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THE RELATION OF TREE DEVELOPMENT TO THE TIMING OF THE FIRST THINNING IN EVEN-AGED HARDWOOD STANDS

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THE RELATION OF TREE DEVELOPMENT TO THE TIMING OF THE FIRST THINNING IN EVEN-AGED HARDWOOD STANDS *

In the past, the wood-using industries have been able to find trees which suited their specific needs, whereas now, when most of the virgin stands have been cut, certain forest products are definitely scarce. The forester, therefore, should aim to produce certain high-quality products which otherwise will be produced only by chance in unmanaged stands. In hardwood forests the highest priced products are clear veneer logs and saw logs. Only when knowledge has been obtained about the relationship of growth of the different parts of the tree is it possible to know when thinnings should be made in order to produce such products.

The first thinning is more decisive in shaping the tree in the stand than any later intermediate cutting. After the first thinning has been made, the tendency is for the crown to expand and the development of clear length of bole to slow up. It is therefore necessary to visualize before the first thinning is made the whole course of thinnings and the end products which will result.

The primary purpose of this study was to determine how the different dimensional growths, such as d.b.h., total height, clear length, crown length, and crown diameter of red oak and white ash are related to one another at uniform intervals throughout the life of a stand. Only when such relationships have been studied will it be possible to determine the time at which the first thinning should be made.

Aim of Thinning

In order to obtain high-quality hardwood products in a minimum period of time, the forester resorts to thinning and other intermediate cuttings. In Denmark, Møller [2] concluded that clear-boled, straight, and large trees can be produced in relatively short rotations by proper thinnings. These large, clear-boled trees will not only command higher prices, but the rotation also will be shortened, thereby reducing the wood capital invested, while the annual increment will not decrease so long as no permanent gaps are made in the crown canopy.

Mørk-Hansen [3] maintained that the essential rule in intermediate cuttings is to develop clear length while the trees are young and the height growth is most rapid. Natural pruning should stop when the most profitable clear bole length has been developed. In young stands, thinning should be only heavy enough to prevent stagnation in order to encourage natural pruning. After the desired clear length has been obtained, the thinnings should be heavy enough to promote maximum crown development. The intensity of the cutting is limited for the most part by the necessity of maintaining a favorable soil condition.

Regarding the length of clear bole towards which the forester should work, Mørk-Hansen believes that natural pruning should continue only so long as high-grade logs are being formed. In another publication [4] he states that, in most countries, the general tendency has been to continue the natural pruning long after it should have been stopped. This results in deficient crown development of the crop trees. In this country, Baker [1] says: "The best way of combining quality and quantity is to thin lightly or not at all in youth, thus forcing . . . a high-placed crown of small branches. When a tall, clean shaft is developed, then the tree can be given more space and rapid diameter increment of the highest quality can be laid on."

Most emphasis in this country, however, has been placed upon the economy of the thinnings. With all due respect to the consideration of a net profit from the thinning operations, the first thing to determine is the time when thinning will be of most benefit to the value of future products. Of secondary importance is the question: Will this operation give immediate returns?

The German foresters, who worked with long rotations and large volumes, maintained a very high density throughout the life of the stand. Consequently the crowns became only a small part of the universally long-boled trees, and the upper logs were of relatively poor quality. The French and Danish foresters who developed the crown-thinning method practiced light but frequent thinnings. In most cases, however, these were started so late that only one-fourth of the total height was in crown.

Method of Collecting Data

The measurements on which this study is based were taken from 120 red oak and 99 white ash in even-aged, second-growth hardwood stands in the transition region between the northern hardwood types and oak types in New England. These stands had never been dense enough to bring about stagnation by root competition. Measurements were taken on dominant and co-dominant trees of red oak (*Quercus borealis var. maxima* (Marsh.) Ashe) and white ash (*Fraxinus americana* L.) to determine the relation between their various dimensions. These two species were selected because they are the most common valuable timber trees in this region. It was impossible to find stands limited to a mixture of red oak and white ash; therefore, it was necessary to take the data from stands of mixed second-growth hardwoods containing desirable specimens of the two species.

For ages up to about 20 years, when the trees had reached a total height of about 35 feet, the sample trees, which were all dominant or co-dominant, were chosen from well-stocked, unthinned stands in the Harvard Forest at Petersham, Massachusetts. For ages from 20 to 30 years, the data were taken in the Harvard Forest from thinned stands, some of which had been thinned once and the remainder twice.

