control areas, diameter growth of dominant trees was significantly greater than that of codominant trees. Codominant trees in thinned areas grew significantly more in diameter than codominant trees in the control areas, but not quite as much as the dominant trees in the control areas.

Staebler (1956) studied the effect of different degrees of release on Douglas fir in dominant, codominant, and intermediate crown classes. He used four treatments in releasing the trees by removing 0, 1, 2, or 3 competitors around each tree. With respect to diameter growth by crown position he found that, "three years following treatment, dominants grew more than codominants, and the codominants grew more than intermediates." In this same study, he found that, "growth is strongly related to d.b.h. within crown class and treatment classifications."

Engle (1952) also made observations on red pine stands, relating diameter growth to crown position in thinned and unthinned areas, but made no comparison within individual treatments. He merely stated that, "the dominant and co-dominant trees on the thinned plots grew almost twice as much in diameter as corresponding trees on the unthinned portion of each stand."

DESCRIPTION OF THE PROJECT AND STUDY AREA

The red pine plantations used in this study are located in Michigan State University's Dunbar Experimental Forest, 17 miles south of Sault Ste. Marie, Michigan, on a relatively flat, old field area of Trimley very fine sandy loam. The study plots within the plantations have site indexes between 65 and 75. The site index estimates were made by using the site index curves given by Brown and Gevorkiantz (1934) based on height of the dominant stand at 50 years of age. The sites tend to have more soil moisture than sites usually occupied by red pine.

The climate here is typical of the northern Lake States, but is modified slightly by the neighboring Great Lakes. The yearly mean temperature is 41° F., and the summer and winter three-month means are 63° F. and 15° F., respectively. The mean annual precipitation is 30.46 inches, and is usually distributed nearly evenly throughout the year, except for a few short dry periods common during the summer.

The plantations were established in May 1927, and May 1928 by planting 2-0 red pine stock at a spacing of 6 x 6 feet. The 1927 planting was in furrows, and the 1928 planting was in disked fields. Survival was good, considering stock size and density of grass cover in the fields at that time.

The stand conditions before thinning in 1953 were somewhat varied. The number of trees varied from 652 to 726 trees per acre, averaging 692 trees per acre. The basal area averaged 176 square feet per acre, but ranged between 163 and 189 square feet per acre. The merchantable volume averaged 2,273 cubic feet per acre, but ranged from a minimum of 2,07[illegible] to a maximum of 2,516 cubic feet per acre. The average dominant-tree height and stand density were fairly uniform throughout the plantations. They were 3[illegible] feet and 21-percent of the average dominant-tree height, respectively.

THINNING TREATMENTS

This study was designed to test the use of height as the controlling criterion in determining desired residual stand density following thinning. The computation of the required number of trees per acre, in uniformly stocked even-aged stands of a given height can be derived by the following formula:

$$n = \frac{43,560}{(hf)^2}$$

Where;

<u>n</u> is the number of trees left per acre,

<u>h</u> is the height of the average dominant tree in the stand, and

<u>f</u> is the percent of height used to determine stand density.

Expressed more simply, if the factor <u>f</u> is constant, the equation means that the ratio of the number of trees to the square of the dominant height is the same for all ages and all sites.

Five spacings at 2-percent intervals, between 16- and 24-percent of the average dominant-tree height, were tested in this red pine thinning experiment. Four replications of each treatment and four controls were established. Plots were of two sizes, 1/10- and 1/5-acre. The first thinnings were made in 1953 on the 20- and 24-percent plots. In the other plots, which were to be thinned to different spacings, the average dominant height had not reached the height where it appeared necessary to thin. Expressed simply, the average growing space per tree in the remaining unthinned plots was greater than the minimum growing space allotted per tree, as computed from the percent of height for each treatment. In 1956 and 1959, further thinnings were made; however, the 16-percent plots still were not dense enough to need thinning.

Measurements were made in 1953, 1956, 1959, and 1961. In the 1956, 1959, and 1961 measurements, crown position was evaluated in addition to diameter at breast height for each tree in each plot. The average height of dominants was determined by measuring the heights of ten randomly selected dominant trees in each plot. All data for each tree were punched into tabulating cards. These cards were processed by electric tabulation machines. Basal areas and cubic-foot volumes were computed by machine and punched into the cards. The stand and stock tables were compiled by machine tabulation. Also, these cards and tabulating machines were used in all statistical analyses.

