HARVARD FOREST

BULLETIN NO. 23

RESULTS OF THE FIRST THIRTY YEARS OF EXPERIMENTATION IN SILVICULTURE IN THE HARVARD FOREST, 1908-1938

PART I

THE CONVERSION OF STANDS OF OLD FIELD ORIGIN BY VARIOUS METHODS OF CUTTING AND SUBSEQUENT CULTURAL TREATMENTS

By

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FOREWORD

The land holdings that form the Harvard Forest were acquired in 1907, and forestry operations were commenced in 1908. This document was originally planned to summarize the results of silvicultural practice in the form of a thirty-year report, but here we have an illustration of the proverbial saying: "Man proposes but God disposes."

In September 1938, the end of the thirty-year period, the Harvard Forest was subjected to the most destructive hurricane in the recorded history of central New England. At least two-thirds of the merchantable sawtimber on the Harvard Forest holdings were completely uprooted or left as broken stubs. It is here recorded that from the fallen trees, within the following two-year period, about 6,500,000 board feet of lumber were salvaged and sold, the equivalent of the allowable annual cuts of nearly fifteen years, and about 2,000 cords of fire wood. Thus it was that many years of lumbering operations were telescoped into a single year. It may be mentioned that as originally projected the Harvard Forest was, in part, to be supported on the basis of sustained production which involved the annual cutting and sale of a predetermined amount of timber approximately equal to the growth. While in the beginning the Forest was preponderantly white pine, which had seeded in on abandoned farm land, thirty years later there remained only two small remnants of this cover type. Such were the cumulative results of systematic cutting over a period of thirty years under a policy of sustained yield management, and the onslaught of a most destructive hurricane. It is now believed that the hurricane destruction was not actually so catastrophic as it at first appeared, but that rather, in the long run, it may prove to have been a blessing in disguise. Fortunately, none of the young stands following the removal of old field white pine or old field hardwoods, which form the basis of this report, suffered heavy damage. Even the oldest stand, described in case No. 1, resulting from the first cutting in the forest under Harvard University ownership and management, was only slightly harmed.

Thus it was that a natural phenomenon emphasized the end of a thirty-year period in no uncertain manner. In spite of the fact that for two years the limited resources of the institution had to be devoted to the tasks of salvage and rehabilitation, and the solution of problems raised by the hurricane devastation, this report was well advanced when the

catastrophe of the world war broke upon us. During the war period, with key members of the staff absent on special war duties or actually in the service, all work had to be suspended. It was these two factors, a hurricane and a war, that delayed the completion of the manuscript, work on which had to be deferred until well after the close of hostilities in 1945.

This report has been prepared and is presented for the purpose of showing what was done and what happened in a series of specific cases. The experience of over thirty years has amply shown that silvicultural practice, even in a single region, cannot be reduced to a manual of rules for general use. Once a firm ecological basis has been established, most rapid progress in an understanding of the art of silviculture, as locally applied, follows from an intensive study of actual cases of treatment applied and results obtained.

In the fourteen case histories covered in Part I, silvicultural treatments have been carried through the establishment period, thus bringing into play planting, weeding, improvement cutting, early thinning, and special insect and disease control measures, as well as methods of natural reproduction, applied under varying conditions of local climate, soil, and land history. The cases were chosen as being representative of stands of old field origin occurring in the Harvard Forest and the treatments applied in their conversion. They do not cover all the old field conditions found in the region, and the results therefore cannot be elsewhere applied without due modification based on an understanding of different environmental and historical factors.

In 1907 nearly two-thirds of the Harvard Forest supported stands of old field pine; and the equally common occurrence of this forest type throughout the region gave rise to a large and profitable outlet for pine lumber. Thus practically all early silviculture centered around the cutting and conversion of second-growth pine. The Harvard Forest was one of the very few places where methods other than clear-cuttings were tried and records of the results preserved. Here may be emphasized the importance of keeping accurate and detailed records, for if this had not been done from the beginning, the cases that are considered in detail in this document could not have been presented.

These cases illustrate the ease with which mistakes can be made in the beginning stages of forestry practice. The pioneer American foresters could not be expected to know all the answers, having no factual background on which to rely other than their observations abroad. They had to learn by trial and error. That silviculture is an exceedingly complex and exacting art when properly applied in the transition zone of central

New England will be obvious. It is easily understood why the undertakings of amateurs have in so many instances turned out unfavorably. The results herein recorded will serve best as guides to trained foresters who are endeavoring to develop sound silvicultural practices under conditions that are more or less similar to the Harvard Forest area.

Also illustrated, most strikingly and convincingly, is the soundness of the basic philosophy of working in harmony with nature, so ably developed and championed by Richard Thornton Fisher, first director of the Harvard Forest (1907-1934), in laying down an ecological foundation as the only secure base on which to erect a structure of silviculture which will stand the tests of time and economic practicability. Almost without exception, the success or failure of the treatments carried out may be directly measured against the extent to which they departed from this basic philosophy. The costly and futile efforts to establish coniferous plantations following the clear-cutting of old field white pine on heavy upland soils bring into sharp focus the disappointing outcome of a once common silvicultural practice which failed to take into account the natural succession in the basic vegetation. It is demonstrated over and over again that white pine does not naturally follow itself on certain types of soil, but that the succession is pine to hardwoods.

While old field white pine is largely a thing of the past, the experience gained at the Harvard Forest in its conversion to stands of mixed composition and greater stability will find wide application to many pure coniferous plantations which have been established in New England and elsewhere, on both cut-over and open land, particularly where these plantations occur on the heavier upland soils naturally adapted to hardwoods. Furthermore, much of the knowledge gained in the silvicultural treatment of the volunteer stands following the cutting of old field pine will be directly applicable to thousands of acres of forest of similar origin now composed of varying mixtures of pine and hardwoods in the formative stage, when weedings, thinnings and similar cultural operations are most effective and profitable.

