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GROWING OF WHITE PINE ON THE YALE FOREST NEAR KEENE, NEW HAMPHIRE

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GROWING OF WHITE PINE ON THE YALE FOREST NEAR KEENE, NEW HAMPSHIRE

INTRODUCTION

THE Yale forest near the city of Keene, New Hampshire, embraces more than 1,400 acres in a fairly compact block situated in the towns of Keene and Swanzey in the southwestern part of the state. The nucleus of the forest, about 220 acres, was acquired in 1913 by gift from George H. Myers and has been added to as opportunity offered through the generosity of several donors including Mrs. J. Whitney Blake, Charles Goodwin, Sanders W. Hart, Payson Merrill, Charles Lathrop Pack, James W. Toumey, and G. Frederick Schwarz. Since its ownership by Yale University, the forest has been used by the students and faculty of the School of Forestry as a field laboratory for scientific research and as a demonstration of desirable forestry practice.

Fourteen publications pertaining to the forest have been issued in the Yale School of Forestry series of bulletins. The most comprehensive is No. 33, "The Yale Demonstration and Research Forest near Keene, New Hampshire," prepared by Professor James W. Toumey and published shortly after his death in 1932. During the latter years of his life Professor Toumey became increasingly interested in managing the property as an object lesson to other timberland owners. The success he attained made the forest a fitting monument to his untiring efforts and an appropriate resting place for his ashes.

In 1938, the Yale forest suffered a major disaster, as it was directly in the path of the tropical hurricane that swept northward through New England on September 21. Virtually all the timber over forty years of age was uprooted or broken off. Sheltered spots escaped, but on exposed aspects even young growth was wind-thrown. The timber on most of the experimental areas was destroyed, thus ruining the demonstrations of cutting practices and cultural operations which had been developed during more than two decades of operation.

Professor Toumey was spared the distress of seeing that picture of destruction, but he would have been the first to realize the opportunity of using the Yale forest as an example in rehabilitation. Hundreds of acres of young timber remained and not all past work had been lost. Within that part of New England affected by the hurricane the need for demonstrations of forestry practice is even greater than before. Fortu-

nately windstorms of such violence are too rare to prevent the growing of profitable forest crops.

There are today few places in New England where the management of land for the production of timber can be observed. However, thousands of forest landowners in the New England States are so situated that they could begin such work to their ultimate advantage. At the present time they are either unaware of the possibilities or are deterred by the numerous though usually not insurmountable difficulties and obstacles which face the private forest landowner. Yet timber growing, although it has some peculiarly troublesome problems, is not essentially different in this respect from other businesses.

The hurricane increased public interest in the forest problems of New England in one way by calling attention to the large area of land bearing merchantable timber in this region. As salvage of wind-thrown trees progressed the poor quality of most of the sawtimber in New England became evident. Now, however, the supply has been so depleted that native material even of poor quality is likely to be worth more than in the past, while increasing value of timber of good quality should induce landowners to take advantage of the knowledge concerning forest crop production which has been gained in the few places where it has been studied and practiced.

The Yale forest, which has experienced most of the difficulties which lie in the path of the timber grower, will continue development according to the policy determined prior to the hurricane. It is believed that as owners of white pine lands face the new situations arising as a result of the hurricane it may be of interest for them to review the policy and forestry practices with respect to growing white pine crops which are in operation on this forest. The purpose of this publication is to present such material. Since the hurricane, the forest has been remapped and an inventory made of the remaining timber. Both the map and inventory are herewith included and discussed.

One of the best ways of learning how forestry operations of various types should be carried on is to study actual operations which have been made in the forest and observe their results. For this purpose a visit to a demonstration forest is valuable. The primary function of a demonstration forest is to provide numerous examples of a wide variety of forestry operations easily accessible to interested forest owners and carefully enough described so that the methods and results are readily understood and ideas can be gained for application on other properties.

Selected examples illustrating various forestry operations in the Yale forest at Keene are included in this publication and many others which are not here listed can be seen. Numbered posts are placed in the woods along the roads and trails near the operations described. The location of the points (called stations) which are referred to are shown on the map in the back of this bulletin.

THE PRESENT CONDITION OF THE FOREST

Topography and Soil

THE Yale forest lies mostly in the rather flat valley of the Ashuelot River. The land is level or gently sloping, except on the western edge of the forest where it rises steeply toward the summit of West Hill. The terrain renders logging relatively easy in most places, although here and there numerous boulders and rock ledges make it difficult. Reference to the map will show that there is an extensive system of woods roads and that two highways pass through the property, while three town roads lie within or adjacent to it. The highways and parts of the town roads are hard-surfaced. Most of the land is within half a mile and nearly all of it within one mile of a good highway.

The soils over the greater part of the forest are fine to coarse sands with occasional gravel deposits. They are typical of the lighter soils found in abundance throughout central New England, where white pine is one of the most important timber trees and where its management is in many respects different from that practiced for white pine on heavier soils. Examples of heavier soils occur chiefly in parts of the forest where the topography is of a rugged character.

Land Classification

For convenience in management, the property has been divided into numerous small areas. The primary lines of division are along roads and other permanent and well-defined landmarks, breaking the forest up into 24 compartments ranging in size from 19 to 150 acres and averaging 58.7 acres. Thus the general location of every condition and operation in the forest can be described readily.

The property has also been classified as to its tree cover into several types of open land and into a number of forest types in each of which a particular tree species or combination of species predominates. The types have been subdivided into individual stands within compartments

to show the age of the forest. Such divisions are valuable in planning the time and place for various operations. They also serve to improve the accuracy of the timber inventory.

The map at the back of this bulletin shows the location of each compartment and each stand within the forest. Table 1 summarizes for the whole forest the acreage of each type and age class and shows in per cent the proportion of the area occupied.

TABLE 1. AREA IN ACRES BY FOREST TYPES AND AGE CLASSES, 1940

Type	*Age Class in Years*						*Per cent of total area*
	1–20	*21–40*	*41–60*	*61–80*	*Unevenaged*	*Total*	
	Area in acres						
White pine	140.4	232.3	39.7	3.8	151.4	567.6	40
Red pine	28.6	39.6				68.2	5
Hemlock	15.9		3.5		78.1	97.5	7
Spruce	2.1					2.1	0
Hardwood	22.4	76.9	24.8			124.1	9
Swamp	39.6	24.6	1.1		15.5	80.8	6
Total	249.0	373.4	69.1	3.8	245.0	940.3	67
Areas not classified as to age of timber							
Areas under regeneration						429.2	30
Open swamps						16.5	1
Nonforested land						23.5	2
						1,409.5	100

A glance at the table or the map will show that the forest is composed principally of white pine. The white pine type, which includes all areas where this species predominates, occupies 40 per cent of the area. In addition, most of the land classified as "areas under regeneration" will within a few years come into the white pine type if certain cultural measures described later in this publication are carried out. Considerably more than half of the forest, then, is actually or potentially in the white pine type.

The term "areas under regeneration" is used to designate land where tree growth is now becoming established but where it is too early to predict with certainty what species will predominate. This includes all recently cutover tracts amounting to 58 acres and stands totaling 371 acres blown down by the hurricane. It is because of the devastation of

the hurricane that this classification temporarily embraces nearly one-third of the total area of the forest.

The red pine and spruce types, comprising 5 per cent of the area, as well as some parts of the white pine type, were established artificially by planting small, scattered, open areas. The hemlock type, occupying 7 per cent, is distributed in small stands throughout the forest. The hardwood type, containing a mixture of various hardwood species, is found principally on the rough mountain land at the western side of the forest. Its aggregate area is 9 per cent of the total.

Lands with excessive moisture are classified as swamp and comprise 7 per cent of the area. Some of the swamps are stocked with hardwoods, scattered balsam fir, spruce, and tamarack, with occasional hemlock and white pine. Others are composed mainly of hardwoods, while still others, because of extreme moisture conditions, support only shrubs and lesser vegetation. The latter are classified as open swamps. It will require many years for them to become stocked with tree species.

An additional 2 per cent of the land is classified as nonforested, consisting of a few open fields which will be kept in this condition, an apple orchard, and the administrative area around the headquarters buildings.

Timber Inventory

In every business an important aid to management is the periodic inventory of stock on hand. In the forest industries this consists primarily of wood in various forms ranging from manufactured lumber to trees growing in the forest. In the business of producing tree crops the growing trees constitute a great part of the working capital of the business and a knowledge of their amount and value is essential to good management.

Just as the quantity of goods for sale in a retail business changes with sales and purchases, so the quantity of standing timber in a forest changes with the cutting of timber and the acquisition of more timberland. Standing timber differs from many commodities in that it also increases naturally, both in quantity and in value, through the growth of the individual trees. While the stock inventory of most businesses can be determined by careful records of purchases and sales, the changes in timber inventory must also take growth into account. The best method of determining the inventory of standing timber therefore is the periodic remeasurement of the trees.

It is the policy of the Yale forest to take an inventory of the growing stock every 10 years. An inventory of each of the original lots purchased was taken at the time of purchase, and an inventory of all the land then owned was taken in 1921. Another inventory was taken in 1930, and the latest inventory was made in 1940. This last inventory, while taken as a matter of routine, is particularly appropriate at this time because it furnishes a description of the forest after the hurricane, at what is undoubtedly the lowest ebb that the volume of growing stock will ever reach.

The value of standing timber is seldom great enough to justify the measurement of all the trees in the forest. Instead a sample, frequently 10 per cent of the area, is taken and the averages applied to the whole forest. By careful measurement of the trees in the sample and the proper unbiased distribution of the sampling over the entire area it is possible to obtain a reasonably accurate estimate for the whole forest. Separating the sample into areas which are fairly uniform within themselves and applying the estimates of each area only to areas which are similar improves the accuracy of the result. Thus mapping of the forest to show the various stands differing in age and type is a part of the timber estimating process.

A summary of the timber inventory of 1940 is given in Table 2. Volumes are given in feet, board measure, for conifers, and in cords for hardwoods, since these are the commercial units of measurement most appropriate for timber of the kinds and sizes present. There is little demand for softwood cordwood, and in the Yale forest there is not enough hardwood of sawtimber size now or likely to be later to warrant its segregation and measurement in board feet.

The volumes in Table 2 are grouped in three size classes: small trees (5 to 7 inches in diameter at breast height for conifers, 4 to 7 inches for hardwoods), medium-sized trees (8 to 11 inches) and large trees (12 inches and more in diameter). The conifers in the lowest size class, although of merchantable dimensions, are not by themselves readily salable for sawtimber, except that a certain number of these small trees might be included in the sale of timber composed principally of larger material. The small conifers are included in the table to give the complete picture of merchantable tree-size distribution in the forest. The medium-sized trees, while more easily sold than those in the smallest size class, should, as a rule, be allowed to grow to a larger and more profitable size before cutting. Except for thinnings most of the

cutting should be confined to the upper size class. A fourth class comprising trees 16 inches and over in diameter would have been separated out of the third class in Table 2 had there been enough of such large trees to warrant segregation. These are the trees which almost without exception should be cut, having reached a most profitable size for harvesting.

TABLE 2. INVENTORY OF STANDING TIMBER, 1940*

Diameter breast high (inches)	*5–7*	*8–11*	*12–*	*Total*
Conifers	*Volume in thousands of feet, board measure*			
White pine	772.0	1,312.0	1,592.0	3,676.0
Red pine	139.5	57.0	19.5	216.0
Hemlock	67.5	232.5	341.0	641.0
Other conifers	11.5	23.0	16.5	51.0
Total	990.5	1,624.5	1,969.0	4,584.0
Diameter breast high (inches)	*4–7*	*8–11*	*12–*	*Total*
	Volume in cords			
Hardwoods	1,220	675	370	2,265

Changes in Land Classification and Timber Inventory

As the years go by the amount of timber in a forest is continually fluctuating, increasing through growth and decreasing through cutting and death of trees. At the same time the areas included in each age class are changing as individual stands advance in age, or are cut off and returned to the lowest age class. The number of acres in each of the forest types is likely also to undergo change, especially when stands are cut off and reproduced to different species. Since the objective in the Yale forest is to grow white pine in pure stands there is a tendency for the acreage of this type to increase with each decade. It is a great help in management and a matter of no little interest to the owner to keep records showing the forest areas and timber inventory at regular intervals. From the accumulation of such records the productive capacity of a forest gradually is determined and inferences can be drawn regarding growth possibilities on other, similar tracts.

*Based on the same standard volume tables as were used in preparing inventory of 1930. See the Yale Demonstration and Research Forest near Keene, New Hampshire, by James W. Toumey, Yale University, School of Forestry, Bulletin 33, 1932.

Although the 1938 hurricane has been an abnormal influence in the Yale forest, nevertheless some interesting observations can be made from the comparison of records taken 10 years apart. For this purpose the 1930 timber inventory of the Yale forest and the results of a land classification made just before the hurricane are presented.