Crown position was classified into six categories: head dominants, strong dominants, conditional dominants and co-dominants, weak dominants and co-dominants, intermediates, and suppressed (Gevorkiantz, et. al., 1943). A complete classification description for each position can be found in the Appendix. Diameter at breast height was measured with a diameter tape at a marked height on each tree.

Several statistical analyses were made, testing the various relationships being investigated. Analysis of variance was used to test (1) the differences in crown position between treatments and controls, (2) the changes in crown position between 1956 and 1961 for all crown positions and treatments, and (3) the changes of each 1956 crown position to 1961 crown positions. Linear correlation was used to test, (1) the relationship between 1956 crown position, and 1956 to 1961 diameter growth at breast height, and (2) the relationship between 1956 diameter class and 1956 to 1961 diameter growth. Regression coefficients for diameter growth over 1956 crown position, and diameter growth over 1956 diameter class were computed for each treatment.

RESULTS AND DISCUSSION

During the development of a stand, the individual crowns change positions with respect to their neighbors, depending upon their aggressiveness and their original positions in the canopy. These changes were investigated to ascertain if they were significant for the 1956 to 1961 period, and to determine if there were significant differences between thinning treatments.

Crown Position Movements

An analysis of variance, combining crown positions from all treatments, testing the crown position changes for the 1956 to 1961 period, show that the average crown position has not significantly changed. Further analysis reveals two conspicuous, and opposite trends. These were revealed when percentage changes from each 1956 crown position to some other 1961 crown position were computed for each treatment. Except for the suppressed trees, the lower three crown classes show improvement in their crown position. The suppressed trees are present only in the control, 16, and 1[illegible]-percent treatments.

The opposite trend exists in the upper crown positions. After thinning, the crowns expand, filling the canopy vacancies left by the crowns removed. Under these conditions, these expanding crowns were classified in stronger crown

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The opposite trend exists in the upper crown positions. After thinning, the crowns expand, filling the canopy vacancies left by the crowns removed. Under these conditions, these expanding crowns were classified in stronger crown positions, because crown competition was absent. In time, the canopy closed, and the upper crown positions again experienced competition. The expression of dominance decreased with the increased competition, and many trees were classified in less dominant positions than before. Thus, the upper crown positions were forced into less dominant crown positions.

These trends are normal for thinned even-aged stands, but do not hold for unthinned even-aged stands. In the unthinned even-aged stands, the canopy is composed of crowns in all positions. This is the result of competition forcing the weaker trees into progressively less dominant positions. However, the aggressive trees will maintain their positions. As stand density increases, the weak trees are forced into progressively weaker crown positions until they are suppressed and die. This process is continuous in a maturing even-aged stand. Therefore, the canopy remains dispersed in its crown-position distribution.

On the other hand, thinnings will narrow the crown-position distribution within the canopy. In low thinning, the suppressed and intermediate crown positions are eliminated, favoring the upper crown positions. This was the basic type of thinning applied in this study, although it was modified by adding some crown thinning to secure a uniform spacing throughout each plot. The thinnings created openings in the canopy, thus releasing the codominants and intermediates so that they could expand their crowns and increase their terminal growth. These trees improved their crown positions with respect to their neighbors. Also, the openings in the canopy allowed the dominant trees to expand their crowns, and assume even stronger crown positions. However, in time, these trees again experienced crown competition and some of them assumed less dominant positions. Therefore, thinned, even-aged stands have canopies with narrower crown-position distributions than unthinned stands.

Analysis of variance showed that these trends and crown position movements were significant. The trees in the suppressed crown position did not change because they were in the control and 15-percent treatment plots, and were not released by thinning. The provisional dominants and codominants did not significantly change their crown position because they were the focal point of the trends. In other words, the upper crown positions moved toward the provisional dominant and codominant crown position, and so did the lower crown positions. Therefore, the opposite trends made the over-all analysis of variance not significant (TABLE 1).