In this report the costs of cultural treatments applied to young stands following the harvesting of old field stands are given in man-hours per acre. Final costs and returns cannot be determined because the stands have not been carried beyond the formative period, approximately the first 25 years. Time alone will tell how well such treatments as weeding and thinning will pay under the conditions prevailing in central New England in the twentieth century.

Thus it was that the year 1938 marked the end of the first thirty years

of forest management and experimentation in silviculture at the Harvard Forest, and, coincidentally, there occurred a major natural catastrophe, the hurricane, followed by the most devastating war in history. Because of the extraordinary damage, this thirty-year period may now properly be looked upon as an era in itself, characterized by the gradual development of a basic philosophy and the testing out, largely on a trial and error basis, of theories founded for the most part on European forestry experience. It is singularly timely to bring together, in the form of what might be termed a progress report, the results of some of the more significant experimentation in silviculture obtained in this thirty-year period.

This thirty-year report will be published in three parts. The first part, the present bulletin, deals with fourteen selected cases appertaining largely to problems associated with white pine. Parts two and three, both nearly ready for publication, will deal with (1) the application of shelterwood and selection methods of cutting to stands on land continuously in forest, and (2) the Harvard Forest plantations.

The authors are well qualified for this difficult assignment. Albert C. Cline became a member of the Harvard Forest staff in 1924, serving as assistant to Director Fisher until the latter's death in 1934, and later becoming Director of the Forest. Russell J. Lutz joined the Forest staff in 1938 as assistant to the Director, and was responsible for compiling the case histories and bringing them up to date by field observations and measurements.

E. D. MERRILL,
Administrator of
Botanical Collections,
Harvard University

June 30, 1946

AUTHORS' ACKNOWLEDGMENTS

This report is the work of many hands. In a large part, the authors' task was one of compilation and synthesis of a great many field observations made over the years by Harvard Forest staff members and students and set down in the Forest records. Likewise, in the interpretation of the results of the various silvicultural treatments, the authors have drawn heavily upon the Forest records and the writings of Forest staff members and members of cooperating agencies.

The authors of published material—and, in some cases, of unpublished manuscripts—have been given recognition by references to their work throughout the text of this report. Among those who contributed most to making the records of stand treatments which form the factual bases of the case histories herein included are R. T. Fisher, A. H. Upham (for many years, Forest Superintendent), Irving W. Bailey, '09, H. H. Tryon, '13, L. R. Gross, '16, J. Nelson Spaeth, '20, N. W. Hosley, '25, W. H. Cummings, '34, James W. Curtis, '35, E. Arnold Hansen, '39, Willett Rowlands, '40, and Robert M. Borg.

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The authors desire to recognize also the contributions of scientists in the U. S. Government agencies who have collaborated with members of the Harvard Forest staff in joint research projects, and without whose continuing cooperation in fields closely allied to silviculture the contents of this report would have been much less comprehensive. Such persons include especially C. Edward Behre, former director of the Northeastern Forest Experiment Station, U. S. Forest Service; F. C. Craighead, R. C. Brown, H. J. MacAloney and H. A. Bess of the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine; and L. M. Hutchins, Carl Hartley, Perley Spaulding and J. R. Hansbrough of the Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering. Particular mention should be made of work of Charles S. Simmons of the Division of Soil Survey of the above mentioned bureau in the identification and detail mapping of the soils of the

Harvard Forest. Without this knowledge, some of the most significant results of silvicultural treatment would remain unexplained.

Special appreciation and thanks are extended to Dr. Elmer D. Merrill, former Administrator of the Botanical Collections in Harvard University, for his interest and support in the preparation of this report and for his review of the manuscript; and to Dr. Hugh M. Raup, present director of the Harvard Forest, for his contributions to the ecological concepts which form so important a part of the philosophy of silviculture at the Harvard Forest and for his review of the manuscript of this report.

Above all, the authors wish to acknowledge their indebtedness to the late R. T. Fisher, first director of the Harvard Forest, whose pioneer work in relating local forest history and succession to the conversion of old field stands furnished invaluable guidance in the further interpretation of the silvicultural treatments applied and refinements in the complete system of conversion which he so clearly envisaged and so ably demonstrated in its major aspects.

The publication of this report was made possible by the generosity of a friend of the Harvard Forest who wishes to remain anonymous.

R. J. Lutz
A. C. Cline

Petersham, Massachusetts
July 15, 1946

INTRODUCTION

The Harvard Forest

Many pages in the earlier publications of the Harvard Forest have been devoted to descriptions of the Forest as an educational institution and as a managed timber tract, and to the central New England region in which it is located. The reader is referred particularly to "The Harvard Forest, 1907-1934: a Memorial to Its First Director, Richard Thornton Fisher," special publication, 1935.

The Harvard Forest was acquired by Harvard University in 1907 and has been under continuous and systematic use and treatment since that date. It was developed with three main objects in view: an experiment station for research in silviculture and related subjects, a field laboratory to aid in the instruction of students in forestry and the underlying biological sciences, and a model forest organized and managed as a demonstration of sustained yield.

The forest itself is composed of three separate blocks of roughly equal size, in all totaling 2,292 acres, located almost entirely in the town of Petersham in north-central Massachusetts, some sixty miles west of Boston (see Figure 1). The three blocks are divided into compartments, and the compartments, in turn, into stands. The records of silvicultural treatments are kept by stands, the fourteen cases herein described forming a small part of all those on record at the Forest headquarters.

Local Conditions

Because of the overpowering influence of local soil, climate and land history in determining the outcome of growing tree crops, a proper interpretation of the results of experimentation in silviculture is very largely dependent upon a knowledge of the nature and interrelations of these factors as they bear upon successional trends, stand form and composition, relative growth rates of the different species, susceptibility to damage by destructive agencies, and innumerable other biological conditions and reactions.