Definite ideas have been developed at the Harvard

* The field work of this study was done in partial fulfillment of the requirements for the Master in Forestry degree at Harvard University. The computations were finished while the author was connected with the Division of Forestry, West Virginia Agricultural Experiment Station, West Virginia University.

Forest in regard to the most profitable form of crop trees. Since such trees are not present in the Forest in the older ages, as none of the managed second growth hardwood stands have reached maturity, trees from wild stands corresponding in development to crop trees in managed stands were selected and measured. These trees all had well-formed crowns and not less than two 16-foot logs. Such a clear length showed that these selected trees must have been surrounded by slower growing trees which had acted as trainers early in life and therefore developed an effect similar to that of thinnings in a managed stand.

It should be kept in mind that the development of the trees from the wild stands may not necessarily agree completely with that of trees in managed stands. However, they should indicate the trend of the future development of crop trees in managed stands which are thinned according to the method used in the Harvard Forest.

Analyses of Data

Figure 1 shows the relation between total height and age for red oak and white ash measured in this study, and the curve corresponds with that of Patton[5] for the

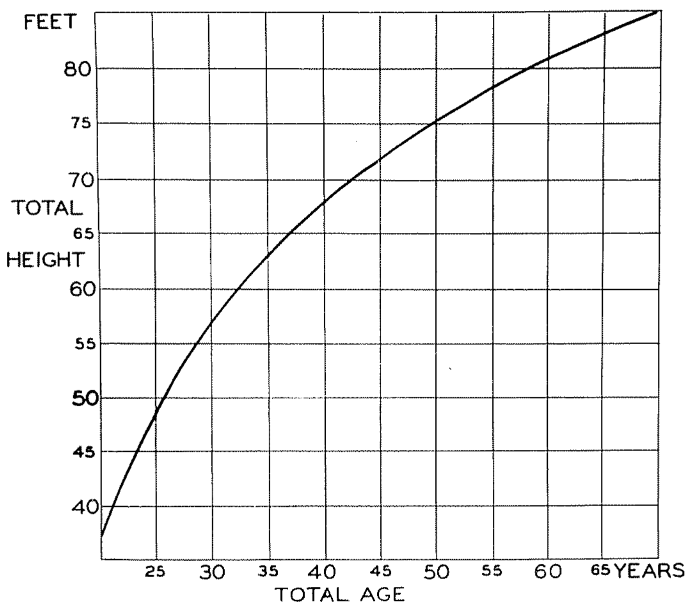

FIGURE 1. Total Height and Total Age of Red Oak and White Ash.

same species. The height growth is more than two feet per year for young trees, but diminishes to one foot at an age of about 35 years. The reduction in the rate of height growth continues until the growth is only about one-half foot per year, when the trees are approximately 60 years old. During the early years, when the height growth still is rapid, the crown is pointed. As the tree grows older the shape of the crown approaches that of a dome. When the tree reaches maturity and the height growth has stopped almost completely, the crown widens and becomes almost flat on top.

Figures 2a and 2b show the relation between total height and crown length, and Figures 3a and 3b show the relation between total height and crown diameter, for red oak and white ash. Total height in preference to age was selected as a basis for these and later relationships, because it presents a truer picture of the relative development of the trees in the stand than does age. In the unmanaged forest, where reproduction usually is established under partial suppression, the trees in the understory often will be relatively old in comparison to their total height. In other words, the reproduction frequently is kept "in storage" for many years before it is released.

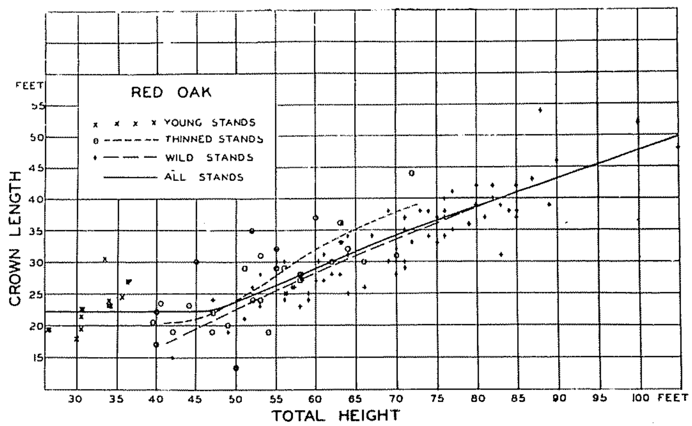

FIGURE 2a. Crown Length and Total Height for Red Oak.