TABLE I

ANALYSIS OF VARIANCE FOR DIFFERENCES
BETWEEN 1956 AND 1961 CROWN POSITIONS

Test	F Ratio	Degrees of Freedom V_1	Degrees of Freedom V_2
All Crown Positions From All Treatments	0.815***	1	4,142
The Upper 1956 Crown Position Movements to 1961 Crown Positions	195.0*	1	3,533
The Lower 1956 Crown Position Movements to 1961 Crown Positions	3.642**	1	653
1956 Head Dominant Movement to 1961 Crown Positions	594.4*	1	426
1956 Strong Dominant Movement To 1961 Crown Positions	311.7*	1	956
1956 Provisional Dominant and Codominant Movement to 1961 Crown Positions	0.025***	1	629
1956 Weak Dominant And Codominant Movement To 1961 Crown Positions	720.7*	1	376
1956 Intermediate Movement to 1961 Crown Positions	3.831**	1	181
1956 Suppressed Movement To 1961 Crown Positions	1.000***	1	14

*Significant at the 99% level.
**Significant at the 95% level.
***Not Significant.

Crown Position Differences Between Treatments And Controls

Analysis of variance, combining all treatments, showed that the average crown position was not significantly different between treatments. This was to be expected, because the controls, the 16-, and two 12-percent treatment plots had not been thinned. However, analysis of variance showed significant differences between the 12-, 20-, 22-, and 24-percent treatments and the controls. (TABLE II).

The Relationship Between Diameter Growth And Crown Position

Five-year diameter growth and 1956 crown position were found to be significantly correlated. This was true for all treatments and controls. The correlation coefficients decreased from 0.565 for the control plots, to 0.365 for the 24-percent treatment plots (TABLE III). The correlation coefficients decreased with increased degree of thinning. This uniform decrease in correlation coefficients with increased degree of thinning was expected. Thinning increased the growing space for the residual trees, allowing them to grow at a more uniform rate, and reducing the influence of crown position. The heavier the thinning, the more uniform will be the resulting growth. The regression coefficient for the treatments and controls substantiate this trend. The control plots had a regression coefficient of -0.159, as compared with -0.116 for the 24-percent-of-height thinning plots (TABLE IV). The regression coefficients decreased with increased levels of thinning as did the correlation coefficients.

TABLE II

ANALYSIS OF VARIANCE FOR CROWN-POSITION DIFFERENCES

Test Between Controls and	F Ratio	Degrees of Freedom	
		V1	V2
18%	43.2*	1	758
20%	3.84*	1	698
22%	26.1*	1	687
24%	35.4*	1	613

*Significant at the 95% level.

The 22-percent treatment deviated substantially from this uniform trend as evidenced in TABLE III. Here the correlation coefficient was considerably below the others, and had a lesser 95 percent significance. This deviation suggests that conditions are not uniform within the 22-percent treatment plots. One replicate in this treatment has a site index of 67, while the other three plots have site indexes of 73, 73, and 74. The canopy on the site index 67 plot was not closed at the time of the 1961 measure-

TABLE III

LINEAR CORRELATION BETWEEN 1956 CROWN POSITION AND 5-YEAR DIAMETER GROWTH, 1956-1961

Treatment	Correlation Coefficient	Level of Significance 95%	Level of Significance 99%	Degrees of Freedom
Control	-0.665		x	415
16%	-0.4[illegible]0		x	502
18%	-0.470		x	364
20%	-0.410		x	303
22%	-0.164	x		294
24%	-0.365		x	222

TABLE IV

REGRESSION COEFFICIENTS OF 5-YEAR DIAMETER GROWTH OVER 1956 CROWN POSITION FOR EACH TREATMENT

Treatments	Regression Coefficient
Controls	-0.157
16%	-0.122
18%	-0.124
20%	-0.121
22%	-0.03[illegible]
24%	-0.116

ments; therefore, the trees were mostly strong dominants and codominants. Diameter growth was slow and generally uniform for all crown positions on this plot. When data for this plot were combined with those for the other plots in the treatment, the regression and correlation coefficients for this treatment were substantially reduced.