TABLE 3. AREA IN ACRES BY FOREST TYPES AND AGE CLASSES AS OF AUGUST 1938

Type	*Age Class in Years*						
	1–20	*21–40*	*41–60*	*61–80*	*Uneven-aged*	*Total*	*Per cent of total area*
	Area in acres						
White pine	170.4	282.0	113.0	2.6	371.6	939.6	71
Red pine	20.7	32.9				53.6	4
Hemlock		1.9	14.2		50.5	66.6	5
Spruce	2.5					2.5	0
Hardwood	14.6	62.6	47.5		21.7	146.4	11
Swamp	37.0	7.7			17.3	62.0	5
Total	245.2	387.1	174.7	2.6	461.1	1,270.7	96
Areas not classified as to age of timber							
Areas under regeneration						44.5	3
Nonforested land						13.6	1
Total						1,328.8	100

Table 3 gives the land classification as of August 1938, the year of the hurricane. Comparison with Table 1 shows that the total area of the forest has increased from 1,328.8 acres to 1,409.5 acres. This net gain of nearly 81 acres came about through the purchase of 2 tracts of land and the sale of 2 house lots. The changes of ownership obscure only slightly the changes in land classification which are due to other causes.

Comparison of the percentages in Tables 1 and 3 shows at a glance the greatest change wrought by the hurricane. The white pine type has been reduced from 71 per cent of the total area to 40 per cent, while areas under regeneration have been increased from 3 per cent to 30 per cent. Areas of other types have changed somewhat due to a combination of causes. In 1938 the open swamp type was not recognized, such areas being included with the swamps 1 to 20 years of age. The red pine, hemlock, and swamp types have increased in area, as has the nonforested land. In the case of red pine and hemlock the increase is due mostly to

the removal from these areas by the hurricane of trees of other species, leaving the areas predominantly in the possession of red pine or hemlock. The swamps and open land have increased chiefly through the acquisition of new land. Inspection of the age class arrangement shows that the hurricane did not appreciably reduce the area of 1–20 and 21–40 stands but did destroy more than half the stands in the 41 to 60 year age class and in the unevenaged class.

Table 4 gives the volume of softwood timber in 1930, the year of the last inventory prior to that taken in 1940. In this table the volumes are classified by age classes rather than by sizes of trees as in Table 2. The latter method gives a more useful picture of tree distribution, for the treatment of an area depends more upon the sizes of trees present than upon their age.

The classification of volumes by age classes in Table 4 does give some indication of the approximate distribution of tree sizes because on the whole the younger age classes contain smaller trees than do the older age classes. Comparison of Tables 2 and 4 indicates that there is a smaller proportion of large trees in 1940 than there was in 1930.

TABLE 4. INVENTORY OF SOFTWOOD TIMBER BY SPECIES AND AGE CLASSES, 1930

Age class (years)	*1–20*	*21–40*	*41–60*	*61–80*	*Unevenaged*	*Total*
Conifers	*Volume in thousands of feet, board measure*					
White pine	103	1,805	2,300	132	460	4,800
Red pine	2	9				11
Hemlock	27	87	372	79	371	936
Other conifers	1	52	11		55	119
Total	133	1,953	2,683	211	886	5,866

GROWTH

Production in the forest is best measured by increase in timber volume. A useful way to express such growth is as an average amount produced per acre each year either throughout the entire life of the forest crop or sometimes for a shorter period. Knowledge of growth in a forest is useful chiefly for estimates of future production and for determination of the amount of timber to be cut annually.

In the present early-development stage of management in the Yale forest approximate estimates of the growth, to be expected now and also when the forest has been brought into better condition, are sufficiently

accurate. One method of obtaining this information is by comparing the inventory of standing timber with a similar estimate made several years previous. In theory the increase in volume between two such inventories, 10 years apart, for example, plus the amount cut in the interval, is the growth for the period. Such a calculation automatically excludes the volume of any trees which may die and not be utilized during the period; thus it expresses the net increment, which is ordinarily what is wanted. If, however, a great many trees die and are wasted because of abnormal circumstances, the net growth shown may be considerably less than that which would be expected to occur under normal conditions. The hurricane produced such a situation in the Yale forest. A great deal of the wind-thrown timber was wasted because for various reasons it was not salvaged. The amount of this waste cannot be determined without a more expensive cruise than the importance of the project warrants. Hence comparison of the inventories made in the Yale forest in 1930 and 1940 for the purpose of estimating growth is futile.

The growth which occurred between the earlier inventories of 1921 and 1930 forms a better basis for discussion of future growth. (See Yale University, School of Forestry, Bulletin 33, pp. 57–59.) The net growth rate for the period of 1921 to 1930 was found to have been 75 cubic feet per acre per year, or conservatively 400 feet, board measure.

This growth was for softwoods only, although part of the land included in the estimate was occupied by hardwoods. As explained on page 11 the ultimate objective on most of the area is to produce pure stands of pine and this purpose will be furthered by converting hardwood areas to pine as opportunity arises. As the proportion of the area occupied by pine increases, the growth rate per acre will increase. It will also increase with the elimination of poorly formed pine trees, which occupy a large amount of space in relation to their lumber content, and their replacement with better-stocked stands. Moreover, the growth rate in timber of very young stands tends to increase with age, because the larger the trees, the greater is the proportion merchantable for lumber. The growth rate should therefore increase as more of the area becomes occupied by older stands. For these reasons the growth which occurred from 1921 to 1930 is too conservative as an indication of future possibilities.

Actually in the case of some individual white pine stands in the Yale forest harvested or ready to harvest before the hurricane an average growth rate of 1,000 feet, board measure, per acre per year had been

maintained. This undoubtedly is too high an average growth rate to set as the goal. Ultimately the growth rate for the total area, well-stocked with pine, should be not less than 700 feet, board measure, per acre per year. Production at this rate is the goal toward which the Yale forest is developing. Such high average production will not be achieved until a better balanced distribution of ages of timber is obtained, with most of the area in the older half of the age classes, nor until white pine occupies fully each acre, with just enough space for each tree to maintain rapid growth.

THE MANAGEMENT OBJECTIVE

IT has always been the purpose on the Yale forest to furnish a demonstration of methods to be used in and results to be obtained from growing pure crops of white pine timber of good quality as a major product. The use of the word "pure" implies that the crop is composed predominantly of a single species—in this case white pine. White pine was selected as the principal tree to grow for several reasons. In the first place it is the principal species used by the woodworking industries of the Keene district and hence commands a ready market. It is estimated that at least 35,000,000 feet, board measure, of white pine are used each year by the mills and woodworking plants within 15 miles of the Yale forest. An abundant supply of raw material obtainable locally is essential for the continued prosperity of mills and woodworking plants within the territory. The community as a whole has a strong interest in maintaining a supply of white pine in the forests adjacent to Keene. It is eminently fitting that a demonstration forest in the region should specialize in the growing of this important tree.

Second, white pine is a highly valuable timber tree in that its wood possesses inherent technical qualities of workability and relative strength and lightness which combine to give it a high rating for many industrial and construction uses. Furthermore it is native to the region and already abundant. It thrives on the relatively light sandy soils characteristic of the forest and reproduces aggressively. Finally there is no other tree that promises to grow equally well on the same ground and prove as profitable.

A question may arise in the minds of some landowners as to the advisability of growing white pine pure rather than in mixture with other species, particularly hardwoods. (For further discussion of this subject

see page 24.) On loamy or clayey soils or in moist sites, mixed stands or even no white pine at all may be better than pure white pine. The soils, however, in the Yale forest, on the whole, are of the sandy gravelly type similar to hundreds of thousands of acres in the New England white pine region. A relatively small percentage of the forest has soils sufficiently heavy-textured and moist enough to permit the growing of good hardwood timber. It is true that hardwood trees and shrubs often seed in abundantly on cutover areas and under the older white pine. These hardwoods are usually either light-seeded species of little or no ultimate value as timber trees or if of good species are incapable of satisfactory growth to timber size on the dry sandy soils.

The following quotation from Yale University, School of Forestry, Bulletin 33, 1930, p. 38, by Professor Toumey concisely sums up the policy with respect to white pine. "Because of the relatively higher market value for white pine than for most other species of the same age and the greater yield per unit of area, relatively pure stands of this species are encouraged. It is believed that here in the optimum range for this species the 1 to 5 per cent of oak and birch reaching into the crowns of the pines and the more or less abundant hardwood vegetation beneath the crowns are adequate to maintain soil fertility and that an overabundance of hardwood would be an economic mistake."

Red pine (Pinus resinosa) will outgrow white pine in diameter and height thus attaining merchantable size in a shorter time, at least on the drier soils of the forest. It has the disadvantage of being so rare in the Keene region, although native there, that it must be artificially established by planting rather than by natural reproduction as is frequently possible with white pine. Another disadvantage of red pine is that it is virtually unknown in the markets of the region and is likely to sell to less advantage than white pine. Some red pine stands have been planted on the Yale forest and will be grown to furnish a comparison with white pine.

ESSENTIAL FORESTRY PRACTICES IN THE GROWING OF WHITE PINE

FOR purposes of this discussion operations in the Yale forest may be grouped under the following four headings:

Harvesting merchantable wood and timber.

Securing the establishment of a new crop on areas from which the

merchantable timber has been removed and also on open fields not needed for agriculture.
Cultural operations to improve the growing crop.
Protection of the growing crop.

Each of these subjects merits consideration by forest landowners who may wish to practice forestry in their own properties. The methods found useful in the Yale forest are discussed and concrete examples are given for each type of operation.

HARVESTING MERCHANTABLE WOOD AND TIMBER

CUTTING and marketing of forest products is the final phase of tree-crop production but in the long run is of primary interest to the owner since it brings in a large share of the income derived from the forest. Most of the mature white pine in central New England was blown down in September 1938 and was harvested perforce in 1939. For some time the attention of timber growers will be devoted principally to the earlier stages of crop management, but for the purpose at hand harvesting is best discussed first, even though actually it is the last stage of the process. In approaching the subject many questions arise such as how much to cut in a given forest, what type of tree to cut, method of selling the forest products, and whether to use clearcutting or partial cutting.

How Much to Cut

In the Yale forest at Keene it was the practice for a few years prior to 1938 to cut each year 200,000 to 250,000 feet, board measure, of pine. This was less than the annual growth of pine on the property, which just before the 1938 hurricane was estimated to be 400,000 feet, board measure. Ultimately as discussed on page 11 when the productive capacity of the forest has been built up by intensive management, growth in the white pine type should be approximately 700 feet, board measure, per acre per year. Attainment of this volume of production has been delayed by the hurricane. The relation of the annual cut to the annual growth should be an important factor in determining the amount to cut on any property. If more than the growth is removed over a period of years the timber supply in the forest may be exhausted, while if less than the growth is taken out timber accumulates. Growth to be expressed in salable products such as lumber must be laid upon trees of merchantable size. This requires that a considerable number of mer-

chantable trees must be kept on hand in the forest at all times to serve as working capital upon which growth can accumulate. Since the amount of timber now present in the Yale forest as working capital is much too small, the right policy is to leave a large share of the growth uncut to accumulate as capital. Most forest properties in New England require a policy of this character. Timber resources throughout the pine region of New England had been severely reduced by past overcutting before the hurricane. Today on forest properties which lay in the path of the hurricane the working capital of merchantable timber has been practically exhausted and will need to be built up for many years before the full growth of the forest can be harvested.

This point has not been properly appreciated by forest owners, namely that growth of timber in as large quantities as the soil is capable of producing can be obtained quickly only on lands already carrying a stand of merchantable trees, capable of laying on growth annually in the form of salable timber. In contrast stands composed of small trees below merchantable size, while often growing rapidly in diameter and height, put the growth all on such small trees that it represents little or nothing so far as salable timber is concerned. If growth each year in merchantable timber is wanted a forest capital in the form of a growing stock of trees of merchantable size must be retained in the forest at all times. Just how much timber per acre would be the most desirable amount to retain in a white pine forest is not definitely known. In fact the amount may be expected to vary with such factors as the quality of the soil, the products into which the timber will be put, and various other details of management. An average of at least 10,000 and probably 15,000 board feet per acre of working capital is considered desirable for the Yale forest. While this amount of growing stock is often spoken of as an average amount per acre it should not be inferred that necessarily on each and every acre just this quantity of timber will be found. Some acres will have no merchantable timber at all, being occupied by small seedlings and young growth. Other acres, covered with older timber, will carry much more than the average volume of growing stock. The essential point is that the forest as a whole should contain a growing stock of merchantable sizes equal to the desired average amount per acre multiplied by the acreage.

The total sawtimber volume (1940) on the Yale forest is 4,584,000 feet, board measure. This is only a little more than 3,000 board feet per acre as compared with the 10,000 to 15,000 board feet per acre considered desirable. Moreover, only a negligible part of this volume is in trees

more than 15 inches in diameter, breast high, and less than half of it is in trees more than 11 inches in diameter. When the growing stock is properly built up a large proportion of the timber harvested should come from trees 16 or more inches in diameter while most of the trees from minimum merchantable size to 15 inches in diameter are retained for further growth.

Thus it is obvious that cutting should be very light for a number of years until the working capital of timber has appreciably increased. In a forest with such a small proportion of large trees, or even in a well-stocked woodlot, the amount which should be cut annually may be so little as to make impracticable an efficient logging operation. Here instead of cutting each year a larger amount may be taken out periodically. However, where logs can be trucked to a near-by sawmill it may be possible to make a cutting each year even though only a small total volume is harvested.

Another indication as to the adequacy of the growing stock on the Yale forest is obtained from the classification of the forest into areas of different age classes (Table 1). Two forms of stand are recognized, evenaged and unevenaged. The evenaged stands are those in which most of the trees are of the same age or differ in age from other individuals in the same stand by less than twenty years. The unevenaged classification comprises stands in which trees of three or more age classes are mixed together quite uniformly or in small groups.