The data for the young stands in Figures 2a and 2b and Figures 3a and 3b are rather variable. This may be due to the tendency of dominant and co-dominant trees in young stands to grow into "wolf" trees. The crown dimensions of such trees are abnormally large in comparison to the trees in the same stands which will be maintained as crop trees after the aggressive "wolf"

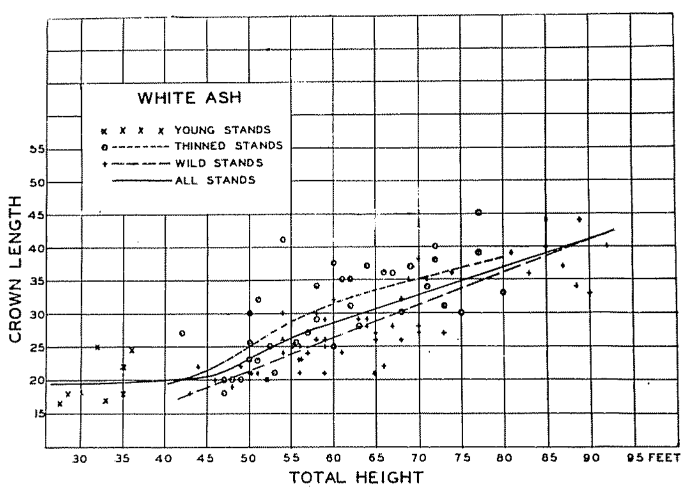

FIGURE 2b. Crown Length and Total Height for White Ash.

trees have been removed in improvement cuttings or thinnings. A curve for the data from the young stands, therefore, will have relatively little significance. An average point for these data has been found to serve as guidance for the trend of the composite curve and has been so used. The seeming discrepancy between the crown length and the crown diameter curves for the thinned stands of red oak is caused by the thinning methods employed in the Harvard Forest. Intermediate

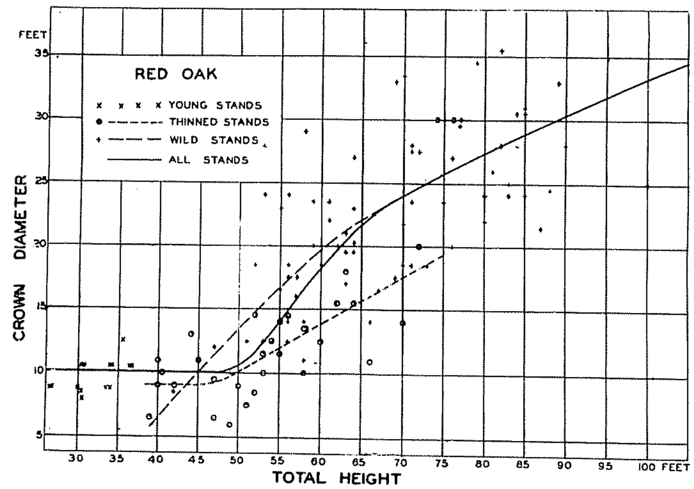

FIGURE 3a. Crown Diameter and Total Height for Red Oak.

trees which were interfering with the lower part of the crown of the crop trees were eliminated, allowing the crop trees to maintain deep crowns. On the other hand relatively few co-dominant trees were cut. This procedure restricts the expansion of the crop trees. In Figures 2a and 2b, therefore, the crown length of the trees in the thinned stands is longer than in the wild