The relationship of diameter growth to crown position is the strongest in the control plots. The stand density in the control plots was greater than in the thinned plots. The regression coefficient of diameter growth over crown position for the control plots was -0.159. Therefore, the head dominants grew 0.159 inches in diameter at breast height more than the strong dominants, and the latter grew 0.159 inches in diameter more than the provisional dominants and codominants, etc. In the control plots, because of high density, the trees are strongly affected by competition. The regression coefficient shows the advantage the head dominants have over the strong dominants, and the strong dominants have over the provisional dominants and codominants, etc., in producing diameter growth. The regression equation gives 0.815, 0.656, and 0.497 inches of diameter growth for the head dominants, strong dominants, and provisional dominants and codominants, respectively, on the control plots, for the 1[illegible] to 1[illegible]1 period. Thus, crown position can be used to evaluate diameter growth of individual trees, which will aid in selecting the trees to be favored in thinning operations in closed stands.

In open stands, this relationship is not as strong as in closed stands. The trees are not subjected to as much crown competition, and diameter growth is fairly uniform for all crown positions. The regression coefficient for the 24-percent treatment was only -0.116. Here, the advantage of a better crown position has a smaller influence on diameter growth. Therefore, this relationship can be used with greater confidence in selecting trees to favor in thinning dense stands than stands of lower density.

<u>The Relationship of Diameter Growth to Diameter at Breast Height.</u>

Diameter class was also investigated and tested for evaluating diameter growth. It was found, irrespective of treatment, that diameter growth was significantly correlated to diameter class. The correlation and regression coefficients for this relationship, as those for diameter growth over crown position, decreased with increasing degree of thinning (TABLE V). The regression value for the lowest density plots (24-percent treatment) showed that the diameter growth was almost uniform for all diameter classes. The controls, on the other hand, had a definite regression slope of 0.15. The stands of the control plots fully occupy the site, and the strong competition between individuals is reflected in the diameter at breast height of each tree. The trees which are competing successfully, will produce good diameter growth each year. These trees will have larger diameters than those which are competing less favorably. In even-aged stands, the trees with the larger diameters are growing in diameter faster than those with smaller diameters. On the other hand, in even-aged stands which do not fully occupy the site, diameter growth tends to be uniform irrespective of diameter class. This is primarily due to the lack of competition. Therefore, diameter class can be used to evaluate diameter growth in closed stands, whereas in open stands it is of lesser value.

TABLE V

CORRELATION AND REGRESSION COEFFICIENTS FOR 5-YEAR DIAMETER GROWTH OVER 1956 DIAMETER CLASS BY TREATMENT

Treatment	Correlation Coefficient*	Regression Coefficient	Degrees of Freedom
Controls	0.909	0.147	417
16%	0.616	0.114	504
18%	0.479	0.080	366
20%	0.354	0.046	305
22%	0.395	0.061	296
24%	0.146	0.022	225

*All correlations significant at the 95% level.

fully occupy the site, and the strong competition between individuals is reflected in the diameter at breast height of each tree. The trees which are competing successfully, will produce good diameter growth each year. These trees will have larger diameters than those which are competing less favorably. In even-aged stands, the trees with the larger diameters are growing in diameter faster than those with smaller diameters. On the other hand, in even-aged stands which do not fully occupy the site, diameter growth tends to be uniform irrespective of diameter class. This is primarily due to the lack of competition. Therefore, diameter class can be used to evaluate diameter growth in closed stands, whereas in open stands it is of lesser value.

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Treatment	Correlation Coefficient*	Regression Coefficient	Degrees of Freedom
Controls	0.979	0.147	417
16%	0.616	0.114	504
18%	0.479	0.080	366
20%	0.354	0.046	305
22%	0.396	0.061	296
24%	0.146	0.029	225

*All correlations significant at the 95% level.

Basal Area and Cubic-Foot Volume Growth

Basal area and cubic-foot volume growth were highest in the 20-percent-of-height treatment plots, but the basal area and volume production was lowest in the control plots. The five-year volume production for the 18- and 22-percent treatments were 871.3 and 854.2 cubic feet, respectively, with 925.4 cubic feet produced by the 20-percent treatment. The 20-percent treatment basal area production was 43.335 square feet, compared to 34.036 and 33.504 square feet for the 18- and 22-percent treatments, respectively (TABLE VI).