At the Harvard Forest, there has been a growing recognition of the importance of environmental factors and a desire to gain an adequate working knowledge of their operation. But it will be evident that, although much has been learned, a great deal more must be known before a course of silvicultural treatments can be applied with reasonable assur-

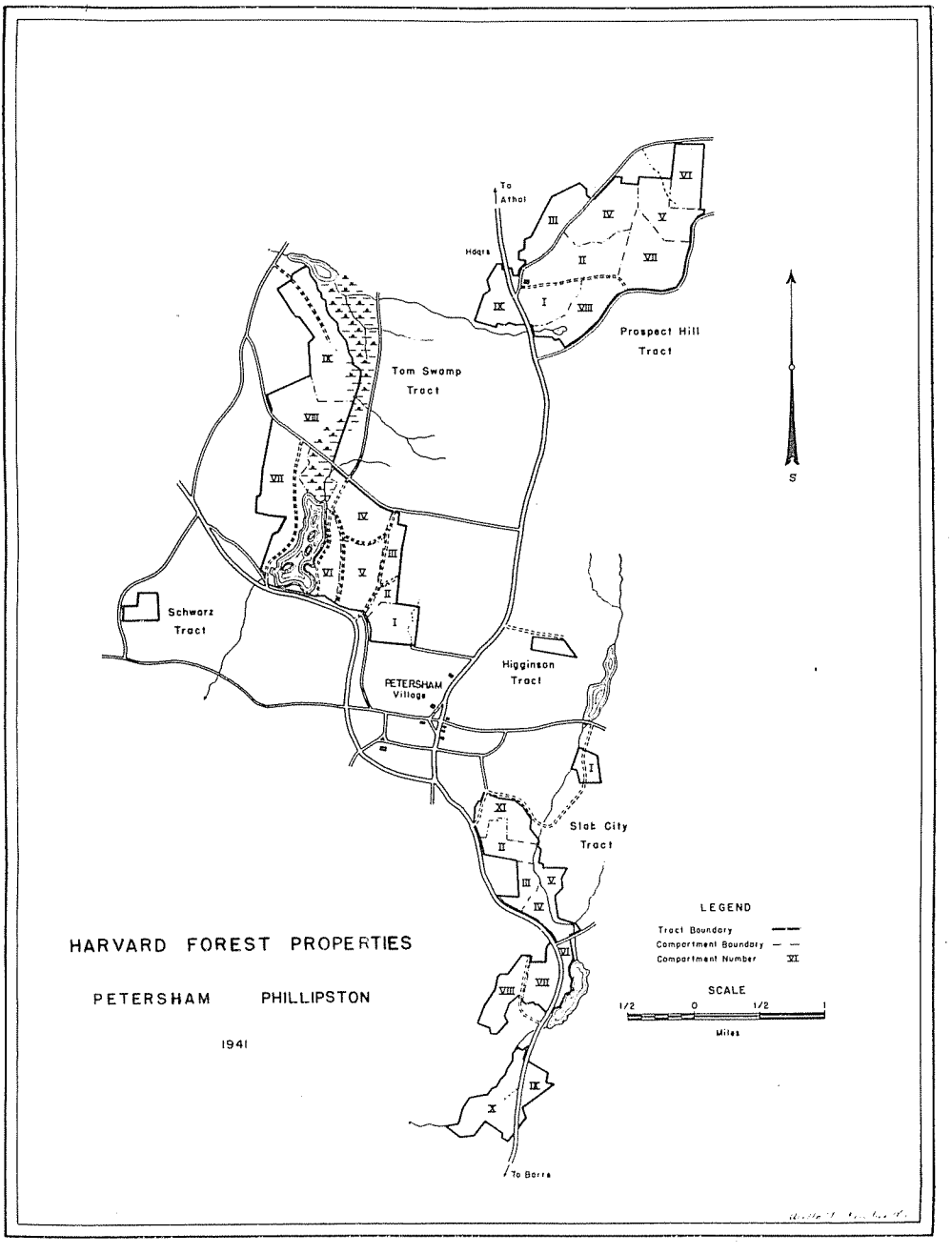


FIG. 1. THE HARVARD FOREST PROPERTIES

The Forest is divided into three main tracts, or blocks, named Prospect Hill, Tom Swamp and Slab City. The blocks are divided into compartments (shown in Roman numerals), and the compartments into stands.

ance of the final outcome. The following description of local conditions, while incomplete in many respects, is presented to assist the reader in interpreting the results of the treatments applied in the conversion of stands of old field origin to stands of varying mixed composition.

Climate

The climate is humid and temperate, with marked seasonal variations, rigorous winters with heavy snowfalls and comparatively short, cool summers. The average annual precipitation is about 42 inches, but such extremes as 25 and 54 inches have been recorded; it is fairly evenly distributed throughout the year. The average annual temperature is 47°F. The average summer temperature, June to August, inclusive, is 67°F., and the maximum on record, 103°F. The average winter temperature, December to February, inclusive, is 25°F., with an absolute minimum record of —35°F. The average number of frost-free days per year is approximately 180, with a recorded range of from 130 to 210 days (Baker et al., 1936).

Topography and Soils

Physiographically, the region is part of the so-called central plateau of Worcester County, Massachusetts. At the present time it is "a plateau only to the extent that the upland areas of comparatively smooth surface and the tops of the greater part of the interstream or interlowland areas are at an accordant elevation, this elevation in the different parts of the county being accepted as the plateau elevation" (Latimer et al., 1927).