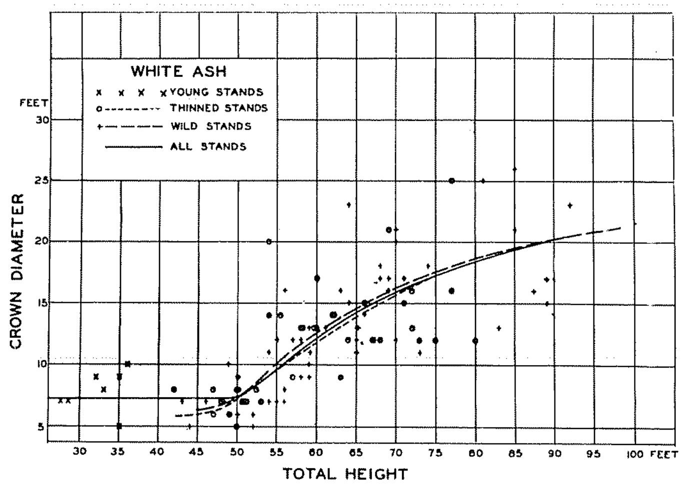

FIGURE 3b. Crown Diameter and Total Height for White Ash.

stands where competition from intermediate trees is still present; while in Figures 3a and 3b the crown diameter of the trees in the thinned stands is smaller than in the wild stands. Another explanation for this difference is that weedings and thinnings in managed even-aged stands tend to eliminate very spreading and over-aggressive trees and develop crop trees of about equal size. In the wild stands, however, the crop trees are much more dominant than those in the managed stands, and they therefore develop wider, more spreading crowns. However, if a more radical crown thinning were employed, the crowns of the trees in the thinned stands would probably expand faster and tend to reach the same dimensions as the trees which were measured in the wild stands.

Considering the origin of the two curves on each chart, the composite curve shows approximately the relationship between total height-crown length and total height-crown diameter if measurements had been taken from one stand throughout its entire development. Until the stands are thinned, the relation between the crown length and crown diameter remains relatively constant due to the high density of the stand. After the first thinning is made, the crown length and the crown diameter increase at a relatively constant rate unless the stand becomes crowded again and crown development is restricted. As the rate of height growth decreases, the normal tendency is for the crown to become more rounded, and for the rate of crown diameter growth and, concomitantly, the diameter of the bole to increase. At the same time, the diameter of the living branches tends to increase, making the development of additional clear length more difficult.

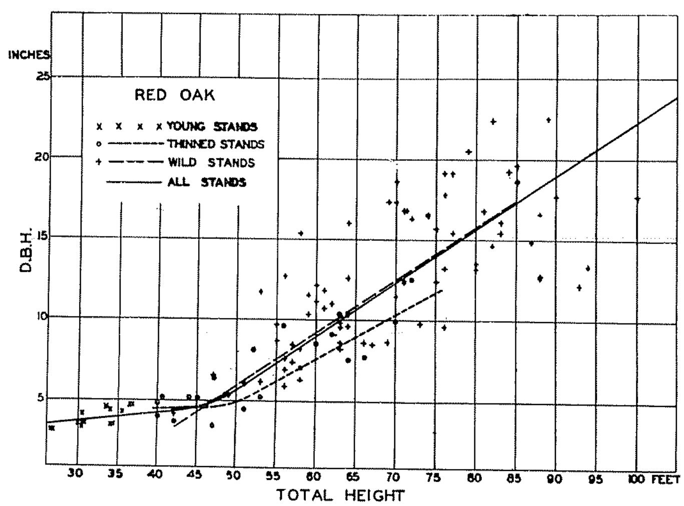

FIGURE 4a. D.B.H. and Total Height for Red Oak.

The result of the crown expansion both in length and in diameter is indicated in Figures 4a and 4b, which show the relationship between total height and d.b.h. growth. The data for the young stands follow the general trend fairly well as indicated by the composite curves. However, the data will not give significant correlation indices due to the great variation in the sample caused by the erratic growth of the trees in these stands. For white ash the d.b.h. curves for trees from thinned stands and from wild stands are situated closely together, as could be expected, inasmuch as the crown diameter-total height curves for trees from these stands almost coincide, as shown in Figure 3b. The red oak d.b.h. curves in Figure 4a show more variation; the curve for trees from thinned stands is situated below the curve for trees from wild stands. However, this again corresponds with the trend for the crown diameter curves as shown in Figure 3a. If the crop trees had been released by somewhat heavier thinnings so the crowns could have expanded like the crowns on the trees measured in the wild stands, the d.b.h. curve for trees from the thinned stands would have been quite similar to the curve for the trees from wild stands.