The largest volumes per acre were present on the control, 16-, and 18-percent treatments in 1961. The 20-percent treatment had slightly less volume, but substantially more than the 22-, and 24-percent treatments.

Thinnings during the five-year period were made in the 18-, 20-, 22-, and 24-percent plots (TABLE VI). The trees cut were generally small in diameter, and from the lower crown positions.

Mortality

Mortality between 1956 and 1961 was confined to the controls, 16-, and 18-percent treatments. Only one 2-inch tree died in the 16-percent treatment area, whereas mortality in the 18-percent treatment and controls, accounted for 1.371 and 1.350 square feet of basal area, respectively

TABLE VI

NET BASAL AREA AND CUBIC-FOOT VOLUME GROWTH PER ACRE FOR THE 5-YEAR PERIOD, 195[illegible]-1961

Treatment	Growth		195[illegible] Thinnings		Net Growth	
	B. A.	Vol.	B. A.	Vol.	B. A.	Vol.
	Sq.Ft.	Cu.Ft.	Sq.Ft.	Cu.Ft.	Sq.Ft.	Cu.Ft.
Controls	1[illegible].372	5[illegible]0.[illegible]	-	-	13.372	5[illegible].[illegible]
16%	20.501	73[illegible].0	-	-	20.501	73[illegible].0
18%	28.107	[illegible]37.2	5.929	34.1	34.03[illegible]	871.3
20%	30.202	736.4	13.133	1[illegible]9.0	43.335	92[illegible].4
22%	21.[illegible]	672.[illegible]	11.646	1[illegible]1.6	33.[illegible]04	[illegible]54.2
24%	19.20[illegible]	557.4	14.[illegible]	201.6	33.214	75[illegible].0

TABLE VII

MORTALITY DURING THE 5-YEAR PERIOD, 195[illegible]-19[illegible]1

Treatment	Growth Loss	
	Basal Area	Volume
	Sq. Ft.	Cu. Ft.
Controls	1.350	1.1
16%	1.371	-
18%	0.[illegible]16	-

(TABLE VII). Mortality was generally confined to the 3- and 4-inch diameter classes, and death was due to suppression. Animals, insects, and disease were not factors in mortality. Therefore, the thinning to an average spacing equal to 20-percent of the average dominant-tree height resulted in maximum basal area and cubic-foot volume growth with no losses to mortality for the five-year period.

SUMMARY AND CONCLUSIONS

The red pine plantations used in this study are located in Michigan State University's Dunbar Experimental Forest, 17 miles south of Sault Ste. Marie, Michigan, on a relatively flat, old field area of [illegible] very fine sandy loam. The two plantations were established in May 1927, and May 1928 by planting 2-0 red pine stock at a spacing of 6 x 6 feet. Five degrees of thinning were tested in this study. The five spacings were at 2-percent intervals between 16- and 24-percent of the average dominant-tree height. Each treatment and control was replicated four times.

The first thinnings were made in 1953 in the 22- and 24-percent plots. In 1956 and 1959, thinnings were made on all treatment plots, except the 16-percent plots, which had not reached sufficient density to need thinning. It was found that spacing in red pine, equal to 20-percent of the average dominant-tree height, resulted in the largest basal area and volume growth for the 5-year period, 1956-1961.

In closed stands, crown position and diameter class of individual trees can be used to evaluate diameter growth. These relationships vary with the degree of thinning. In the 24-percent treatment, the use of either crown position or diameter class alone, or both characteristics combined in evaluating diameter growth, is of little value. In this wide spacing, diameter growth is nearly uniform for all trees. Competition between trees in the 24-percent treatment stands is at a minimum. However, thinning to a spacing equal to 20-percent of the average dominant-tree height appears to maintain a stand density in which crown position and diameter class can be used reliably to evaluate diameter growth. These relationships can be used with confidence in closed red pine stands. In general, therefore, trees of larger diameter and stronger crown position should be favored in thinning red pine.