Using the figures of area for the Yale forest in Table 1 it is evident that the forest on 73 per cent of the acreage now listed as in the white pine type is evenaged and only 27 per cent unevenaged. In the evenaged portion of the type 89.6 per cent of the area is occupied by reproduction and young growth less than 40 years old, 9.5 per cent by timber 41 to 60 years of age and only 0.9 per cent by timber over 60 years old. In addition to the 568 acres now in the white pine type 429 acres are shown in Table 1 as "areas under regeneration." It is expected that within a few years most of these acres will be restocked with white pine in evenaged form by natural or artificial means, but even so they will then fall into the youngest age class (1 to 20 years) and serve to emphasize the fact that the evenaged stands of the white pine type are preponderately composed of reproduction or small timber.

This is an unfortunate distribution of ages from the management standpoint. Little or no timber can be harvested for many years, because the market will not readily take the small trees and also because it would

be unwise to cut young stands just at the age when they are rapidly increasing in merchantable volume. The forest capital must be built up for 20 to 40 years by keeping the annual cut far below the annual growth.

Unfavorable distributions of age classes similar to or even worse than the situation in the Yale forest are the rule over the pine region of New England as a result both of past overcutting and of the hurricane. In many instances, there will be a strong temptation to cut heavily in the young stands. For the good of the forests in the long run this temptation should be avoided. Such cuttings as are made in these young stands should be in the nature of thinnings which should not be confused with the harvesting of mature timber. (See page 39.)

There are some places within the hurricane zone where timber of size ready to harvest escaped destruction, due either to the vagaries of the storm, which did not strike everywhere with equal intensity, or to the shelter from the wind afforded by the topography. In these stands harvesting may be carried on as usual. This applies also to that portion of the New England white pine region which is located outside the hurricane zone.

Type of Tree to Cut

In any managed forest when the approximate amount of timber to cut in any given period has been decided upon the next step is to select the individual trees which should be cut. Naturally of course the trees must be of merchantable size and quality as otherwise they could not be profitably harvested. There is however a great deal of choice between white pine trees of merchantable size. Immediate financial returns are better when only the trees of such character and sizes as will yield products of high quality are removed. Trees of this type may be either the largest trees in the stand or in many cases be trees of medium sizes which through the aid of competition have developed straight trunks either free of branches or with branches of small diameter.

On the other hand the productivity of the forest is built up and increased most rapidly by removing trees, usually the largest individuals, which while salable today can never grow into trees of high quality because of their present branchiness and poor form (Plates I and III). Such trees should be removed while those capable of growing into trees containing high quality timber should be retained for future cuts (Plates IV and XI). In this way growth will be concentrated upon the best indi-

viduals in the stand. Unfortunately the ideal cannot always be obtained at once. Frequently a compromise has to be struck between the type of cutting which would give the highest present profit and the type of cutting which will in the long run result in the highest returns. For example some of the better quality trees may have to be included with a quantity of low quality trees in order to make possible the sale of the latter.

The objective on the Yale forest is to improve the forest capital not only in amount, which is accomplished by cutting less than the growth, but also in quality by removing principally the merchantable trees of poorest form and quality. After a forest has been worked over once in this way the average quality of the material available for subsequent cuttings will be substantially better than that secured in the first cutting.

Selling Forest Products

There are several ways in which the timber to be removed can be sold. It may be sold standing and be cut and removed by the purchaser. The owner may cut the timber and sell it as logs either in the forest or delivered at points outside the forest. A third method is for the owner not only to cut the timber into logs but to saw it into lumber or other products and sell it as rough or dressed lumber or in more highly manufactured form. This third plan is not suitable for the small owner because the amount which he can cut each year is too small to justify his operating a mill. Even for the larger owner this plan, while in theory it appears to give him a greater chance for profit, often may not be best. The business of growing timber is quite distinct from that of manufacturing, and selling manufactured forest products, and calls for different qualifications on the part of the manager. While the two sometimes may be combined successfully yet in many cases one of the two sides of the project is likely to be overshadowed by the other to the detriment of the former. On the whole the average forest landowner will find his organization better fitted for managing the growing of the timber than for its manufacture and sale as manufactured products.

In the Yale forest timber has been sold principally in the form of logs delivered to near-by mills and woodworking plants, or in some cases as it stands in the woods. So far as possible all operations such as the work of cutting, skidding, and hauling by truck to the plant of the purchaser have been contracted for on a piecework basis. Fuelwood is sold either

as standing wood which the purchaser must cut, or the wood is cut on a piecework basis and sold as piled in the woods or after being hauled out to a truck road.

The accessibility of a tract has a great deal to do with the prices which can be obtained both for timber and for fuelwood. The same quality of wood or timber is worth more if easily reached and cheaply logged. Accessibility includes not only distance from the woods to the place where the forest products are to be used but also the character of the main roads leading from the forest to the point of delivery and the condition of the wood roads. Finally the character of the ground surface in the forest as influenced by the presence of ledges and boulders, swamps and steep slopes over which the forest products must be taken in order to reach a road has a bearing on timber accessibility.

The Yale forest is very accessible, being located only 2 to 5 miles from wood-using plants in Keene and being connected with these plants by hard-surfaced highways. To enable trucks to enter the forest many of the wood roads have been improved sufficiently for truck travel. A network of improved wood roads has now been nearly completed so that few parts of the forest are more distant than one-eighth mile from one of these truck roads. The system of improved wood roads is shown on the map.

Correct Use of Clearcutting and of Partial Cutting

Harvesting merchantable white pine timber sometimes results in removing all the trees from several acres. This is likely to be the case with evenaged stands of old pine of such character as to warrant clearcutting the stand. For example, the trees in dense stands of old pine may have grown in close contact for so many years as to suffer severe breakage and uprooting by wind if their neighbors are removed in a partial cutting. Such stands when harvested have to be clearcut. A second condition best treated by clearcutting is that of rather open-grown evenaged stands. Here the trees, while windfirm if some are left in a partial cutting, are all of such poor quality, due to large branches, as to be not worth saving for further growth. A stand of this kind should be clearcut.

An important advantage in clearcutting white pine stands is that logging operations and later various cultural treatments are concentrated, all of which tends toward more efficient results.

In the Yale forest even before the hurricane there were no really large

stands of old evenaged timber. Some relatively evenaged stands of merchantable pine five to fifteen acres in area did occur but in most of these stands there was irregularity in age and, due to partial stocking, a great difference in form and quality between the individual trees. Over much of the forest small groups of pine of different ages are intermingled and trees of merchantable size but poor form often are scattered in areas of smaller timber (Plates VI and VII).

In carrying out the policy already mentioned, which attempts to improve the quality of the growing stock by removing in each cutting the most limby and poorly formed merchantable trees, harvesting of timber on the Yale forest has in the past been located principally in the stands containing timber of mixed ages, and there has followed a system of partial cuttings, which leaves the smaller trees and better-formed large trees to grow. Frequently patches of timber one-quarter to one acre in size are encountered in these stands where the character of the trees is such that they should all be cut (Plate III). An example of this type of cutting is described below.

Partial cutting, Station 16. This stand was composed of densely grown pine principally 40 to 50 years of age but with single trees and clumps of pine 50 to 70 years old. These older trees were larger, more limby and to some extent deformed by the white pine weevil (Plate I). In the winter of 1935–36 these older and larger trees were cut. The cutting should be termed a partial cutting as the more promising trees of merchantable size were left standing. The result was a thinning in the more regular portions of the stand and also where the older trees occurred singly. Approximately 70 per cent of the area was thinned. Elsewhere small clearcut strips or patches were made by the removal of the clumps of older and more limby trees (Plate II). The clearcutting covered 30 per cent of the area.

The amount cut was 60,000 feet board measure and the amount left was 38,000 feet board measure. Since the area of the stand was 5.5 acres this represented an average cut per acre of 10,900 feet board measure. The cost of logging per thousand feet, board measure, for the timber cut in this partial cutting was 17 per cent greater than would have been the case had a clearcutting method been used. The pine was sold to a box company and after the expenses of logging were deducted gave a stumpage return of approximately $5.00 per thousand feet, board measure. After the timber was removed the cordwood in the pine tops and limbs was sold for $0.25 a cord. The few hardwoods present, chiefly red maple and gray birch, were sold standing to be cut for cordwood.

The advantage of a partial cutting is that while it harvests the larger, more mature, and better-paying trees it reserves the remainder of the stand for further growth and increase in size and value. The reserved trees, freed from competition, are in a much better position to grow rapidly. A second cutting usually can be made in about 20 years and subsequent cuttings can follow at 10 to 20 year intervals. The continuous retention on the area of numerous white pine trees capable of producing seed (Plate II) makes natural regeneration more certain than is the case on large clearcut areas. In the cutting area at Station 16 most of the reserved trees were blown down in the 1938 hurricane. On the protected hillside adjoining the cutting area on the southeast is a stand of young pine which will serve to illustrate the kind of trees which were reserved.

Occasionally clearcutting of a whole stand has been needed. Aside from hurricane salvage the largest stand of this character which has been harvested was one of 7½ acres of open-grown limby pine which was cut clear in the winter of 1935 as described below.

Clearcutting a stand of poor quality pine, Station 35. This stand was about 60 years of age when cut. The trees had grown under conditions of relatively wide spacing and consequently were large-limbed and several were of the many-forked type known as cabbage pine. The policy with such low-quality stands of merchantable white pine is to cut clean and replace them as rapidly as possible with young stands of more promising character. The clearcutting took place in the winter of 1934–35 and extended over 7½ acres. The cut amounted to 143,000 feet, board measure, or an average of 19,000 feet per acre.

Clearcutting is also used in the Yale forest in harvesting stands of low quality hardwoods and in some cases hemlock preparatory to establishment of the pine type on these areas. After the 1938 hurricane it was of course necessary to carry on salvage operations throughout the forest. Where all or nearly all of the merchantable timber was blown over or broken off the salvage operation became a special type of clearcutting. Illustrations of clearcutting inferior hardwoods and hemlock and of a salvage operation are here included.

Clearcutting a stand of overmature hemlock and hardwoods, Station 10. This overmature stand of hemlock and hardwoods (Plate VIII-a) was cut clear in September 1934 (Plate VIII-b and IX). The composition was hemlock, white oak, beech, red maple, and black birch with a scattering of other hardwoods such as red oak, hard maple, and white birch. The average age was 140 to 150 years with some trees over 200 years old. All of the trees in the upper crown classes had reached or passed maturity and practically none gave promise of attaining greater timber value in the future. In fact most of the hardwoods and some of the hemlock were already rotten-hearted. For timber of this character clearcutting is the best practice. The 1.1 acre piece which was clearcut yielded 18,000 feet, board measure. In addition 24 cords of hardwood fuel were cut from the tops of the lumber trees and from the trees too small for lumber.

Clearcutting a hardwood stand for fuelwood, Station 4. A young hardwood stand large enough for fuelwood and consisting of species not desirable for timber (chiefly gray birch and red maple) was cut clear in the winter of 1927 with the purpose in mind of utilizing the gray birch before it decayed and of replacing this stand of low-grade material with white pine.

Clearcutting in hurricane salvage, Station 3. This stand comprising 17 acres of white pine about 60 years old was completely blown down in 1938. The volume is estimated to have been about 235,000 board feet, or 13,800 board feet, per acre. It is one of the largest continuous areas of blowdown on the forest and except for its size is typical of such areas.

In an operation of this sort it is rarely possible to salvage as much material as would be merchantable in an ordinary cutting operation. The trees lie in a tangled mass of tops, trunks and upturned roots, so that cutting and removal of the logs is much more difficult than in a planned cutting of standing timber. The difficulty of logging combined with a scarcity of skilled woods labor makes logging prices high, and the price paid for logs averages lower than usual. Under these circumstances it is necessary to leave on the ground

in stumps, tops, broken logs, and small trees much material which ordinarily would be worth removing. However the salvage in per cent of the volume standing before the hurricane was higher here than in any of the other wind-thrown stands. The majority of the logs here were of relatively good quality, the merchantable trees were tall, dense-grown, and comparatively few small trees were intermingled.

The amount salvaged in this stand was approximately 200,000 feet, board measure, or about 85 per cent of the estimated volume before the hurricane.

In spite of the waste the slash left after logging was so distributed in relatively small piles that it did not present a serious obstacle to reproduction. The reason for this was the good form of the trees on this area. The stand had grown densely enough so that the live crowns were relatively long and narrow rather than bushy. The slash did, however, constitute a serious fire hazard. Therefore the government fire hazard reduction crews protected this area by clearing all the slash from a 50-foot strip around the edges.

Many timber operators are still of the belief that partial cutting is much more expensive than clearcutting because more ground has to be covered to obtain the same amount of timber and because of the extra care needed in the logging operation to avoid injury to the trees (from seedlings to those of merchantable size) left on the area. Experience in the Yale forest in contracting for the logging of the timber indicates that, in stands composed principally of trees of merchantable size and which consequently might be clearcut, the extra cost of partial cutting, per thousand feet, board measure, for the trees cut, does not exceed 10 to 15 per cent of the cost per thousand feet, board measure, when all the merchantable timber is clearcut. This extra cost exists sometimes only in the imagination of the operator unaccustomed to the partial cutting method. When additional cost actually will be incurred as a result of partial cutting it is likely to be brought about by the care needed in felling the marked trees and getting the logs from the area without injury to young growth and remaining merchantable trees. In some cases where the smaller-sized trees would be removed in clearcutting, but not in partial cutting, logging costs may be reduced by partial cutting because of the higher cost of operating small timber. Smaller trees are likely to be more expensive to operate than larger trees per unit of volume. Consequently when most of the smaller-sized trees are left as in partial cuttings the cost per unit of volume may be less than in clearcutting.