The town of Petersham is traversed by three parallel north-south ridges, the middle one, the highest, reaching an elevation of 1,300 feet above sea level. All three are inclined in a southerly direction, the central one dropping 400 feet between the northern and southern limits of the town. They are broad-topped and separated by wide valleys, each with a well-defined drainage system. The surfaces of the ridges and valley bottoms are rough, with frequent minor but relatively abrupt elevations and depressions. According to Bowman (1911), glacial action was the chief factor in roughening the surface. Subglacial and englacial material was deposited irregularly as the ice sheet retreated. Rock outcrops are common but, in the main, the ground surface consists of a thin sheet of glacial till and outwash material, of local origin and of very complex composition. Of the local soils Bowman says, "The lower hilltops and many of the hill slopes bear quantities of glacial material. Hillside and

the clearing of land for cultivation gain impetus. At the height of agricultural development (the 1840's), about 85 percent of the land area in Petersham had been cleared for farm use, very largely for pasture (Raup and Carlson, 1941, p. 26).

On the land which was most favored for agricultural purposes—the broad tops and gently sloping sides of the ridges and secondary elevations—the forest was chiefly mixtures of hardwoods, with lesser amounts of hemlock and white pine. The studies by Raup and Carlson (1941) and Cline and Spurr (1942) have disclosed the presence of several distinct forest types, ranging from oak, hickory, and chestnut on exposed southern slopes to beech, yellow and black birch, maple and hemlock in the cool, sheltered situations. In between, there were more extensive areas where mixtures of red oak, white ash, paper birch, black cherry, red maple, white pine and hemlock predominated.

FIG. 2. THE START OF AN OLD FIELD PINE STAND

Old white pines along the roadsides and left in the pastures as a shade for cattle furnished an abundant source of seed.

Peter Whitney, a native of Petersham, in writing about the local forests in 1793 reported that "On the high lands the growth of wood is oak, more chestnut, and a great deal of walnut (hickory) of later years. In the swamps and low lands, there is birch, beech, maple, ash, elm and hem-

lock." With due allowance for the recent loss of the chestnut, by the blight, the first part of his description refers to the present oak-hickory type; the second part fits the association more characteristic of the northern forest—the northern hardwoods and hemlock—found in cool, protected locations. It is noteworthy that Whitney did not mention white pine. Undoubtedly, it was present, but not in any great numbers.

Many factors contributed to the next stage in land history—farm abandonment. The lure of higher wages in the growing industrial centers, the declining fertility of the local soils, the opening up of the Middle West with its vast stretches of highly fertile land, and the discovery of gold in California all had their effect. Farm abandonment started on a large scale about 1850, and has proceeded at a variable rate up to the present time (Fisher, 1933).

The natural seeding in of white pine on the thousands of abandoned fields and pastures throughout the region ushered in the old field white pine era, one of the most unexpected and productive in land use history. This gratuity of nature completely reversed the downward trend in lumber production. Large-scale logging operations in old field white pine started about 1890, and reached a peak in 1909. This twenty-year period probably witnessed the most intensive lumbering operations in the history of the region. Pine-using industries sprang up in many of the larger centers, and portable saw mills dotted the landscape. Clear-cutting was universally practiced.

The stands following the clear-cutting of old field pine on the better soils were composed largely of a mixture of hardwoods of advance growth origin together with hardwoods which seeded in after logging. Thus the next stage in local forest history, predominant to the present time, is characterized by mixed hardwoods, even-aged in form and mostly single-stemmed.

When the stands following old field pine are clear cut for fuel wood, as has often been the case in recent years, the next stage is hardwood coppice composed of coarse stump sprouts, markedly inferior in quality to the preceding generation and comparatively unsusceptible to improvement by silvicultural measures. In some places a second generation of coppice now occupies the land and deterioration of the growing stock has reached a new low. Over a period of slightly more than 200 years, since the first settlement and the beginning of land clearing, virgin sawtimber of fine composition and quality has been replaced by rank-growing stump sprouts and weed species suitable only for fuel wood and similar products.

The Harvard Forest in 1908

When the Harvard Forest was taken over by the University, it repre-

sented, as Fisher, its first director, said, merely what 150 years of ups and downs in rural colonization had done to the virgin wilderness (Fisher, 1931). Over 80 percent of the stands, by area, were even-aged, originating either on abandoned farms or on clear-cuttings. Most of them were properly classed as temporary cover types. Outstanding among these was the old field white pine type. In 1907, nearly two-thirds of the area of the Harvard Forest was in pure, even-aged white pine ranging chiefly from 40 to 70 years of age.

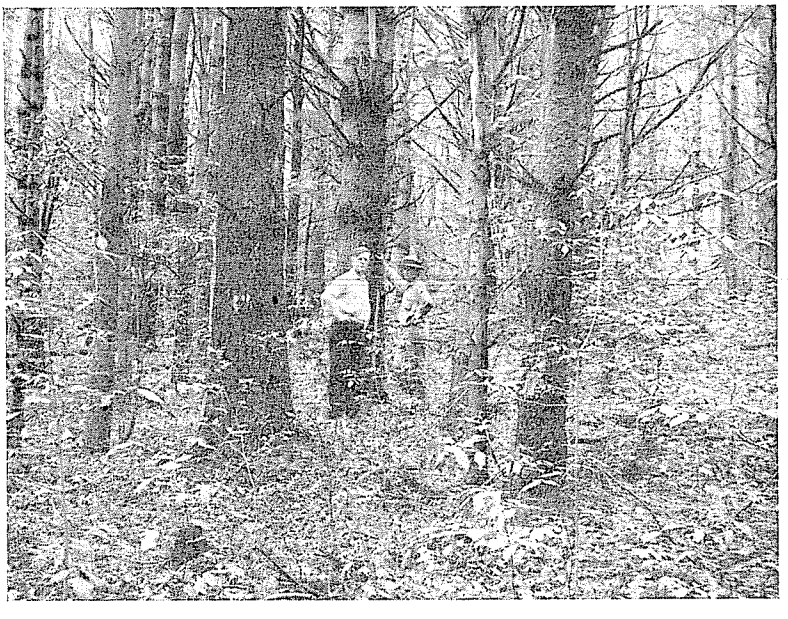


FIG. 3. A TYPICAL OLD FIELD PINE STAND AT SIXTY-FIVE YEARS

This is the stand described in Case No. 1, a few months before it was clear cut, in 1908. Note the dense stocking of hardwood seedlings (the advance growth) on the ground.