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APPENDIX

TREE CLASSIFICATION[1]

1. Head dominants are trees which dominate all their immediate neighbors and have crowns which are definitely above the general level of the canopy.

2. Strong dominants are those which compete directly with trees of the same crown class but of poorer development.

3. Conditional dominants and codominants compete with other trees of the same crown class and development and are not in immediate danger of being crowded out of the stand.

4. Weak dominants and codominants are those competing with other trees of better development but not better crown class.

5. Intermediates occupy small holes in the canopy but compete with trees of higher crown class and development.

6. Suppressed trees are those definitely below the general level of the canopy.

1/Source: Gevorkiantz, S. R., P. O. Rudolf, and P. J. Zehngraff 1943. A tree classification for aspen, jack pine, and second-growth red pine. Jour. Forestry 41: 268-274.

PERCENTAGE CHANGE OF 1956 CROWN POSITIONS TO OTHER 1961 CROWN POSITIONS

CONTROL PLOTS

1956 Crown Position	1961 Crown Positions					
	6	5	4	3	2	1
	Changes in Percent					
6	100.0	-	-	-	-	-
5	15.0	60.0	20.0	-	5.0	-
4	-	13.2	76.3	10.5	-	-
3	-	-	22.5	67.5	10.0	-
2	-	0.7	1.4	44.6	50.6	2.7
1	-	-	-	3.7	66.7	29.6

16-PERCENT TREATMENT

1956 Crown Position	1961 Crown Positions					
	6	5	4	3	2	1
	Changes in Percent					
6	83.3	16.7	-	-	-	-
5	26.0	54.0	20.0	-	-	-
4	-	11.9	61.9	23.8	2.4	-
3	0.8	-	29.4	61.4	8.4	-
2	-	-	5.5	74.3	19.3	0.9
1	-	-	-	50.7	44.9	4.4

10-PERCENT TREATMENT

1956 Crown Position	1961 Crown Positions					
	6	5	4	3	2	1
	Changes in Percent					
6	100.00	-	-	-	-	-
5	-	61.5	38.5	-	-	-
4	-	-	75.8	13.8	10.4	-
3	-	-	22.1	55.8	22.1	-
2	-	-	2.4	41.3	54.0	2.4
1	-	-	-	17.3	37.9	44.8

20-PERCENT TREATMENT

1956 Crown Position	1961 Crown Position 6	5	4	3	2	1
			Changes In Percent			
6	-	-	-	-	-	-
5	-	-	-	-	-	-
4	-	-	100.0	-	-	-
3	-	-	78.1	21.9	-	-
2	-	-	26.3	60.0	13.7	-
1	-	-	-	50.0	47.2	2.8

22-PERCENT TREATMENT

1956 Crown Position	1961 Crown Position 6	5	4	3	2	1
			Changes In Percent			
6	-	-	-	-	-	-
5	-	42.9	42.9	14.2	-	-
4	-	-	56.5	34.8	8.7	-
3	-	-	2.3	62.5	35.2	-
2	-	-	-	31.4	64.2	4.4
1	-	-	-	5.0	55.0	40.0

24-PERCENT TREATMENT

1956 Crown Position	1961 Crown Position 6	5	4	3	2	1
			Changes In Position			
6	-	-	-	-	-	-
5	-	-	-	-	-	-
4	-	-	23.5	53.0	23.5	-
3	-	-	5.4	44.6	50.0	-
2	-	-	0.9	21.4	71.7	6.0
1	-	-	-	21.1	66.7	12.2

REGRESSION EQUATIONS FOR DIAMETER GROWTH BASED ON 1956 CROWN POSITIONS FOR EACH TREATMENT

General Equation Form:

DBH Gr. = Mean Growth - Regression Coefficient x (Crown Position - Mean Crown Position)

Controls:

DBH Gr. = 0.545 - 0.159(X - 2.70)

16-Percent Treatment:

DBH Gr. = 0.613 - 0.122(X - 2.52)

18-Percent Treatment:

DBH Gr. = 0.614 - 0.124(X - 2.54)

20-Percent Treatment:

DBH Gr. = 0.702 - 0.121(X - 2.36)

22-Percent Treatment:

DBH Gr. = 0.530 - 0.039(X - 2.45)