The argument which is often brought against partial cuttings, namely, that severe wind-throw will follow, applies normally only to densely grown timber where the trees have short, narrow crowns. Openings created in stands of this kind are apt to result in considerable wind-throw of remaining trees because their roots are not well developed.

Such stands should be opened up gradually over a period of years by repeated light thinnings which will not create individual openings larger than the space occupied by one tree. Small openings of this size usually do not increase wind-throw. By gradually enlarging the space available for the remaining trees they will be developed into windfirm individuals.

On well-drained soils trees with live crowns extending down for at least one-third of the total height can usually be left without danger of overthrow. On poorly drained soils the entire root system is likely to be near the surface, and this condition makes wind-throw more likely than with deep-rooted trees on well-drained soil. In storms of extreme violence such as the hurricane of 1938 wind-throw is apt to be severe regardless of past cutting practices, with dense uncut stands suffering as much damage as those which have been partially cut. Fortunately such storms are of rare occurrence.

When young pine trees are suddenly exposed by creating an opening on the south or southwest side they are likely to suffer from injury to the tender bark and the growing wood immediately beneath. This is usually termed sunscald and while it seldom kills a tree, it is likely to leave a permanent scar lowering the value of the tree for lumber. Cuttings can sometimes be planned so as to minimize this type of injury, by being made very light along the south and southwest sides of young stands which would suffer if suddenly exposed. The damage is not likely to be serious when the exposure is in other cardinal directions.

To minimize injury to reproduction and larger trees which are left, and to restrict the cutting definitely to the trees selected for removal, the owner should in all partial cuttings mark with paint or a blaze each tree which is to be cut and should designate the direction in which each tree is to be felled. To the uninitiated it will be surprising how little damage needs to be done when the trees are carefully spotted for felling and then felled as designated. It is desirable that the blaze indicating felling direction be placed low on the tree and be stamped with the owner's mark so that it will remain on the stump after the tree is felled, thus affording a check on the cutting and direction of felling.

SECURING THE ESTABLISHMENT OF A NEW CROP

ESTABLISHMENT of a new crop will be needed both on areas from which the merchantable timber has been removed (Plates II, V, and IX) and on open fields not needed for agriculture. Crops of pine

timber other than the crop now present cannot be grown unless provision is made to establish a new stand of pine on areas from which the merchantable timber has been cut. This is an essential part of timber crop production and a part which is entirely neglected or inadequately attended to by most forest owners. Thousands of acres of white pine timber have been cut over in the past and the land has been allowed to seed to brush and inferior hardwoods. Where young pine exists today it is for the most part the haphazard result of gradual natural seeding on old pastures. The trees are poor in form and will never make a high quality of timber. No intelligent farmer would expect to harvest a crop of corn or potatoes and obtain another similar crop the next year without the expenditure of skill, time, and money. Neither can the grower of white pine timber secure without similar expenditures new crops to replace the pine harvested. The failure by forest landowners over the last fifty years to understand this simple truth and to take appropriate action is the explanation for the generally poor quality of New England white pine timber cut today. Many industries dependent upon white pine have been driven from this territory by the progressive depletion and deterioration of their raw material supply. Obtaining a new crop of white pine following the harvest of the mature timber is not a simple operation which anyone can accomplish without effort or knowledge. It requires energetic and persistent action. Similarly the white pine stands destroyed by the hurricane cannot be replaced without such action.

The relations between white pine and the other tree species with which it is associated are such that white pine reproduction, which started just before or after the removal of the old timber, is in the great majority of cases crowded out and unless judiciously aided is replaced by other trees usually to the financial disadvantage of the owner. It is generally recognized that the original forest in central New England was composed of a variety of species, principally hardwoods with hemlock and some white pine, and that white pine did not occur in large pure stands. The pure stands of white pine which now exist arose as a result of interference with the natural process of competition between the different species. These white pine stands owe their purity to the fact that they originated principally on pastures and fields once used for agriculture. As pure stands of white pine advance in age seedlings of the shade-enduring kinds of hardwoods (such as the maples) and of hemlock appear in abundance beneath the white pine, gradually develop a dense understory, and when the pine is cut they hold possession of the area and transform a white pine

stand into a less valuable hardwood stand. The white pine seedlings which may start among the hardwoods, being less tolerant and slower growing in youth than many of the hardwoods, are overtopped and eventually killed. This natural process of replacement of pure white pine by hardwoods must be thoroughly understood by forest landowners if they expect to be successful in growing white pine crops. By skillful treatment the natural process can be reversed and white pine can be established in possession of the area after the mature timber has been removed. (Plates VIII-a, VIII-b, IX, and X.)

At this point the question may be raised why, since stands of pure white pine are replaced as a natural process by hardwoods or hemlock, the production of pure white pine stands should be taken as the objective of management on many of the sandy soils in New England. Sometimes it is argued that the forester should never attempt to work against the trend of natural forces and consequently in this instance should not strive to produce crops of pure white pine. This line of reasoning is about as logical as it would be to argue that because potatoes never grew originally in pure stands in New England and cannot maintain themselves without assistance, no effort should be made to grow them under cultivation. It must of course be recognized that crop production becomes easiest when it is in harmony with the natural process of plant succession and development on given areas and that too radical departures from nature are likely to result in disaster. But in the management of plant crops whether agricultural or forest it is rarely if ever the case that the natural plant crop can be accepted without modification as the one which it is desired to grow on a given area. Nor is it true that every modification of the composition of the original forest is unsafe. Full knowledge as to the plant succession (both in trees and in other forms of vegetation) is essential if the forest owner is to recognize and overcome the difficulties to be met in growing his forest crop and is to understand how far he can safely go in modifying crop composition. Equipped with such knowledge he is in a position to undertake production of the crop which will give the best results.

White pine is native to central New England and is well adapted to the climate. It thrives on most classes of soil and develops particularly well in relation to other forest tree associates on the lighter and sandier types of soil so prevalent in parts of central New England. Ability to produce high yields of timber in pure stands has been demonstrated in many places. For the reasons mentioned on page 11 white pine in pure stands

is considered the best tree to grow in most of the Yale forest and on thousands of acres of similar soils in New England.

In this connection it may be well to call attention to the fact often overlooked that in practice a stand is defined as pure when its composition is 80 per cent or more of one species. It is not the intention in the Yale forest to develop stands with such a large percentage of species other than white pine although occasional trees of several other species will undoubtedly occur. One of the arguments urged for growing mixed stands (containing a proportion of hardwoods with a relatively high amount of calcium in their foliage) is that thereby soil fertility is maintained and often improved as contrasted to stands composed 100 per cent of pure white pine. Although this is theoretical and unsubstantiated by reliable experimental evidence, yet for the purpose of this discussion it will be assumed to be correct.

How then can soil fertility be maintained in white pine stands practically 100 per cent pure? It can be accomplished without expense simply by applying thinnings systematically as described elsewhere in this publication. While fully stocked young white pine stands are very dense and will if left untreated exclude practically all living ground cover, yet as soon as thinnings are started and openings are made in the closed canopy a variety of herbs, shrubs, and broadleaved trees will establish themselves as a living understory beneath the pure pine. The foliage of this broadleaved understory mixing with the pine needle litter on the ground will function in the same manner as would the fallen leaves from hardwood trees with crowns occupying room in the main canopy. Thus decrease in soil fertility, one of the arguments sometimes urged against pure stands, need not be feared in the case of managed crops of pure white pine.

A second argument advanced against growing timber in pure stands is that the ravages of insects and fungi are likely to be increased, due to the concentration of large supplies of available food for those pests which prey on white pine. Such an argument is of least weight in regions optimum for the development of a given tree species, as are the sandy soils of central New England for white pine. Furthermore a large amount of definite information exists as to the enemies of white pine and how to combat them and on the whole there are no indications that because of insect or fungus pests pure stands of white pine cannot be maintained successfully in this region. Indeed the danger to white pine from certain of its enemies may be greater in mixed than in pure stands.

A third argument is the familiar platitude about "having all your eggs in one basket." If a landowner devotes all of his acreage to a crop of cotton, or of white pine, and some disaster overtakes that crop, he may be ruined. There are areas, however, which are best suited to a pure crop of a single tree species. The way to avoid courting disaster is not to attempt diversification on such areas but rather to grow the crop in the most approved way and to diversify by acquiring additional lands suitable for other crops.

The poor quality of a large proportion of the stands of pure white pine cut in recent years is sometimes attributed to the purity of the crop and used as an argument to show that white pine should never be grown without a mixture of other species. This is an erroneous viewpoint. Improper management of the growing crop rather than its purity is the reason why the quality of the product is low. Usually the lack of a sufficient number of trees per acre when the stand was young reduced healthy competition thereby allowing the final crop trees to develop relative large branches and to suffer excessively from injuries by the white pine weevil.

In establishing a new crop of white pine on areas from which mature timber has been harvested the important points to consider are (1) a supply of seed or young plants to stock the area; (2) sufficient disposal of the logging slash so that reproduction can become established; (3) cutting back hardwood seedlings and sprouts which overtop and threaten to kill the pine seedlings and (4) felling or girdling of cull trees which occupy space which should be made available for the new crop. In the Yale forest these cull trees are usually defective or crooked hemlock and badly deformed white pine.

A Supply of Seed or Young Plants

White pine produces seed abundantly at irregular intervals often two to four years apart. Less abundant seeding may occur in some of the intervening years. The failure of white pine to produce crops of seed every year increases the practical difficulties of obtaining natural regeneration. As soon as the merchantable timber is cut a large portion of the cutover area is in good condition for the establishment of white pine seedlings. The hardwood understory, if present, has been at least partly broken down by the logging and the forest litter often has been partially mixed with the top soil. If white pine seed is on the ground or falls within a few months an abundant crop of pine seedlings is likely to start. Un-

fortunately it is only in the occasional year that a supply of seed is on the trees the year of the cutting. Even if there happens to be a supply of seed on the standing trees they are frequently cut before the seed is ripe. This point should be borne in mind and when possible cutting of timber should be deferred until the seed is ripe or has fallen. When this can be arranged a good stocking of pine seedlings is almost certain to start.

It is impractical in most cases to cut timber only in seed years and where a supply of seed cannot be distributed naturally over the cutover areas it may become necessary to establish a new crop artificially, usually by planting 2 to 4-year-old trees (Plate X). Large clear-cuttings where it is impossible for seed to be blown in from seed-bearing timber located alongside the clearcut area will usually need planting unless cut in a seed year after the seed is ripe.

Partial cuttings where only small groups of mature timber up to an acre in size are cut clear (Plate V) or where numerous trees of seed-bearing size are left scattered over the cutover area should restock naturally as soon as a good seed year occurs. The shade furnished by trees left on the area in partial cuttings is often a factor in the survival of young seedlings. During the summer on clearings the heat of the sun develops temperatures at the surface of the ground so high as to prove fatal to many newly germinated seedlings. Shade from older trees frequently is an effective protection to seedlings from such injury. The need of shelter for the sensitive young seedlings of white pine is best provided by removing a mature evenaged stand in two cuttings 4 to 10 years apart taking out about half the volume in the first cut. The trees left for the second cut furnish an abundant supply of seed and the desired amount of shade for the seedlings. This is known as the shelterwood method of securing reproduction. Ultimately it will be the chief method of establishing new crops used in the Yale forest but today the character of the timber and the arrangement of age classes require the use of other methods in practically all cases.

An example of natural reproduction following partial cutting is given below.

Natural regeneration of white pine following partial cuttings, Station 3. Most of the pine stands on the Yale forest are composed entirely of trees of natural origin. In many of the plantations there is a substantial sprinkling of natural seedlings among planted trees. The group of young pine near Station 3 will serve as a specific example of natural reproduction by the shelterwood method.

Here in 1926–27 a portion of the stand, which consisted principally of white pine with some pitch pine about 60 years of age, received a partial cutting. Under one group of pitch

pine, white pine reproduction had already started and was 3 to 10 feet in height. All the pitch pine dominating this group was removed leaving the reproduction fully released. Following the cutting of 1926–27 more seedlings started in the open portions of the stand. A few trees were cut in 1932 releasing more of the reproduction. In 1938 the remainder of the old stand was wind-thrown. When the area was planted in 1940–41 after the hurricane, very few trees were needed in the portion of this stand where partial cuttings had been made and advance reproduction had started. If the stand had not blown down, all of it could have been reproduced over a period of about twenty years by repeated light cuttings designed to let in more light and reduce the root competition of the old trees.

In the Yale forest natural reproduction is preferred to artificial if it can be secured within not more than two years following the cutting. If adequate natural regeneration has not started at the end of that period the usual practice has been to restock the area with strong nursery-grown plants. Because of the hardwood competition 3-year or 4-year-old transplants, particularly the latter, are preferred to seedling stock which while cheaper usually does not make so vigorous a start as the transplants. Seven hundred planted trees per acre which is equivalent approximately to a spacing of 8 by 8 feet are enough where hardwoods or hemlock come in abundantly to complete the stocking. Where few if any other trees are present or probably will not seed in, 1,200 trees per acre requiring a 6 by 6 foot spacing are planted. Several examples of artificial establishment of the new crop are described in the following paragraphs.