With so much of the Forest in merchantable or near-merchantable stands of pine, amounting in all to some 10,000,000 board feet, and a strong local market willing to take all the lumber that could be produced, it will be readily understood why practically all of the early silviculture centered around methods of cutting old field white pine. In fact, from 1908 to 1938, old field pine stands constituted the great bulk of the annual cuts, year after year, and would have continued to do so for approximately another decade had it not been for the hurricane and the necessity of cleaning up the equivalent of nearly fifteen years' cuts within a period of two years.

THE OLD FIELD PINE — MIXED HARDWOODS SUCCESSION

Description of the Two Cover Types

The white pine stands which nearly everywhere became so quickly and fully established on the abandoned farms of central New England were characteristically well stocked and nearly pure. In many cases the sources of seed were scattered old pasture trees used as shade for live stock. Because the stands were even-aged, natural pruning proceeded very slowly, the dead branches persisting along the entire bole for several decades. Quality was further reduced by the repeated killing of the leading shoot by the white pine weevil (*Pissodes strobi* Peck), a native insect which increased enormously, along with its food supply, causing forked and crooked stems except where the stand density was very high. Another weakness caused by the one-level canopy was severe crown friction in the older stands. Swaying of the tall, spindling trees with the wind wore down the sides of the crowns, reducing the growth rate and lowering the general vigor of the trees (Tarbox, 1924).

Also characteriestic of old field pine was the hardwood advance growth, which ordinarily began forming when the stand reached about 50 years of age. It was composed of a wide variety of shade-tolerant hardwoods, some starting from seed from scattered hardwoods growing with the pine and others from seed brought in by wind, or birds and rodents. A study of cut-over old field pine lands by McKinnon, Hyde, and Cline (1935) showed the composition of the scattered hardwoods present in old field pine stands and the occurrence and spatial distribution of the various species in the ensuing stand, as influenced by the previous stand, site, and other factors. The species most commonly occurring as advance growth are red oak, white ash, black and yellow birch, red and hard maple, and black cherry. On the best sites, white ash and red oak share leadership; but on the poorer sites, the oaks predominate.

Following the clear-cutting of old field pine and full exposure of the ground, such light-seeded species as gray and paper birch and poplar seed in rapidly, together with pin cherry (from seed stored in the duff), and, to a lesser extent, seedlings of light-seeded species occurring as advance growth, and white pine. Thus the new stand is composed of scattered sprout clumps from the stumps of hardwoods in the previous stand, seed-

ling sprouts from the small stools of advance growth cut at the time of logging, and seedlings—a heterogeneous mass of competing individuals of different species, forms, and growth rates. Except on the poorer soils, white pine is unable to compete with the more aggressive hardwoods.

In the absence of treatment to check the weed elements, the young hardwood stand is soon dominated by the most rapid-growing trees, largely of sprout origin. On the better sites, by the end of the first 25 years, the period of greatest competition—the formative period—is over, and thereafter cultural treatments are comparatively costly and ineffectual

FIG. 4. THE RESULT OF CROWN FRICTION IN AN OLD FIELD PINE STAND

The stands were even-aged and the crowns all in one canopy. With age, the crowns became worn down by the swaying of the tall, spindling trees, and growth and vigor declined sharply.

in improving composition and quality.

As the stands advance in age, their final composition becomes more evident. It varies with soil and exposure in much the same way as in the original forest. McKinnon, Hyde, and Cline (1935) classified the hardwood stands following old field pine under three cover types: the transition hardwoods, so named because it contains species representative

of both the northern and central forests, in which red oak, white ash, and red maple are the leading species; northern hardwoods, in which beech, hard maple, and paper and yellow birch are more prominent; and the oak type, in which red, white, black and scarlet oak, and hickory predominate. All three types are found in the Harvard Forest, but the transition hardwoods type is the most prevalent.

It is with the cultural treatment of young transition hardwood stands that the case histories in this report largely deal. From growth and yield studies made by Spaeth (1920) in even-aged, second growth hardwoods, it was found that unmanaged stands on the better soils would yield close to 20,000 board feet per acre at 70 years. With such productiveness and the ready availability of a variety of good sawtimber species, silviculture gives promise of profitable results.

Soil Changes

The marked changes which have taken place in the top soil under the old field pine—hardwood succession have been a subject of special interest and investigation at the Harvard Forest (Fisher, 1928; Griffith, Hartwell, and Shaw, 1930). Beginning at the time of farm abandonment with no organic layer, the litter, duff, and humus build up over a period of 60 to 80 years of pine occupancy to a depth of approximately 2 inches, while the depth of the dark brown (enriched) mineral layer decreases from about 9 inches to less than 2 inches. Also, by the time the old field pine reaches 60 years of age, a thin leached layer, between the humus and the dark brown layers, develops, thus completing the profile characteristic of podzol soils. In contrast, following the clear-cutting of the pine and the taking over of the land by hardwoods, the organic layers accumulated under the pine disappear, the dark brown horizon deepens, and the podzol profile gives way to crumb mull of greatly improved tilth and generally higher fertility (Griffith, Hartwell, and Shaw, 1930, p. 21).