24-Percent Treatment:

DBH Gr. = 0.818 - 0.116(X - 2.23)

REGRESSION EQUATIONS FOR DIAMETER GROWTH BASED ON 1956 DIAMETER CLASS FOR EACH TREATMENT

General Equation Form:

DBH Gr. = Mean Growth + Regression Coefficient x

(Diameter Class - Mean Diameter)

Controls:

DBH Gr. = 0.545 + 0.147(X - 7.26)

16-Percent Treatment:

DBH Gr. = 0.618 + 0.114(X - 7.37)

18-Percent Treatment:

DBH Gr. = 0.614 + 0.070(X - 7.67)

20-Percent Treatment

DBH Gr. = 0.702 + 0.046(X - 7.87)

22-Percent Treatment:

DBH Gr. = 0.630 + 0.061(X - 7.70)

24-Percent Treatment:

DBH Gr. = 0.818 + 0.027(X - 7.95)

1956 STAND AND STOCK TABLES
PER-ACRE BASIS

CONTROLS

Diameter Class	No. of Trees	Basal Area Sq. Ft.	Volume Cu. Ft.
2	3	0.077	-
3	21	1.100	-
4	45	3.975	-
5	78	10.617	86.17
6	97	19.342	232.00
7	145	47.433	673.33
8	217	74.302	1,213.33
9	93	46.910	829.00
10	35	18.170	343.00
11	2	1.320	20.50
Totals	722	223.286	3,396.33

15-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area Sq. Ft.	Volume Cu. Ft.
2	2	0.071	-
3	27	1.359	-
4	36	3.069	-
5	69	9.138	75.63
6	79	15.416	153.00
7	141	37.070	532.00
8	179	61.249	1,001.00
9	111	47.906	834.38
10	42	25.519	477.75
11	8	4.579	92.25
Totals	701	205.636	3,166.01

1956 STAND AND STOCK TABLES
PER ACRE BASIS

16-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
1	3	0.016	-
2	10	0.193	-
3	23	1.215	-
4	43	3.648	-
5	45	6.070	49.50
6	77	15.010	184.00
7	132	34.[illegible]	5[illegible]0.33
8	163	64.027	1,026.[illegible]7
9	132	56.5[illegible]	9[illegible]7.50
10	42	21.[illegible]0	40[illegible].33
11	3	2.012	41.[illegible]
Totals	666	203.625	3,197.33

20-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	2	0.023	-
3	2	0.105	-
4	8	0.640	-
5	33	4.632	36.67
6	65	12.7[illegible]	156.00
7	113	2[illegible].825	430.67
8	170	57.405	942.67
9	120	51.7[illegible]	900.00
10	43	2[illegible].[illegible]42	424.[illegible]7
11	10	6.140	123.[illegible]
Totals	5[illegible]	1[illegible].407	3,[illegible]

1956 STAND AND STOCK TABLES
PER-ACRE BASIS

22-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
4	10	0.909	-
5	24	3.351	2[illegible].71
6	60	11.727	144.00
7	94	25.020	358.29
8	114	39.101	640.00
9	104	44.993	782.14
10	51	27.503	504.00
11	14	8.[illegible]4	175.71
Totals	471	161.598	2,630.[illegible]5

24-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	3	0.063	-
3	2	0.082	-
4	5	0.473	-
5	20	2.[illegible]45	22.00
6	37	7.317	[illegible].00
7	100	26.670	380.00
8	123	42.302	690.67
9	92	39.405	607.50
10	33	16.867	326.67
11	7	4.2[illegible]7	82.00
Totals	430	140.371	2,27[illegible].60

1961 STAND AND STOCK TABLES
PER-ACRE BASIS

CONTROLS

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	2	0.03[illegible]	-
3	-	-	-
4	22	1.877	-
5	50	6.767	55.00
6	62	11.717	136.40
7	132	35.300	520.00
8	190	66.758	1,102.00
9	150	65.403	1,105.00
10	67	35.322	676.70
11	20	12.547	244.00
12	2	1.331	30.00
Totals	697	237.056	3,[illegible]57.10