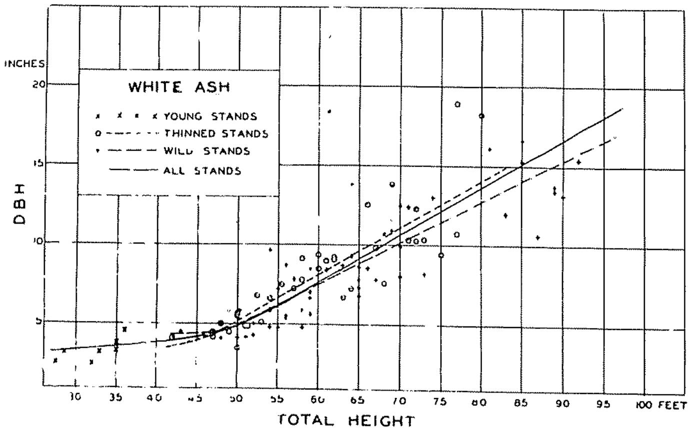

FIGURE 4b. D.B.H. and Total Height for White Ash.

These curves for red oak and white ash show that the d.b.h. growth is relatively slow while the trees are young. When a total height of about 50 feet has been reached, the growth on the diameter will increase rather rapidly and will then maintain a constant rate in its relationship to total height. During this time a rapid expansion takes place in both crown length and crown diameter, and consequently the d.b.h growth will increase rapidly.

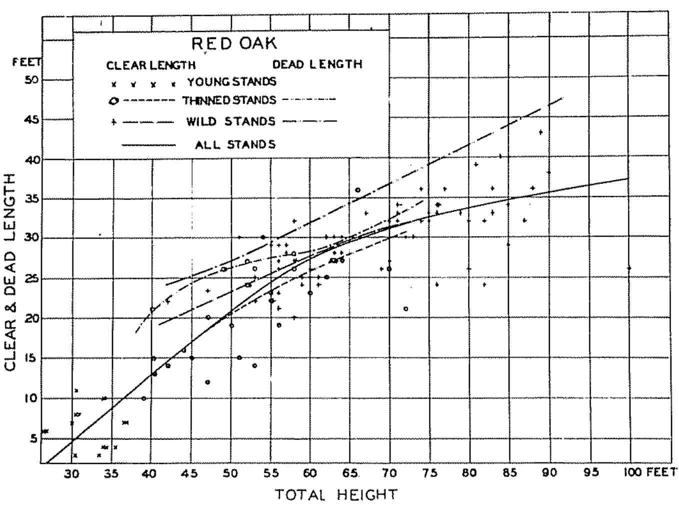

FIGURE 5a. Clear and Dead Length and Total Height for Red Oak.

The final and commercially most important analysis of the tree is given in the relationship between total height and clear length as shown in Figures 5a and 5b. The data from trees in the young stands of red oak and white ash are rather scattered and show hardly any relationship. However, in as much as these data were collected in stands where some of the trees have been exposed to less interference from neighboring trees than others, such spread can be expected. The variation between the clear-length curves of data collected from

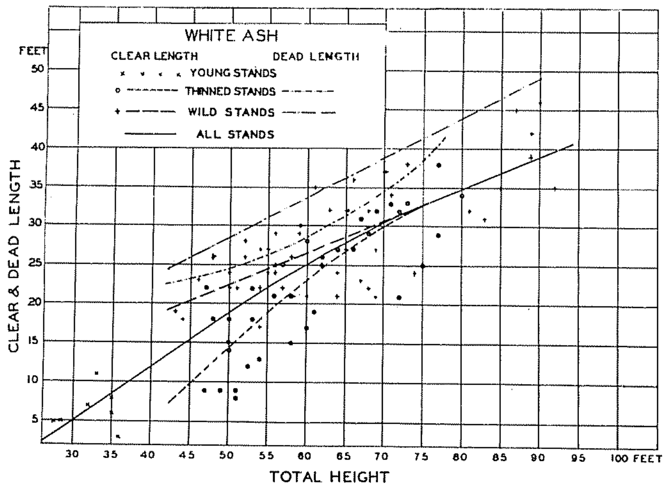

FIGURE 5b. Clear and Dead Length and Total Height for White Ash.

thinned stands and wild stands corresponds very well with the respective curves for crown length as shown in Figures 2a and 2b. When the crown length is longer, as in the case of trees from thinned stands, the clear length necessarily will be shorter (Figures 5a and 5b). The composite curves which go through the average points for the data from the young stands give an indication of how the clear length development takes place throughout the life cycle of red oak and white ash growing under conditions where space is available for the development of a well-balanced crown. It is apparent that red oak and white ash behave differently in regard to the development of clear length. While the red oak curve begins to flatten out at a total height of about 60 feet, the white ash curve continues to show clear length without much decline.