The simplest and quickest method of establishing a new crop is to cut clear the old stand and set out new trees. This is an especially good method where the crop now on the ground is to be replaced by a new crop of different species.

Planting a clearcut area, Station 10. The clearcutting of this stand in September 1934 is described on page 20. The purpose of the cutting was to harvest the overmature timber (Plate VIII-a) and to clear the area for the establishment of a more valuable new crop of white pine, white spruce, and red oak. White pine and white spruce transplants and red oak acorns were planted in the spring of 1935, spaced six by six feet apart except where slash lay thickly. The red oak acorns were destroyed by rodents, presumably red squirrels. The acorns were replaced in the spring of 1936 with one-year-old red oak seedlings. The three species were planted as three separate groups.

Before planting could be successfully accomplished the logging slash left after cutting of the timber (Plate VIII-b) had to be reduced in volume. This was accomplished so as to yield a profit in the case of the hardwood tops by cutting them into cordwood. This so reduced the hardwood tops that planting could be done right through them. Unfortunately hemlock cordwood on this lot was practically unsalable. Nevertheless, since hemlock tops occupied parts of the area very thickly, it was deemed advisable to reduce the accumulation by cutting 8½ cords of wood out of these tops. The final result was that no windrows of slash wider than 15 to 20 feet remained on the area and it was possible by making holes in these windrows to plant trees as close as 10 by 10 feet apart (Plate IX). This spacing supplemented with the hardwoods which seed in naturally will adequately restock the area. About 200 spruce and oak were set out in the spring of 1938 to refill gaps where the trees first planted had died.

Planting a clearcut area, Station 3. This is the area for which hurricane salvage operations

were described on page 20. In 1939 and 1940 the slash was entirely removed from safety strips around the edges, and elsewhere it was so distributed as to constitute only a minor obstacle to reproduction. However, the 1938 seed crop in this area was very light, and after the hurricane there were hardly any trees of seed-bearing age left in the vicinity. Consequently satisfactory natural seeding did not occur. Therefore the area was planted in 1940 and 1941. White spruce was planted in the low, wet places, but the uplands comprising most of the area were planted with white pine and red pine. Little planting was needed in the northern part where a considerable amount of advance reproduction was already present (page 28). Because of the slash it was impossible to plant trees as close together as is desirable, but by setting trees close to the slash piles an average spacing of less than 15 feet was obtained.

Planting clearcut patches in a partially cut area, Station 16. The cutting made in 1936 in this stand has already been mentioned on page 19. On the area cut clean a new crop is desired (Plate II) and the 30 per cent which was originally clearcut was planted in the spring of 1938 because there had been no seed crop to provide natural regeneration in the interval since the cutting. The pales weevil was no longer active. After removal of pine and hardwood cordwood very few patches of slash sufficiently dense to prevent reproduction remained on the clearcut areas. There were a few such patches of slash which were burned in the fall of 1937. One cleaning has been made in the planted area and two or three more will be needed.

Reproduction is also desired in the additional clearing created by the hurricane. Much of this area lies within 50 feet of roads and was cleared of slash by the fire hazard reduction crews. Their work was completed in 1941 and trees will be planted in the spring of 1942 wherever natural seeding has not taken place.

The pales weevil, *Hylobius pales*, an insect which feeds upon the stem and branches of young pines often killing small plants, is a serious factor to be reckoned with in securing white pine regeneration. The insect breeds principally in the stumps of recently felled trees and is active for two growing seasons following the cutting of the timber. During the first season the beetles are most voracious in feeding upon small pines. They are considerably less so in the second season and have gone to other areas before the third summer. The ravages of this insect make it unwise to plant cutover pine areas until the second or third spring after the cutting of the timber. One-year-old seedlings are not attacked and often 2-year-old seedlings are not severely injured the second season of the insect's presence on a cutover area. Hence if natural regeneration starts at the time of the cutting, or later, it is not destroyed by the pales weevil although most of the seedlings already present and more than a year old will be killed. An exception to this statement is that older seedlings particularly those over 2 feet in height are not likely to be killed outright by the insect although many of the smaller twigs may be girdled.

The amount of planting needed in the Yale forest has been increased temporarily as a result of the 1938 hurricane. The forest on approximately 370 acres was so severely damaged as to require the establishment

of a new crop. So far as possible natural seeding of pine will be utilized. The white pine seed crop in the fall of 1938 varied from a heavy crop in some places to little or none in others. Unfortunately in most parts of the Yale forest there was comparatively little seed. At the end of the following summer there had been insufficient germination and survival of pine seedlings to provide adequate restocking. Most of the trees of seed-bearing size on these areas were overthrown, so that very little additional seeding could be expected. Already the scanty natural regeneration on about half of the devastated area has been reinforced by planting. The remaining areas will be similarly treated in 2 to 3 years. The planting problem is complicated by the unusually large quantities of slash remaining over much of the area.

Disposal of the Logging Slash

The branches and tops of trees felled in a cutting often cover a portion of the ground so thickly as to bury any pine seedlings already there and to prevent new reproduction from starting for several years. (Plate IV.) This is especially true in areas of wind-thrown timber. On most tracts logged after the hurricane, slash is unusually thick because it was not possible to utilize the trees as fully as in normal logging. Wind-throw in stands of trees too small or poor in quality to be worth salvaging has left some areas completely covered with a tangled mass of slash several feet deep.

To secure a fully stocked new crop it is necessary to get rid of the thick heaps of slash. However, spots densely covered with slash may be so scattered and each so small in size that the area on which reproduction is prevented is well distributed and forms such a low percentage of the total area that the slash needs no treatment. Usually on any cutting area there will be some relatively large heaps of slash which should be removed. In many stands felled by the hurricane such heaps occupy most of the area, and their removal would be too expensive to be justified for the sake of establishing a new crop.* The only practical procedure in such places is to wait for the slash to rot away. Complete disintegration may take as long as 20 years. Meanwhile, however, it is possible for seedlings to become established around the edges of the pile where the slash is thinnest. The unproductive area is gradually reduced to

*Slash disposal as a fire prevention measure is another matter, which is best discussed under the heading "protection of the growing crop."

smaller and smaller dimensions as the young trees develop and spread their branches over the old slash piles. Where patches of dense slash are less than 15 feet wide and are so distributed as to occupy less than 25 per cent of the area the disposal of such slash is usually not justified as a reproduction measure. Heavy accumulations of slash lying under standing trees which will remain for 20 or more years can be left untouched. On partially cut areas a large proportion of the slash is apt to be located in this manner and consequently requires no disposal.

The cheapest method of disposing of the heavy windrows of slash found on clearcutting operations is to allow the slash to lie on the area just as it is left by the logging contractor until the late summer or early fall following cutting of the timber. Since most timber is cut in the late fall and winter this plan allows the slash to dry for 6 to 12 months. During the summer it drys thoroughly. In late summer or early fall the windrows of slash are set on fire. A cloudy, quiet day with high atmospheric humidity must be selected, preferably in the period just before a rain. It is neither necessary nor desirable to obtain an absolutely clean burn as a thin cover of slash is beneficial in protecting the seedlings against excessively high temperatures at the ground surface and in maintaining surface-soil moisture. To prevent fire spreading a supply of water and several men with pumps to apply the water must be available. Admittedly this method of burning slash is dangerous and for its success depends upon accurate appraisal of weather conditions and burning only when conditions are just right. In New Hampshire a brush burning permit would have to be secured from the town fire warden and presumably could not be obtained except on safe days and by reliable men of proven experience in slash burning and fire fighting. Burning slash in windrows as it lies on the ground without any handling should be done for less than 25 cents per thousand feet, board measure.

Where pine cordwood can be sold the larger branches and tops should be utilized for this product as a first step in slash disposal. If such action is taken the percentage of the area which is covered by slash so dense as to impede reproduction is greatly reduced (Plates VIII-b and IX). On spots where the slash still lies thick enough to impede reproduction it can be burned in the manner just described.

A safer method is to burn the slash (either with or without first cutting cordwood from the tops) late in the fall, after rains or snow have wet the ground so as to prevent fires running freely over the whole area, or in the early spring before the ground has dried out. The slash is itself not so

dry as in late summer and usually does not burn readily when ignited as it lies on the ground. Usually it is necessary to start a fire and pile the slash upon the fire. This increases the expense to $0.50 to $1.00 a thousand feet, board measure, of the timber cut depending upon the size and character of the timber. The slash from large-sized densely-grown timber will be less bulky in relation to the volume of logs cut than the slash coming from open-grown stands of small-sized trees.

In the Yale forest it has usually been possible to sell the cordwood in the tops and thereby reduce the amount of slash which needs disposal. The relatively few dense patches of slash remaining after cutting cordwood from the tops have been burned, preferably in the late fall, by throwing the slash on fires. Burning the slash in windrows has been used in only a few cases because of the difficulty of finding enough opportunities in the late summer and early fall for safe burning. There are some areas of slash resulting from the hurricane which are a serious hindrance to reproduction and yet they cannot be disposed of by any safe, economical method. On those areas it is inevitable that the establishment of a new crop will be delayed for many years.

Cutting Back Hardwood Seedlings and Sprouts Which Overtop and Threaten to Kill Pine Seedlings

This operation is known technically as a cleaning or weeding and is an almost indispensable type of treatment if crops of white pine timber are to be grown (Plate X). The aggressive hardwoods often have established their seedlings under the old pine timber before it is cut or else these hardwoods seed in quickly after the cutting and by rapid growth overtop the pine seedlings which are on the ground or which may start with the hardwoods. Any delay in establishing pine seedlings on a cutover area, such as results through lack of a seed supply or because of the pales weevil gives the hardwoods additional advantage over the pine.

One to three cleanings usually are necessary before the pine secures a dominant position in relation to the hardwoods. In making a cleaning the hardwoods which *overtop* or are *about to overtop* the pine should be cut. The tendency in making cleanings is to cut too many stems. Where a clump of hardwood sprouts is encountered it is sometimes good policy not to cut the entire clump at one time even though the pine underneath may not be completely uncovered. Such clumps when entirely cut off resprout prolifically and may offer more severe competition with small pine than did the original clump. Leaving temporarily one or more of the

stems in a sprout clump keeps down the growth of new sprouts. While the pine may still be overtopped by the stems left uncut yet it receives more light and suffers less from competition than before the cleaning was made.

Successive cleanings should come 2 to 4 years apart and be repeated until the pine is tall enough and growing in height fast enough to keep above the hardwoods. The first cleaning is needed immediately when the pine by its slow height growth and weak development shows the effect of competition. Better practice anticipates this situation and makes the cleaning before the overtopping hardwoods have affected unfavorably the height growth of the pine. Each cleaning is likely to require from a quarter to one day's labor per acre. The tool preferred for this work on the Yale forest is a heavy broad-bladed knife something like a meat cleaver. Machetes are also frequently employed. The material cut is of such small diameter that an axe cannot be used to advantage. A cutting tool which can be handled with one hand is preferable.

Those hardwoods such as red maple which have a dense foliage are much more serious competitors of the pine than are light-foliaged species such as aspen and gray birch. The pine will require more cleanings, repeated more frequently, where the former type of hardwoods prevail than in mixture with such trees as aspen and gray birch. Where cleaning in pine stands has been neglected until the hardwoods have grown to size large enough for cordwood they can, if the cordwood is salable, be cut for fuelwood without expense or even at a small profit. At first thought this may seem to be the cheapest way to remove hardwoods in young pine stands. Unfortunately although the work is cheaper, provided the small cordwood obtained can be sold, yet the delay in making cleanings to a period long beyond the time they are first needed results in killing many of the overtopped pine and consequently does not produce as fully stocked pine stands as can be secured when the cleanings are made early before the hardwood has reached cordwood size. In the Yale forest cleanings are made early except on properties which were acquired too late to make cleanings when they were first needed.

The extensive areas of young pine in the Yale forest today are testimony to the effectiveness of cleaning as a stand improvement measure. Had this work been neglected most of these areas would now be occupied by hardwoods of low value like so much of the potential pine land in central New England. Two examples of the use of cleanings are described below.

Cleanings in plantations, Station 4. This area has already been mentioned as an example of clearcutting a young hardwood stand for fuel. Following the clearcutting, which took place in the winter of 1927, the area was planted to white pine in the spring of 1927. The trees were spaced 6 by 6 feet apart. In 1931 the hardwood sprouts from the trees cut in 1927 had overtopped the white pines and threatened to smother them. To remedy the situation a cleaning was made in 1931 cutting back those hardwood stems which were dominating the pine. A second cleaning, lighter than the first, was made in 1934, and a third, still lighter, in 1938. The treatment consisted of cutting back with a machete or heavy knife all the inferior trees which were interfering with the pine. Only hardwoods which overtopped the pine were cut back. Those which crowded pine on the sides but did not overtop them were left as trainers to prune the branches of the pine. The method of cutting was to lop the stem at any convenient height below the top of the adjacent pine, usually 2 or 3 feet from the ground. Preferably the stem is nearly severed and bent over rather than cut completely off, as the latter practice results in more vigorous sprouts from the root collar which soon overtop the pine again.