16-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	1	0.029	-
3	5	0.259	-
4	24	2.129	-
5	49	6.524	53.90
6	53	10.245	116.60
7	95	25.634	360.00
8	142	49.558	823.60
9	130	56.133	1,027.00
10	90	46.045	909.00
11	45	20.590	549.00
12	6	4.814	90.00
13	3	2.235	54.00
Totals	643	226.197	3,904.[illegible]0

1961 STAND AND STOCK TABLES
PER-ACRE BASIS

15-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
3	1	0.043	-
4	[illegible]	0.682	-
5	20	2.776	22.00
6	53	10.745	116.60
7	92	24.143	360.00
8	135	46.23[illegible]	753.00
9	152	70.503	1,277.60
10	117	61.3[illegible]	1,1[illegible]1.70
11	22	14.145	2[illegible].40
12	1	0.720	15.00
Totals	611	231.732	4,034.50

20-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
4	2	0.202	-
5	8	1.25[illegible]	8.80
6	33	6.6[illegible]3	72.60
7	73	19.537	292.00
8	113	39.4[illegible]0	655.40
9	1[illegible]0	62.547	1,204.00
10	93	49.635	939.30
11	40	25.313	480.00
12	2	1.494	30.00
Totals	524	206.609	3,750.10

1961 STAND AND STOCK TABLES
PER-ACRE BASIS

15-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area Sq. Ft.	Volume Cu. Ft.
3	1	0.043	-
4	8	0.692	-
5	20	2.776	22.00
6	53	10.745	116.60
7	92	24.143	360.00
8	135	46.030	753.00
9	162	70.573	1,277.00
10	117	61.557	1,151.70
11	22	14.145	230.40
12	1	0.720	15.00
Totals	611	231.732	4,034.50

20-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area Sq. Ft.	Volume Cu. Ft.
4	2	0.202	-
5	9	1.251	8.80
6	33	6.583	72.60
7	73	19.537	292.00
8	113	39.440	655.40
9	140	62.547	1,204.00
10	93	49.635	939.30
11	40	25.013	430.00
12	2	1.494	30.00
Totals	524	206.609	3,750.10

1961 STAND AND STOCK TABLES
PER-ACRE BASIS

22-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
5	6	0.797	6.60
6	27	4.670	59.40
7	57	14.471	228.00
8	84	29.224	487.20
9	100	43.583	790.00
10	94	50.710	949.40
11	43	27.329	524.60
12	16	11.806	240.00
13	1	0.866	18.30
Totals	444	183.456	3,303.50

24-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
6	18	3.602	39.60
7	35	9.375	140.00
8	98	34.247	568.40
9	107	46.490	845.30
10	90	48.847	909.00
11	22	13.646	268.40
12	3	2.436	45.00
13	1	0.860	18.30
Totals	374	159.577	2,834.00

1959 THINNINGS STAND AND STOCK TABLES
PER-ACRE BASIS

10-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
1	5	0.020	-
2	8	0.175	-
3	10	0.495	-
4	20	1.705	-
5	15	2.103	16.50
6	8	1.428	17.60
Totals	66	5.929	34.10

20-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	1	0.022	-
3	-	-	-
4	10	0.865	-
5	8	1.175	8.80
6	10	2.152	22.00
7	10	2.540	40.00
8	7	2.173	40.60
9	7	2.950	55.30
10	1	0.590	10.10
11	1	0.666	12.20
Totals	55	13.133	189.00

1959 THINNINGS STAND AND STOCK TABLE
PER-ACRE BASIS

22-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
4	6	0.546	-
5	10	1.344	11.00
6	14	2.526	30.80
7	6	1.497	24.00
8	13	3.469	75.40
9	-	-	-
10	4	2.264	40.40
Totals	53	11.646	181.60

24-PERCENT TREATMENT

Diameter Class	No. of Trees	Basal Area	Volume
		Sq. Ft.	Cu. Ft.
2	4	0.114	-
3	2	0.112	-
4	2	0.202	-
5	10	1.310	11.00
6	6	1.170	13.20
7	14	3.806	56.00
8	12	4.806	69.60
9	4	1.360	31.60
10	2	1.112	20.20
Totals	56	14.006	201.60