In trying to relate the turning point on the red oak curve with the other data given, it will be noted that it corresponds roughly with the increase in d.b.h. growth and the increased expansion of the crown. It is generally known that with slow d.b.h growth the diameter growth of the branches is considerably reduced; while an increased growth rate of the d.b.h. will be accompanied by an increased diameter growth of the branches. It is therefore natural to expect a decrease in clear-length development when the crown expansion takes place, since the lower branches will get additional light which will enable them to stay alive for a longer time. In the case of white ash, its intolerance is so pronounced that even when it is grown in managed stands the lower branches will stop functioning due to the shade from its own crown and neighboring trees unless very heavy thinnings are made.

The curves as shown in the different figures have been determined by the least squares method and treated statistically. The following table shows the correlation indices obtained. In all cases the relationships are highly significant.

45 to 50 feet. This change takes place at the time the first thinning is made. Furthermore, the curves which are based on data collected from wild stands correspond fairly well with the data from the older thinned stands, as has been shown in the discussion of the different curves. If this can be taken as a measure of the validity of the selection of crop trees in wild stands, it is possible from these curves to obtain some indication of how the crop trees in the thinned stands will develop until they reach maturity.

Correlation Indices for Relationship Between Total Height and

Stands	*Crown Length*		*Crown Diam.*		*D.B.H.*		*Clear Length*	
	Oak	*Ash*	*Oak*	*Ash*	*Oak*	*Ash*	*Oak*	*Ash*
Thinned	.711	.720	.722	.712	.795	.842	.684	.800
Wild	.888	.854	.707	.757	.746	.876	.680	.726
All (Including young stands)....	.863	.777	.852	.762	.858	.873	.894	.820

Quality of the Logs

A further study of Figures 4a and 5a reveals some information concerning the quality of logs which can be obtained from red oak trees grown according to the trend indicated in the curves. From the composite curve in Figure 5a it is found that the first 16-foot log above a 2-foot stump is clear when the tree has a height of about 46 feet. The d.b.h. corresponding to this height is about 5 inches (Figure 4a). At this stage of development, the upper part of the log is just cleared and has no continuous layer of wood outside the knotty core. From this time on, the annual rings are of clear wood and will yield high-grade lumber. The knotty core in the first log has the shape of an inverted cone with its apex at the ground line of the tree and with its base at the top of this log, which has a diameter of approximately 3 inches if the allowance for taper is considered to be one inch for each 8 feet of log length.

The second log, or a total of 34 feet, is included in the clear length, according to Figure 5a, at a total height of 82 feet. This corresponds to a d.b.h. of about 17 inches. Taking a normal taper into account, the top diameter of the second log is therefore 13 inches. The second log consequently has a knotty core which is 3 inches in diameter at the larger end of the log and 13 inches in diameter at the smaller end. It is obvious that this log produces a considerably smaller percentage of clear lumber than the first log.

The third and subsequent logs usually contain only knotty wood. A similar analysis can be made from the curves for white ash with slightly different values resulting.

Discussion

As will be seen from the figures showing the relationship between total height-crown length (Figures 2a and 2b), total height-crown diameter (Figures 3a and 3b), and total height-d.b.h. (Figures 4a and 4b), there is a definite break in the curves based on trees from the thinnned stands corresponding to a total height of about 45 to 50 feet.

The total height of 45 to 50 feet, or the time the first thinning was made, corresponds with the time when the crowns of red oak and white ash change from a pointed to a dome-shaped form, or when the total height growth starts to slow up. At this time the dead length, that is, the entire length of the tree below the live crown, has reached a height of about 25 feet in the cases of both red oak and white ash as seen in Figures 5a and 5b. During the following years the dead length will not increase very rapidly in the thinned stands, due to the additional space which is given the crop trees. However, the dead length will become clear length, and clear wood will be produced outside the knotty core.