Although most of the pine are now definitely above the hardwoods, an inspection will be made in 1942 and if any overtopping hardwoods are found, they will be cut back.

Cleanings in plantations, Station 7. In 1916 plantations of pure red pine, pure white pine, and mixed red and white pine were made (Figure 1) on land which had been cut clear in 1910 to 1912 and burned over in 1914 before being purchased by Yale University. The area was practically bare as a result of this fire when planted in 1916 and consequently did not need a cleaning as early as plantations on unburned areas. Two spacings, 4 by 4 feet and 8 by 8 feet, were used in these plantations. Several permanent sample plots were laid out as shown in Figure 1, half of which were left without any treatment while the others were cleaned of hardwoods in 1924 so thoroughly that the pine were able to dominate the hardwoods.

Inspection of the plots shows marked differences in development due both to the cleanings and to the variation in spacing. The trees on the plots which received cleanings average much larger and more vigorous than those on plots which have never been cleaned. The figures given below indicate that the trees are larger, but do not adequately convey an idea of the great superiority of the pines on the cleaned plots.

Plot No.	*Treatment*	*Range of diameter, breast high, inches*	*Diameter, breast high, of average tree in inches*
21	White pine, 4 x 4, cleaned	1 to 8	3.8
23	White pine, 4 x 4, never cleaned	1 to 8	2.1
22	White and red pine, 8 x 8, cleaned	1 to 10	5.5
25	White and red pine, 8 x 8, never cleaned	1 to 8	3.4
19	Red pine, 4 x 4, cleaned	1 to 8	4.3
20	Red pine, 4 x 4, never cleaned	1 to 8	2.6
24	Red pine, 8 x 8, cleaned	1 to 10	6.4

Hardwoods averaging at least 9 feet higher dominate the plots never cleaned and are suppressing all but a few of the pines which got an early start in some small opening. Another effect of the hardwoods has been to reduce appreciably the number of living pines on the plots never cleaned as compared to those cleaned.

When plots of different spacing (but of the same treatment as regards cleanings) are compared the results appear to favor the 8 by 8 foot spacing for red pine. The wider spaced plantation is stocked with bigger trees with finely developed crowns and has suffered less from snow injury than the more densely stocked plantation spaced 4 by 4 feet. In the latter a few stems have proved too slender to withstand the weight of snow

and have been bent out of their normal straight form. Since an 8 by 8 foot spacing results in the trees developing rather large branches it is advisable that trees intended for the final crop be selected and pruned as soon as possible. This has already been done.

White pine is likely to develop better when spaced 6 by 6 feet, but this point is not illustrated by this series of plots.

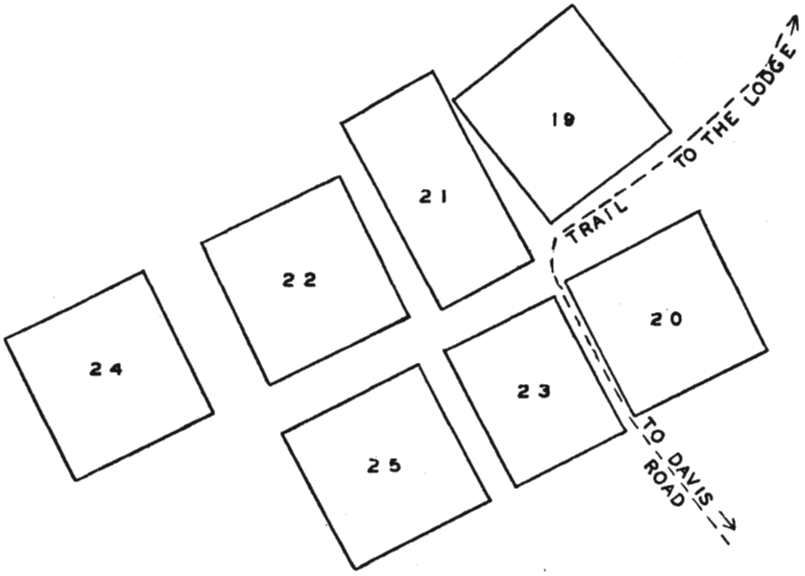


Figure 1. Arrangement at Station 7 of plantation plots to illustrate results of different spacings and effect of cleaning. Spacing and treatment have already been given. The scale of the map is 130 feet to the inch.

Felling or Girdling Cull Trees Which Occupy Space That Should Be Made Available for the New Crop

On an area from which the merchantable timber has been cut there often remain, in addition to trees intentionally left for further growth or to supply seed, other individuals undesirable for retention but which for one reason or another were not merchantable at the time of cutting. Such trees should either be felled or be killed by girdling for the benefit of the new crop. In girdling trees a ring is chopped or hacked well into the sapwood completely around the tree. This treatment usually results in killing the tree within 1 to 3 years.

Trees below 6 inches in diameter can be disposed of more cheaply by

being felled than by girdling. However, individuals of such small size are not so frequently found among the cull trees left on cutover areas as are those of larger size. Hence girdling usually will be employed as the method of disposal. Girdling has an advantage over felling in that while the girdled trees are dying they furnish partial shade for one or more years. This shade may be of protective value to white pine seedlings. When mature trees are felled their protective cover is removed suddenly. In the management of some species quick removal of older trees may be desirable, but in growing white pine a temporary light shade on cutover areas is likely to assist the establishment of a new crop. Another advantage of girdling is that the girdled trees disintegrate slowly and fall to the ground piece by piece without serious damage to the reproduction.

Crooked and defective hemlock, exceptionally knotty hardwood, and occasional badly weeviled white pine comprise the cull trees which require treatment in the Yale forest. Except from the aesthetic standpoint girdling is a better way of treating these trees than is felling.

CULTURAL OPERATIONS AFTER THE REGENERATION PERIOD TO IMPROVE THE GROWING CROP

DURING a period of several years (1 to 10) immediately following the harvesting of the mature timber from a given stand efforts of the owner should be centered on establishing a new crop upon the open portions of the cutover area. This includes getting seedlings of desirable species started and assisting these seedlings to obtain a dominating position in the stand over the less desirable trees. Details of this work have already been discussed (pages 22 to 36). When the desirable trees have been placed in possession of the area the new crop may be considered established. From this point on efforts are directed toward improving the growing crop through cultural operations of which pruning and thinning are the two important types of work.

Pruning

Pruning of selected trees is a cultural operation which should prove profitable in many white pine stands because thereby production of lumber clear of knots is obtained. The lower branches of white pine trees die soon after they become shaded by the growth of higher branches, but under natural conditions the dead branches remain on the trees nearly

to the ground for at least 60 to 80 years. This results in the production of lumber of the lower grades. Most knotty lumber is of relatively low grade, but that which contains dead knots is apt to be particularly poor in quality. When new wood grows around a dead branch the resulting knot is known as a dead knot. It is more susceptible to decay than a live knot and since the wood fibers of the knot and of the main stem have no connection the knot is apt to fall out after the boards have been sawed and dried. Lumber which contains live knots of small diameter is of much better quality than that containing dead knots.

The usual practice in pruning is to remove the limbs from the ground upward to a height of either 13 or 17 feet depending upon whether a 12- or a 16-foot clear butt log is wanted. Only the trees which will be left to grow 30 to 40 years longer should be pruned and not over 125 to 175 trees per acre. To secure best returns from the expenditures for pruning, the pruned trees should be kept growing at a fast rate after pruning. The trees which are most profitable to prune are those individuals so located with relation to other trees that they can maintain rapid growth.

Among the most profitable trees to prune are those which have been given abundant room as a result of partial cuttings. (Plates XI and XII.) Such trees are relatively cheap to prune as they are easy to work on and have only dead limbs on the lower log because before the cutting they grew in comparatively dense stands. They are in a position to grow rapidly for 15 to 30 years without further assistance.

In the Yale forest pruning has been done first on areas where mature timber has been removed recently in partial cuttings leaving many of the remaining trees in exceptionally good position for rapid growth and secondly in the more sparsely stocked young pine stands 20 to 40 years of age where similar conditions for fast growth prevail. The trees pruned range from 4 to 10 inches in diameter at breast high and are selected on the basis of their form, crown development, and opportunity for rapid growth. No white pine should be pruned where live limbs more than 2 inches in diameter would need to be cut. This is principally because of the high cost of cutting large limbs, but also because healing of such large wounds is very slow and decay may set in.

It is sometimes stated that no trees bigger than 6 to 7 inches in diameter breast high should be pruned. Where the pruned trees will be allowed to grow for at least 30 years more and be kept growing at a rapid rate individuals up to at least 10 inches in diameter breast high can be pruned profitably. In fact the basis for selecting a tree for pruning is not

primarily its present diameter but rather the length of time it will be left to grow, its position with respect to neighboring trees, its probable rate of growth, and its form and crown development.

The method of pruning white pine preferred in the Yale forest comprises three operations, as follows:

(1) Pruning with a curved handsaw as high (6 to 7 feet) as a man standing on the ground can easily reach. A slightly curved saw equipped with pistol grip handle with blade 12 inches long, 2 inches wide at base and tapering to a narrow tip, with 7 teeth to the inch, makes an effective tool for pruning white pine (Plate XII).

(2) Pruning with the same handsaw from a light 8-foot ladder equipped with long spikes on the bottom ends and a curved metal top rail covered with rubber hose to rest against the tree (Plates XI and XII). This second operation carries the pruning up to or just above 13 feet.

(3) Pruning with the same handsaw from a 14-foot ladder of similar construction. The third pruning finishes the operation to 17 feet above the ground. The second and third operations are sometimes carried on by using a saw mounted on an 8- or 12-foot pole.

The ladder and handsaw method has been found by experience to be better than the pole-saw method for conditions in the Yale forest. Figures of cost obtained at Keene* indicate that pruning by the pole-saw method costs more than by the handsaw and ladder method and is less satisfactory in other ways. Most of the pruning so far done in the Yale forest has gone only as high as 13 feet. The intention is to carry the pruning up to 17 feet as soon as more of the lower pruning needed on the forest has been completed. In naturally reproduced stands approximately 10 white pine trees per hour can be selected and pruned up to 13 feet.

Pruning in plantations is more expensive than similar work in naturally reproduced stands because the latter have a larger number of trees per acre and in consequence form a denser stand resulting in a smaller average diameter of the branches which are pruned. In white pine plantations about 7 trees can be selected and pruned to 13 feet in an hour.

The majority of limbs cut in pruning white pine trees in natural stands 20 to 40 years of age are dead but usually a few whorls at the top are

*Artificial pruning in natural stands of eastern white pine, by Paul Schaffner. Unpublished manuscript in Yale University, School of Forestry, Library.

alive. There is no objection to pruning live limbs provided only a few whorls are taken off from the bottom of a long live crown. Healing over of the cut stubs progresses faster where live rather than dead limbs are cut.

In pruning young plantations live limbs frequently are cut. No injury need be expected from this provided pruning is not carried so high up the tree at one time as to appreciably reduce the live crown. A safe rule is to remove only such live limbs as are touching limbs of adjoining trees and consequently are at least partially shaded.

Two examples of pruning operations are described below.

Pruning in an open-grown stand of naturally reproduced white pine, Station 6. This stand is 20 to 40 years of age. Selected trees have been pruned and will be favored in subsequent cuttings for the next 30 years at least. The trees have been picked for pruning on the basis of: (*a*) Relative crown position and development. Trees with deep symmetrical crowns growing rapidly and with room enough to continue rapid growth for 10 to 15 years without help are selected. (*b*) Limb size. Only trees whose largest limbs up to 13 feet and preferably 17 feet above the ground do not exceed 2 inches in diameter are pruned. (*c*) Character of stem; straight, and free from defects.

No effort is made to prune a specified number of trees per acre. Only trees worth pruning are taken. The trees usually pruned in these open-grown stands range from 4 to 10 inches in diameter, breast high.

Pruning following a partial cutting, Station 16. As a result of the partial cutting made in the fall of 1935 many thrifty trees were placed in position to grow rapidly for the next 10 to 30 years (Plates XI and XII). Such trees are the most profitable type to prune. On 3.5 acres of this cutting area 167 trees were pruned or an average of 47 trees per acre. The pruned trees ranged in diameter from 4 to 10 inches and were in most cases located on borders of openings created by the cutting. While a good many of these pruned trees were blown down in the hurricane, a number of them remain and other well-formed trees have been placed in a position for rapid growth and should now be pruned. This is characteristic of a great many partially blown down stands throughout the forest. Pruning is being carried on in such stands as rapidly as time permits and by 1943 all of the partial blowdowns will have been treated in this way.

Thinning

Another important cultural operation which should be carried on is the thinning of dense stands at intervals throughout their life. In making thinnings in white pine stands the better-formed and more vigorous trees should be favored by removing those individuals which are of relatively poor form, defective, or are crowding the better trees. The object is to make numerous small openings in the crown canopy. The more vigorous trees will expand their crowns into these holes and when, after a few years, the openings are closed, another thinning is made. The

advantages of thinning white pine have been discussed in a previous bulletin* and are summarized in the following paragraphs.

One result of thinning is that diameter growth is increased and trees of larger diameter are secured in thinned as contrasted to unthinned stands within the same length of time. As a consequence of the bigger diameters the quantity of material of the larger sizes is increased.