Closely related to the improvement in soil which takes place under the hardwoods is the greatly increased activity of earthworms, resulting in rapid incorporation of dead organic material, largely leaves, with the mineral soil, increasing its porosity and general productiveness. Studies by Johnston (1936) in the Harvard Forest disclosed sharp differences in the food preferences of earthworms, which go far towards explaining differences in ground surface conditions under hardwood stands of varying composition. White ash leaves were found to be the most highly favored food of earthworms, and oak leaves the least, a finding which in a large measure accounted for the almost total absence of leaf litter under ash groups during late summer and the presence of a thickening mat of slowly decomposing leaves under pure oak.

Thus the silviculturist was provided with a new tool for controlling soil fertility, to be applied most effectively during the formative period, when stand composition can be modified and regulated, within certain limits, by timely weedings and improvement cuttings.

Logging Practices in Old Field Pine

Since, almost without exception, old field white pine stands were harvested by clear-cutting at around 60 to 70 years of age, the question often arises as to why clearing at such an immature age became almost universal practice in the region. It was well known that old growth white pine attained ages of well over 300 years, diameters of 3 to 4 feet, and

Fig. 5. CLEAR-CUTTING WAS THE COMMON METHOD OF HARVESTING OLD FIELD PINE

The trees were felled in windrows, such as is shown in the picture, and the logs hauled to the mill on a low sled, or scoot. This stand yielded 50,000 board feet per acre of round-edge lumber.

heights of 130 feet or more; furthermore, that white pine was a superior softwood species which produced excellent lumber when grown to sufficient size. The answer lies largely in the lumber requirements of the wood-using industries which developed around this highly productive and wholly volunteer crop—a crop which frequently yielded 40,000 board feet per acre at 60 years.

With some shifts of emphasis due to changes in market demand from

time to time, the principal products of these industries were pails and tubs, boxes and shook, toys, match blocks and so-called woodenware products (Downs, 1926). Because old field white pine stands were even-aged, and the wood-using industries customarily accepted all sizes and qualities almost indiscriminately, clear-cutting naturally developed as the most economical method of harvesting the crop. The trees were felled in strips, a practice called "windrowing." There were no standard log or lumber grades in common use. Nearly all lumber was sawed "round-edge," with the bark left on, which resulted in a maximum usable width of the boards and planks, as well as in a relatively high scale. Under such conditions, woodland owners, many of them farmers, were persuaded to

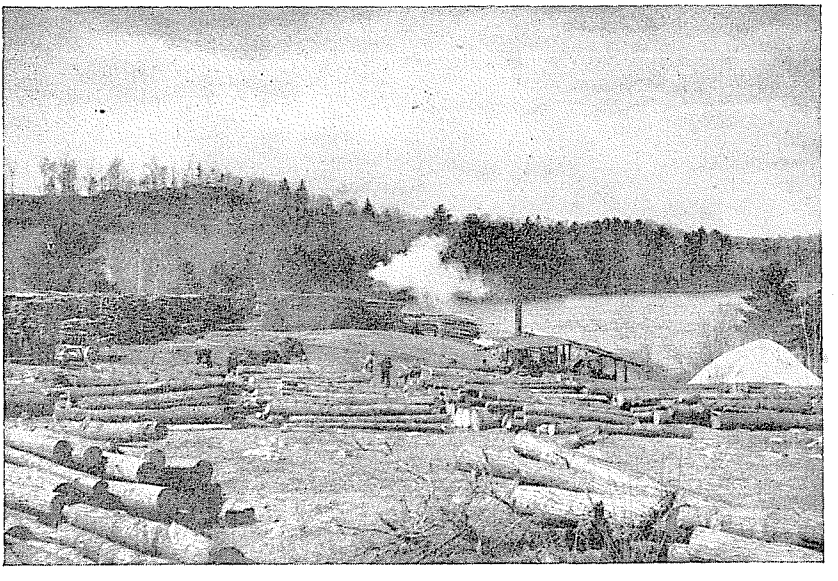


FIG. 6. A MILL YARD ON THE HARVARD FOREST

Portable mills ordinarily sawed from 10,000 to 15,000 board feet of round-edge white pine lumber per day. The lumber was sold locally for boxes, match blocks, pails and woodenware.

sell entire woodlots for a lump sum, or at a flat rate per thousand board feet, without separation by grade or quality, and with little or no concern over what effect the practice of stripping might have on the future stocking of the land.

Old field white pine was considered to be of inherently low quality, and many of the early foresters agreed with the rank and file of lumbermen in advising clear-cutting as soon as the stand reached merchantable saw log size. It was further maintained, in support of this policy of

clear-cutting, that the pine reached "maturity" at around 70 years, that thereafter the growth rate declined sharply, and red rot (*Fomes pini* Thore) developed rapidly. There were some who believed that this early maturity was apparent rather than real and was due to the even-aged form with its congestion of stems and friction between crowns; they believed that timely thinnings would greatly lengthen the period of economically productive growth. However, clear-cutting continued to be practically the one and only commercial method of harvesting old field pine, and it is unlikely that the future will provide another similar opportunity for fully testing the application of other methods and longer rotations.

Because the Harvard Forest staff was able to carry out various cutting methods in old field pine, the case histories which follow are particularly valuable, constituting, as they do, some of the very few examples of the systematic conversion of old field white pine to be found in the region. However, it should be made clear that, under a policy of sustained yield management and with the object of demonstrating the practice of forestry as a business enterprise, those in charge of the Forest were necessarily compelled to employ cutting methods which gave promise of best results for the least expenditure. While all of the early methods applied to the management of old field stands, other than straight clear-cutting, were experimental in character, in the sense that no previous local experience could be drawn upon, they were nonetheless planned and executed to bring practical results in the form of sufficient income to make the Forest continuously self-supporting. Thus, the shelterwood method of reproduction, to cite an example, was not used for the sake of testing one of the well-known European systems, but because it promised to provide adequate natural restocking of white pine seedlings at low cost.