For the two species which have been studied, some additional clear length will still be developed after the first thinning has been made. This is especially pronounced for white ash, whose clear length curve (Figure 5b) continues with only slightly decreased steepness. In red oak, also, there is a continued, although slower, development of clear length. It can safely be concluded that a half log or better will be cleared during the period from the first thinning until the tree has reached 20 inches in d.b.h., so that the tree at this time will have more than two clear logs.

Figure 5a indicates that the development of a red oak with two clear logs may be divided up into two periods. The first period lasts until half of the second log, or a total of 25 feet, has been included in the dead length. The corresponding total height of 57 feet will be obtained, according to Figure 1, in about 28 years for the site on which the sample trees were measured. The second period extends from the release of the trees until maturity, arbitrarily set at 20 inches d.b.h. This corresponds to a total height growth from 57 feet to 93 feet, or, according to Figure 1, about 48 years. Altogether it takes about 76 years to grow an oak with two clear logs to a size of 20 inches d.b.h.

If it is desired that the third log produce as much clear wood as possible, the stand cannot be opened up until half of this log or 42 feet has been included in the dead length. The upper part of the third log will be included in the dead length and subsequently be cleared during the latter part of the rotation. However, the dead branches on the third log will have greater diameters than those on the lower part of the tree and will therefore leave more catfaces and irregularities in this log than did the branches in the first and second logs. Only a very thin layer of clear wood will be present on the lower part of the third log which will therefore be of little value. The attempt to develop additional clear length will prolong the rotation, due to the continued high density of the stand. Assuming that the dead length development will continue with the same rate as before the trees were released by thinning, two logs and a half of dead length would correspond to a total height of 75 feet for red oak. Figure 1 indicates that it takes the tree 50 years to obtain this total height. Using the same method of estimation, Figure 4a shows that the d.b.h. of such a tree will be approximately 7 inches. According to Figures 4a and 1, it takes 63 years for a two-log tree to grow from 7 inches to 20 inches d.b.h. For a three-log tree, the growth will be slower due to the comparatively smaller crown and root systems. The rotation for red oak in which three logs are being developed will then be composed of the time it takes to develop a dead length of two logs and a half, or 50 years, plus the time it takes to grow the 7-inch tree to a 20-inch tree, or at least 63 years more. The total rotation, therefore, for three-log trees will be 113 years or more, as compared with 76 years for the two-log trees.

The data on which this study is based have been taken from trees growing on good sites. For similar sites, two clear logs are the most favorable to work for. However, on poorer sites the total height-age curve flattens out sooner and this causes a slower clear length development. On such sites, therefore, it will not be profitable to try to develop the same clear length as on good sites. On poorer sites it may be feasible to develop only one log, or one log and a half, while on the best sites two logs and a half, or even three logs may be profitably developed. However, if more than the optimum number of logs are developed, the rotation will be prolonged disproportionally and the additional logs will be of poor quality.

Conclusions

1. There is a definite relationship among the different dimensional growths of the tree. When the crown dimensions (crown diameter and crown length) increase, the rate of growth of the d.b.h. will also increase.
2. Total height has been found to be a better guide than age on which to base the different dimensional growths of the tree.
3. There is a period in the life of the tree when height growth starts to slow down. This is the time when the crown form changes from a pointed to a dome-like shape.
4. It is recommended that the first thinning be made when this change takes place. The clear length at this time will depend on the site and species.
5. Additional clear length can be obtained only by keeping the stand dense for a disproportionate number of years beyond the recommended time for the first thinning.
6. Upper logs obtained by this treatment will be of poor quality because they will contain only a small part of clear wood.

Literature Cited

[1] Baker, F. S. Theory and Practice of Silviculture, McGraw-Hill Book Co., Inc., 1934, p. 366.

[2] Møller, C. M. Traeproduktionens Formaal. Dansk Skovforenings Tidsskrift, 1939, pp. 161-166.

[3] Mørk-Hansen, K. C.H. Schroder's Udhugnings i Bøg. Det forstlige Forsøgsvaesen i Danmark, 1908, pp. 379-397.

[4] Mørk-Hansen, K. C.H. Schroder's Udhugning i Bøg. Det forstlige Forsøgsvaesen i Danmark, 1920, pp. 156-176.

[5] Patton, Rueben T. 1922. Red Oak and White Ash. Harvard Forest Bull. No. 4, Petersham, Mass.