Better financial results should be obtained in stands properly thinned than in those unthinned for at least three reasons: First, the greater quantities of larger-sized material secured are likely to increase financial returns; second, income is obtained earlier in stands systematically thinned than in those where there is no utilization of material until the final harvest of the crop; third, the capital invested in the standing timber is appreciably reduced by the thinnings while at the same time the annual growth is kept constant or increased so that the rate of return on capital invested in timber is raised.

Another effect of thinnings, particularly in stands past middle age, is to encourage natural reproduction. This often may result in starting a new crop of white pine by the time the old crop is ready for harvest.

Thinnings are of exceptional importance where the stand contains trees which have been pruned. In order to realize on the pruning investment the pruned trees must be kept growing at a rapid rate. This is possible only if they have room to expand their crowns. As already described (page 37) trees selected for pruning should so far as possible be those already standing in such position, with respect to the neighboring trees, that rapid growth for the next few years is guaranteed (Plate XII). If such selection is made, immediate thinning to stimulate growth on the pruned trees is unnecessary. Even though trees of this type are picked for pruning they will eventually come into competition with their neighbors and need to be assisted by thinning (Plate XI).

In the Yale forest early thinnings in pure white pine stands are not made until the cost of the operation will be returned by sale of the trees to be cut. Under the market conditions which prevail around Keene, this means that the first thinning cannot be made until the stand is 30 to 40 years of age. Other localities may be more fortunately situated as regards markets enabling landowners to thin profitably at an earlier age. Advantage of market conditions which permit the sale of small-sized

*Hawley, R. C. Observations on thinning and management of eastern white pine (*Pinus strobus* L.) in southern New Hampshire. Yale University, School of Forestry, Bulletin 42, 1936.

trees should always be taken to make a thinning as early as possible in the life of a stand. Oftentimes competition is severe in young pine thickets less than 10 years of age. Fortunately in white pine stands occasional individuals always seem able to get ahead of their neighbors and express dominance. Consequently early thinnings, while desirable to stimulate growth, are not absolutely essential in most stands to prevent stagnation in white pine crops, as is the case with crops of some other trees. There will be exceptional cases where the young crop is so dense that a small investment per acre for thinning crops 10 to 20 years in age will be a paying measure.

Mixed stands of white pine and hardwoods usually can be thinned at an immediate profit at a younger age than pure stands of pine because the small hardwoods can be more readily sold for cordwood than can the pine. Where hardwood is in the mixture in the Yale forest thinnings can often be made without expense between the 10th and 20th years when the material cut is only 1 to 4 inches in diameter. In these cuttings, which combine the principles of thinning and of cleanings, the hardwoods are cut and the pine left with the result that a pure stand of pine is gradually developed.

PROTECTION OF THE GROWING CROP

ADEQUATE protection must be secured against the dangers which threaten to injure or destroy the crop. In the Yale forest the white pine blister rust, the pales weevil, and the white pine weevil have been the principal injurious agencies during the last 20 years. None of these enemies should prevent the production of profitable crops provided the proper methods of management are employed.

Fire is of course always to be feared but the fire record in the Yale forest has been favorable. The largest fire since the acquisition of the forest was one of 8 acres in 1938. This started beside a public road, probably from an unextinguished cigarette or cigar butt, during a period of unusually dry weather and high winds. It burned through a young plantation thick with weeds and briars and was stopped upon reaching older timber. The aggregate area which had been burned in 25 years before that was less than 2 acres, although there were 5 separate fires during that period. This good record is due partly to favorable climate and the relatively low inflammability of the forest types, but also

to thorough patrol work by the forest employees and to careful habits among the people who frequent the forest and its borders.

Logging slash forms one of the most serious fire hazards in the white pine type. Disposal of slash as a fire preventive measure may be justified under some conditions where it is not justified as a reproduction measure. Particularly along public roads is this likely to be the case. Five of the 6 fires in the Yale forest started near public roads. In planned cuttings near roads the trees usually can be felled and the tops lopped in such a way that most of the slash is left at a considerable distance from the road without any expense for disposal. Except near roads there are few instances where slash disposal purely as a fire preventive measure is justified.

The slash resulting from the hurricane presented an exceptionally great fire hazard because of its depth and continuous extent in windthrown stands. Here safety of life and property on a large scale was at stake and it was worth while for the government through its Northeastern Forest Emergency Project and State agencies to accomplish a large amount of slash disposal work which individual landowners could not afford. All slash was removed to a distance of 50 to 100 feet from woods roads and public highways and in some of the larger areas of slash firebreaks were created by removing all slash from strips gridironing the area. This has been done in areas of high fire hazard in the Yale forest.

Most of the hurricane fire hazard reduction work was done by Civilian Conservation Corps crews from a near-by camp in West Swanzey. While this camp was in operation there were always crews available to fight fires which might have occurred. The Civilian Conservation Corps constructed two permanent waterholes near highways to supply power pumpers. More waterholes are needed.

The Yale forest keeps a supply of fire-fighting tools ready for instant use during the fire season. The road system which brings practically all points within ⅛ mile of a truck road enables ready access to all parts of the forest. The West Swanzey fire department, located only 2½ miles from the forest, responds to forest fire alarms and has rendered efficient service on the few fires that have occurred. The forest is under observation for detection of fires by a state lookout tower.

White pine blister rust is prevalent on the currant and gooseberry plants in the Keene region and has spread from these plants to occasional trees in the forest. The life history of the white pine blister rust and methods of control are too well known to require detailed discussion

in this report. The disease spreads from white pine to currant and gooseberry plants and from the latter back to white pine. It cannot spread directly from one pine to another. Control is obtained by eradicating the currant and gooseberry bushes in and for a distance of approximately 900 feet around all areas of white pine which are to be protected. A single eradication of the currant and gooseberry bushes is not enough. They must be re-eradicated at intervals of less than 10 years. Currant and gooseberry bushes have been eradicated three times in the vicinity of the Yale forest. The last eradication took place in 1934–1936. The work of re-eradication will be repeated every few years and this should prevent any serious attack by the blister rust. Cutting the pine trees affected will not ordinarily be effective in eliminating the disease because the spores which come from the pines to infect the currants and gooseberries can travel long distances. It would be necessary to eradicate the disease on all pines in a large area in order to obtain complete control by that method. Nevertheless whenever a pine infected with blister rust is found in the Yale forest it is cut down. This may help somewhat in reducing the amount of infection and it improves the appearance of the forest.

Injury to reproduction by the pales weevil can be seen on every area where white pine has been cut within 24 months previous to the inspection.

The pales weevil is controlled, as has been already described, through the methods used in securing regeneration either by delaying planting until the third year after cutting, when the beetles have gone, or by relying upon natural regeneration, which may be on the area before cutting and be abundant and large enough to escape complete destruction by the pales weevil, or else originates on the area after the cutting.

The white pine weevil attacks the terminal shoots of trees more than 2 to 3 feet high. Its work can be observed in practically all stands. The eggs are laid in these terminals and hatch into grubs which work downward in the shoot eating the growing tissues and destroying the terminal shoot. The result is that one or more of the side branches takes the place of the terminal and a crook in the main stem is caused, sometimes ruining the log for lumber. Control in the Yale forest is sought through establishing thick stands of reproduction. While the trees in such stands are frequently weeviled the competition of neighboring trees forces the side shoot to straighten and results in such small crooks that they are overgrown as the log develops. The worst injury occurs in

sparsely stocked plantations. Here weeviling in successive years results in producing bushy trees which may never be capable of yielding good lumber.

To avoid severe injury from the white pine weevil, plantations of white pine on open fields should not be made with less than 1,200 trees per acre (6 by 6 foot spacing). If many trees die during the first few years after planting the gaps should be replanted so that adequate competition between trees may be provided to produce upright stems.

Wind assumed major importance as a destructive agency in the forest in 1938. Fortunately windstorms of hurricane proportions are rare in central New England. Precautions which may be taken against wind damage apply particularly to partial cuttings and are discussed on page 22. No precautions are possible against storms of such violence that they blow down entire fully stocked stands as did the 1938 hurricane.

Undoubtedly in other localities and at other periods of time various additional enemies of the growing crop will assume prominence. The forest landowner must be continually on the lookout for injurious agencies and when one is discovered must take action appropriate for controlling the enemy or, better yet, preventing the damage.

The best examples of the effectiveness of protection obtained through careful management of the forest against the various injurious agencies which attack forest trees are found in the general healthy and vigorous condition of the forest and in the absence of abnormally large amounts of injury sufficient to lessen appreciably its production. The Yale forest today does show an abnormally large amount of wind injury and its development toward a fully stocked forest has been set back by the hurricane about a quarter of a century. There is no preventing a disaster such as this. Its effects can be seen in nearly every woodlot in central New England. On the other hand, the Yale forest is at the same time a good example of what can be done by intensive management and careful protection, for its healthy young timber spared by the wind, showing the results of 20 to 30 years of care, now stands out in striking contrast to the ordinary, unmanaged, young woodlots of the region.

ILLUSTRATIONS

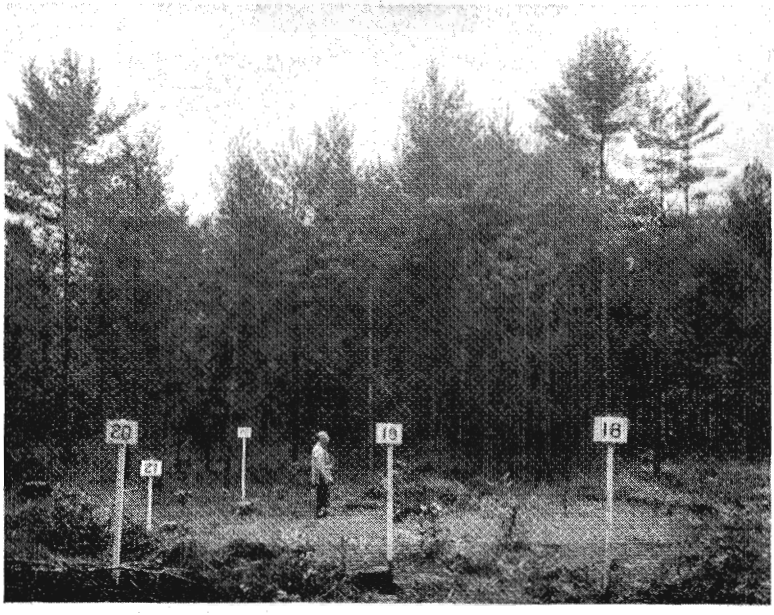
PLATE I.

A portion of the stand at Station 16 before the partial cutting made in September 1935. The 6 or more limby but merchantable trees approximately 50 years old in the foreground will be removed. They make up a clump of 20 to 25 trees of similar character which will be cut clear, leaving the more promising group of younger trees in the background with increased opportunity for development. The tree with the caliper is 11 inches in diameter. As a result of this cutting the quality of the timber produced in the stand from this time on will be improved, due to the removal of the low-grade trees shown in the picture. These trees illustrate the open-grown, branchy type of white pine altogether too common in pine woodlots today. White pine will not be of this character when grown in properly managed stands.

See Plate II which is taken in the same location but subsequent to the cutting.

PLATE II.

A portion of the stand at Station 16 taken in May 1936 after the partial cutting of September 1935. This picture is taken in the same location as Plate I and the numbered stakes indicate the former position of some of the felled trees. A potentially valuable clump of white pine has been freed from competition, from the side and overhead, exerted by the trees removed in the cutting. The remaining trees, having straighter trunks and branches of smaller size, ultimately should produce lumber of higher quality than that secured from the limby deformed trees which were cut. Unfortunately this stand was blown down by the 1938 hurricane.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21
19
18

PLATE III.

In the center is shown a strip of timber that, while now forming a dense stand, is really composed of individual trees which started with too much room and consequently have large limbs, rendering them unfit for high quality lumber. The strip will be cut clear, partially releasing young and better timber on all sides. The trees with numbered stakes beside them range in diameter from 13 to 17 inches and are approximately 50 years old.

Taken in September 1936 in Compartment 12.

See Plates IV and V for views after the cutting.

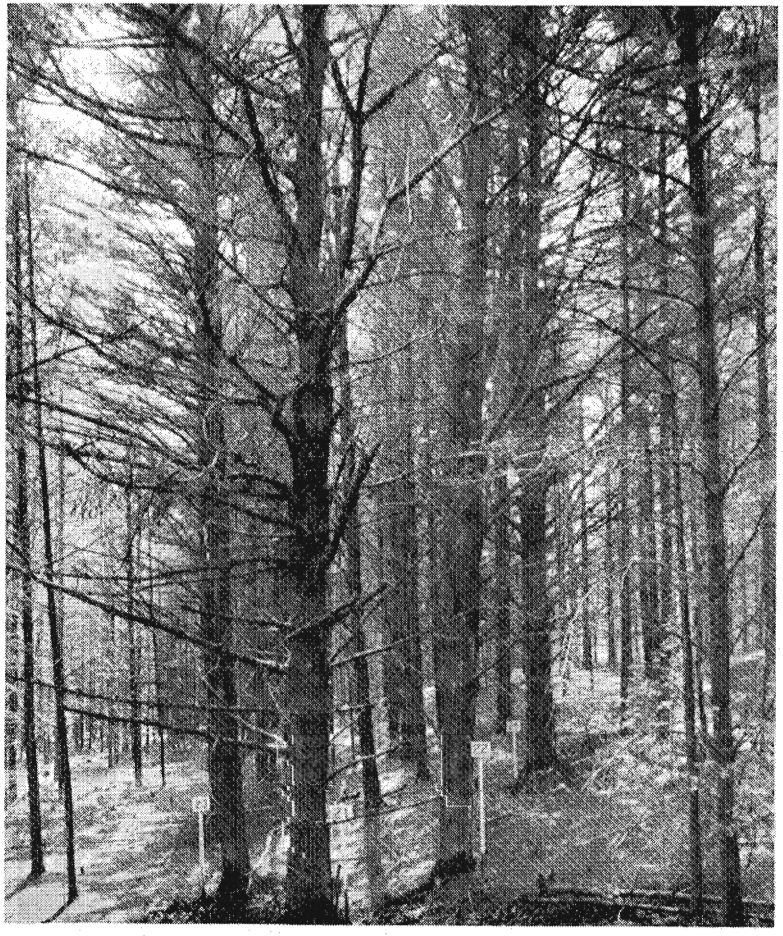

PLATE IV.