GENERAL SILVICULTURAL POLICY OF THE HARVARD FOREST

In the words of Fisher (1929), "When the study of forestry began actively in this country, almost nothing was known about the silvicultural characteristics of American forest trees and, in the absence of that knowledge, it was impossible to translate into terms of American practice the principles which were being applied in the older countries, or to apply new principles with any confidence. The great body of classified, factual information, which is the first essential of any science or art, was lacking." Furthermore, although much that was learned by our earliest foresters from European experience in silviculture might have been applied, with modifications, to American conditions, it was soon recognized that cultural methods which were financially feasible in Europe could not be economically applied in this country. Forestry abroad had developed under conditions of cheap labor, high land values, and good markets for all kinds of timber.

Thus, the early enthusiasm for trying out here the intensive silvicultural methods being used in Europe shortly ran into so many practical difficulties that American forestry suffered a temporary set-back. The one practice which did persist, however, was the planting of even-aged stands of conifers, with the attendant establishment of large forest nurseries and the sale of planting stock to private owners. This practice fitted in exceedingly well with the popular concept of growing a crop, whether it be corn, potatoes, or trees, as well as with the common local practice, referred to above, of clear-cutting the even-aged stands which had come in on abandoned farm land. By and large, the more favorable conditions for tree growth here and the great extent to which dependence could be placed on the natural restocking of cut-over land, was overlooked, and planting continued to be one of the principal activities in forestry.

Through the unusual perception and far-sighted approach of its first director, the Harvard Forest avoided many of the mistakes which so commonly were to be observed in the early days of forestry. Fisher soon recognized the importance of distinguishing between those forest types which are purely temporary, like old field pine, and hence transitional in character, and those composed of species which are characteristic of the more stable and permanent associations. Thus he was better prepared

than most foresters of his time to be guided by natural tendencies in forest succession and to accept and make the best use of the volunteer stocking which followed the cutting of temporary forest types, albeit that material, in composition, might be strikingly different from that of the preceding stand. To be sure, much supplementary planting of conifers was done in the early years, which later proved to be unnecessary, but always with the aim of developing a mixed crop and never with a view to perpetuating a temporary coniferous type.

The general silvicultural policy of the Harvard Forest adopted in the beginning and maintained, with scarcely any change, to the present day, is to work in close harmony with nature, utilizing to the fullest possible extent the best native elements available on a given area, as to species, individual tree vigor and quality, and adaptability to growth on the particular site. In the absence of adequate knowledge of the silvical characteristics of the local species, it was necessary to proceed more or less blindly in regulating the composition of the new stands, through such cultural treatments as weedings and improvement cuttings, but it was believed that favoring the best-formed, thriftiest volunteer elements, always in a mixed composition, would result in the most easily protected and maintained, and, at the same time, the most profitable tree crop which could be grown under existing conditions.

The policy was definitely one of producing high quality timber, great emphasis being placed on the early elimination, during the formative period, of the so-called weed species, such as gray birch, poplar, and pin cherry, and rank-growing stump sprouts and poorly formed individuals generally. While rotations could not be definitely fixed so far in advance, the thought was that sawtimber softwoods should be grown to at least 60 years and hardwoods to at least 80 years. Not much weight was given to choice of species as influenced by considerations of the existing market prices for lumber, there being every assurance that the pattern of future prices would be considerably different from that of the present, and that high quality lumber of all the better species would in time command a good price. Departures from the policy of favoring a broad mixture of all the better species were prompted by considerations of crop security rather than changes in relative market values. The depredations of the white pine weevil and white pine blister rust (*Cronartium ribicola* Fischer), the chestnut blight (*Endothia parasitica* Murr.), and the gypsy moth (*Porthetria dispar* L.) had more influence upon composition control treatments than the varying demands of the lumber market.

It is still untimely to say whether so much weight given to sawtimber

production was wise; but under such favorable conditions for growing good sawtimber species like red oak, white ash and paper birch, and the mounting shortage of high quality hardwood timber in this country, there is no reason to believe, at present, that a policy of growing lower grade crops on shorter rotations would be more profitable.

STANDS FOLLOWING THE CUTTING OF OLD FIELD WHITE PINE ON HEAVY SOILS

CASE NO. 1

Hardwoods Following the Clear-cutting of Old Field White Pine in a Seed Year

Block: Tom Swamp — History to September 1938
Compartment: II
Stand: Hd-1, 7.2 acres (Eastern Portion, 4.5 acres)

Although the temporary character of the old field pine type was recognized in the early years of the Harvard Forest, very little was known about the influence of various cutting methods on the composition of the ensuing stand. It had been observed that new stands containing appreciable numbers of white pines in mixture with hardwoods had followed clear-cuttings which happened to be made in pine seed years; but little was really known of the influences on the next generation of such factors as soil, climate, and the condition of the old stand at the time of cutting.

This case deals with the stand resulting from the first harvest cutting made in the Harvard Forest, in 1908 (Fisher, 1911, p. 4). Historically, it is probably the oldest intensively managed stand of its kind in the country. It is an example of volunteer hardwoods following the clear-cutting of old field white pine on a very fertile soil, despite strenuous efforts to develop a mixed stand of white pine and hardwoods. When the treatment of this stand was first undertaken, experience in local silviculture was almost entirely lacking. However, the significance of the hardwood advance growth beneath the old field pine was partially recognized, and it was expected that hardwoods would form part of the succeeding stand. It was also anticipated that by cutting the pine in a seed year pine reproduction would become established and might, through timely weedings, constitute one-half to two-thirds of the new stand. The experience of thirty years has clearly shown to what little extent these expectations have been realized.

Site and Land History

The area is located on a flat (elevation 850 feet) near the foot of the long westerly slope ending in Tom Swamp. It is traversed by an inter-

mittent stream with three small branches. Along the water courses the soil is especially rich and moist, creating ideal conditions for white ash and red maple. In these moister places, or swales, the soil is either Sutton stony silt loam or Whitman stony silt loam; in the drier portions, a Charlton stony loam. These are considered among the most productive soils in the region.