Taken from the same location as Plate III but in June 1937 after a partial cutting which was made in January 1937.

The strip of coarse timber trees has been removed. The original positions of two of the trees are shown by the numbered stakes. Portions of the adjoining younger timber which have been freed from side competition are seen. At present the tops of the felled trees make a dense cover over most of the strip, preventing the establishment of a new crop of pine. These tops will be cut up and partially utilized for fuelwood. The remaining small limbs, if they lie too thickly to permit reproduction will be thrown into piles and burned. See Plate V.

The length of the strip cut clear is 200 feet and its average width 50 feet.

The surrounding trees should scatter seed all over the area and furnish considerable side protection from the drying and heating effects of sun and wind.

PLATE V.

Taken from the same location as Plates III and IV but in March 1938 after the tops of the felled timber have been cleared away for the purpose of leaving the area open for natural seeding in of pine from the surrounding trees. These trees now are bearing cones the seeds in which will ripen in the late summer.

PLATE VI.

Some portions of the forest have several age classes of pine on the same area, one age class usually more or less overtopping the other. In this picture merchantable timber approximately 60 years of age is now beginning to overtop a group of young pine which came up 10 to 15 years ago in a small opening. The trees beside the numbered stakes will be cut as well as some of the larger trees in the background.

Taken in Compartment 12 in September 1936.

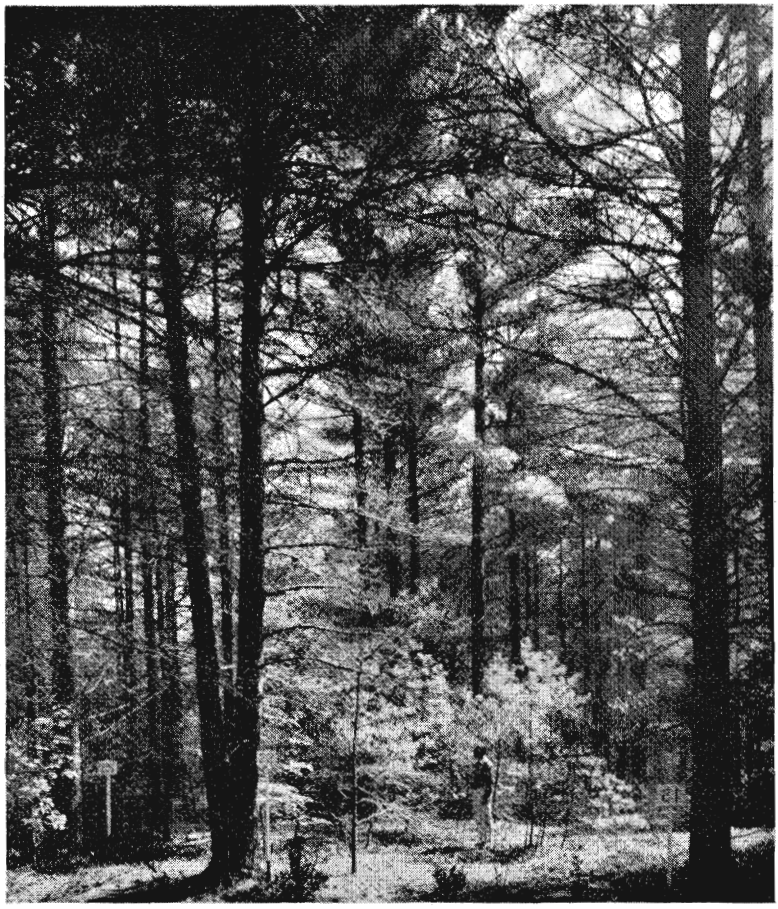

PLATE VII.

In June 1937, following a partial cutting of timber in January 1937, this picture was taken from the same location as Plate VI. In the center is seen the group of young pine 10 to 12 feet in height and now freed from the competition of the older timber. Middle-aged timber of various ages is seen in the background. The small area in the foreground approximately 40 feet square should be reseeded in the summer of 1938 by the surrounding trees.


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PLATE VIII.

a. An overmature stand of hemlock and hardwoods located at Station 10. The large tree near the left side is a white oak over 200 years in age. Beech, black birch, paper birch, red maple, and hemlock also appear in the foreground. Most of these trees are around 150 years of age and, except for some of the hemlock, are injured by heart rot. The stand as a whole has a low timber value at present and if left uncut will ultimately be composed almost entirely of cull trees. The soil is somewhat heavier than the average for the forest, but still better suited for pine than for hardwoods. This picture was taken in July 1934 and the stand was clearcut two months later (see Plates VIII-b, IX, and X).

Photograph by Lloyd Smith.

b. Taken from the same location as Plate VIII-a but in September 1934 immediately after the material suitable for saw logs had been removed. Trees standing are suitable only for cordwood or else are unmerchantable hemlock. The hardwood tops and the standing trees suitable for cordwood will be cut into this product and the unmerchantable hemlocks will be felled. 18,000 feet, board measure, of logs and 24 cords of fuelwood were cut on the 1.1 acres included in this clearcut area.

The stump of the large white oak seen in Plate VIII-a is buried by brush in the lower left-hand corner of the picture.

Photograph by Lloyd Smith.

PLATE IX.

The same area at Station 10 shown in Plate VIII but after the cordwood has been cut and the unmerchantable trees have been felled. To reduce the accumulation of hemlock slash 8½ cords were cut out of these unmerchantable trees at a small financial loss. The area is now ready for planting. What slash remains after removal of the cordwood does not lie thickly enough to prevent planting practically all the area. See Plate X.

Red oak 1-year-old seedlings, white spruce 3-year-old transplants and white pine 3-year-old transplants were planted in separate blocks on the area in the spring of 1935.

Photograph by Lloyd Smith.

PLATE X.

Taken from the same location as Plates VIII and IX but in March 1938.

Three years have elapsed since the area was planted. Many of the planted trees are appearing above the brush and the hardwood sprouts and seedlings which started after the clearcutting.

A cleaning is now needed and was made a few weeks later. This operation may have to be repeated once or twice more before the pine, spruce, and red oak are released from the competition of undesirable hardwoods. Then the process of replacing an unhealthy stand of low value timber with a thrifty new crop of valuable timber trees will have been accomplished.

PLATE XI.

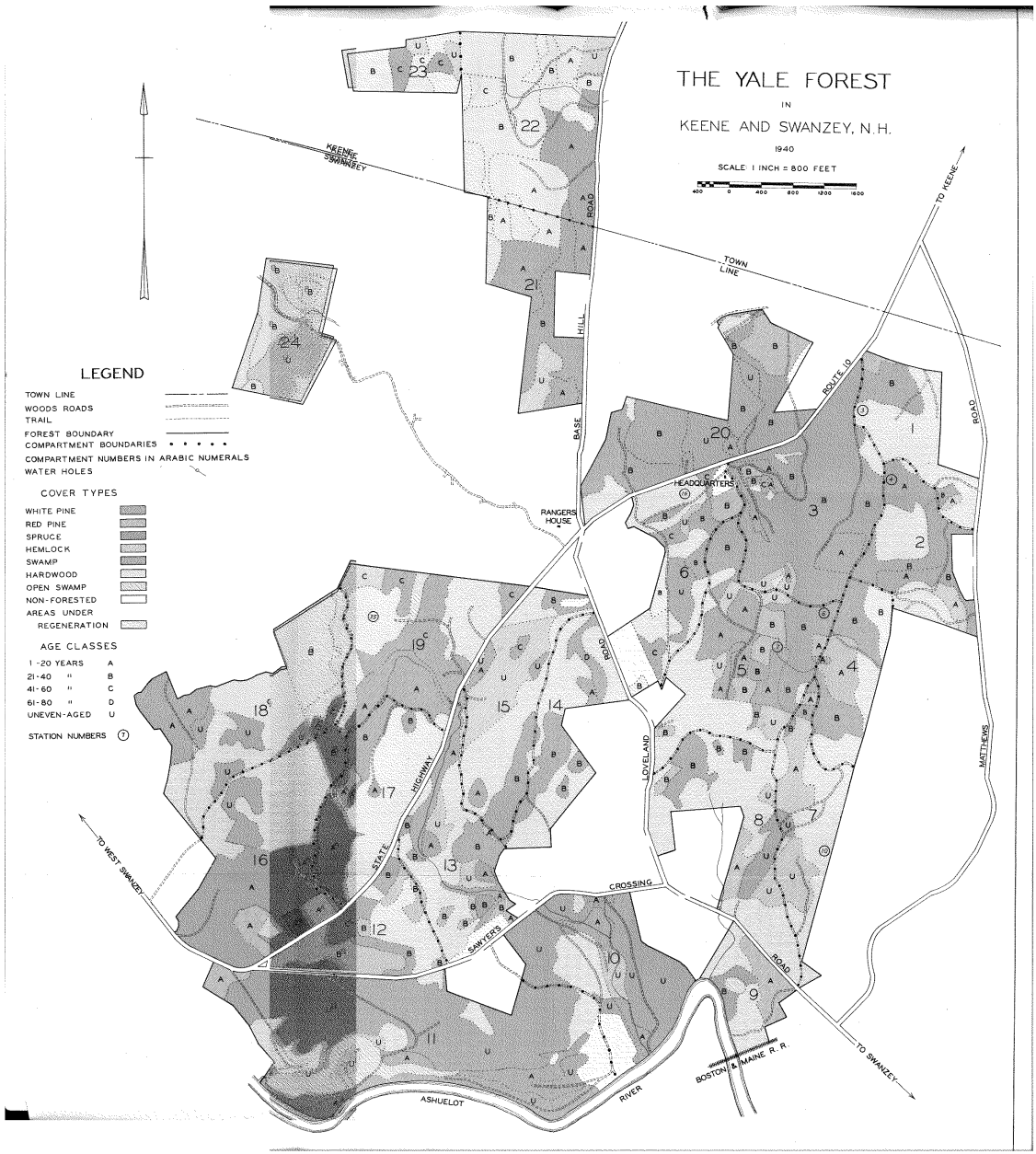
A portion of the stand at Station 16 taken in September 1937 two years after the partial cutting made in the fall of 1935 and immediately after trees selected for their potential rapid growth and excellent quality have been pruned to a height of 13 feet from the ground. Approximately 50 trees per acre sufficiently promising to be worth pruning were found.

The lower 7 feet of bole were pruned by a man standing on the ground. The interval from 7 to 13 feet above the ground was pruned by a man standing on the 8-foot ladder shown in the picture with curved iron top rung covered with rubber tubing or burlap and with iron spikes on the bottom of the uprights. Later in the fall of 1937 the pruning on all the selected trees was carried up to 17 feet above the ground using a 13-foot ladder.

The tool used in the pruning was a curved handsaw shown in Plate XII.

PLATE XII.

Taken in the same stand as Plate XI. The man is in process of pruning the section from 7 to 13 feet above the ground using the 8-foot ladder described in Plate XI. The saw used is of the curved orchard type, with a blade 12 inches long with 7 teeth to the inch and tapering to a blunt point at the end. The dead branches which seem to protrude back of tree number 155 are on other trees in the background.


THE YALE FOREST
IN
KEENE AND SWANZEY, N.H.
1940
SCALE 1 INCH = 800 FEET
400 0 400 800 1200 1600
LEGEND
TOWN LINE
WOODS ROADS
TRAIL
FOREST BOUNDARY
COMPARTMENT BOUNDARIES
COMPARTMENT NUMBERS IN ARABIC NUMERALS
WATER HOLES
COVER TYPES
WHITE PINE
RED PINE
SPRUCE
HEMLOCK
SWAMP
HARDWOOD
OPEN SWAMP
NON-FORESTED
AREAS UNDER REGENERATION
AGE CLASSES
1-20 YEARS A
21-40 " B
41-60 " C
61-80 " D
UNEVEN-AGED U
STATION NUMBERS
KEENE
SWANZEY
TOWN LINE
TO KEENE
BASE HILL ROAD
ROUTE 10
MATTHEWS ROAD
HEADQUARTERS
RANGERS HOUSE
LOVELAND ROAD
STATE HIGHWAY
SAWYERS CROSSING
TO WEST SWANZEY
TO SWANZEY
BOSTON & MAINE R.R.
ASHUELOT RIVER

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