Prior to the seeding in of the old field stand, the area was a cleared portion of a farm originally granted in the second division, in 1738. Because of wetness and extreme rockiness, it is quite probable that the land was used as pasture rather than for cultivation. Abandonment took place around 1843, and white pine and hardwoods seeded in shortly thereafter. The pine was concentrated in the drier portions, while the hardwoods claimed the water courses, forming arm-like protrusions into an otherwise nearly pure pine stand.

Clear-cutting—Winter, 1908-09

The stand had reached an age of 65 years, and the trees a height of 80 to 90 feet. Seventy-five percent by volume was white pine, and the rest chestnut, black cherry, red oak, white ash, black birch, and red maple. There was an abundant advance reproduction of hardwood seedlings in which white ash, black cherry, red oak, and chestnut were prominent. Reproduction of white pine was lacking.

The stand was clear cut following an exceptionally heavy fall of pine seed in the autumn of 1908. Many of the older hardwood seedlings (the advance growth) were cut or broken in the course of logging; others, younger and less than one foot high, were not damaged. The slash was burned green as the logging progressed and the area left in good condition for the start of the new stand. The harvest yielded 32,000 board feet of pine lumber, 18 cords of hardwood fuelwood, and 6 cords of pine fuelwood, per acre.

Condition of New Stand During First Growing Season

In June 1909 the pine reproduction ranged from 10,000 to 65,000 seedlings per acre, but an exceptionally dry summer season followed, and by autumn nearly half the seedlings had died. Mortality was highest in places where the seedlings were growing on thick litter and duff by chance left undisturbed during the logging. Those still living were in moist depressions or in the shade of the adjacent stands. The hardwood element apparently was but little affected by the drought. The small stumps of the cut and broken hardwood advance growth sprouted vigorously, giving rise to what are known as seedling sprouts.

Weeding[2] *(First)—October, 1912*

This weeding was made at the end of the fourth growing season. There were from 10,000 to 13,000 seedlings and seedling sprouts per acre, of all species. Chief among the hardwoods were white ash, elm, black and paper birch, aspen, red oak, and red maple. Yellow birch, chestnut, gray birch, hard maple, pin cherry, hickory, hornbeam, and basswood occurred less frequently. Red maple and chestnut sprouts from large stumps were

FIG. 7. NOVEMBER, 1908. CLEAR-CUTTING THE OLD FIELD PINE STAND

Hardwoods occurred in the wettest parts of the area (the swales) and a thicket of hardwood seedlings (the advance growth) had developed underneath the white pine.

the dominant elements in height, ranging from 8 to 15 feet. Hardwoods of seedling origin averaged 3 feet in height, and, in contrast, the white pine only 10 inches.

The weeding was concentrated on the cutting of undesirable, rank-growing sprouts and trees of short-lived, inferior species, such as aspen and gray birch, particularly where they were overtopping promising white pine.

[2]For a description of weeding, see "Forest Weeding" (Cline, 1929).

Weeding (Second)—Fall, 1916

The second weeding was made at the end of the eighth growing season. In spite of the earlier attempt to favor the pine, as part of a mixed stand, only a small number showed promise of competing favorably with the faster growing hardwoods. Many were reported as having been killed by suppression and drought but, since the feeding habits of the pales weevil (*Hylobius pales* Herbst) were unknown before 1914, it is likely that this insect also was a factor in the death of the pine. Most of the

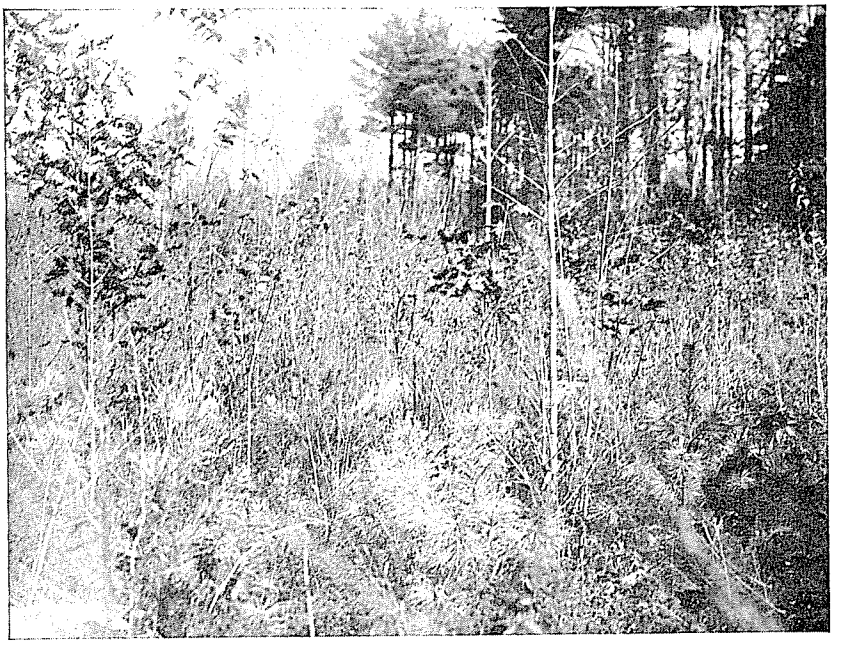


FIG. 8. NOVEMBER, 1915. THE NEW STAND SEVEN GROWING SEASONS AFTER LOGGING

White pine from the seed year of 1908 is overtopped by hardwood seedlings and seedling sprouts. One weeding (in 1912) has been applied to favor the pine.

cutting was confined to hardwoods of inferior species or form; but where desirable hardwoods were competing with pines, the latter usually were given preference. White ash, yellow birch, and elm were favored in the wetter places; and red oak, white ash, and paper birch in the drier.

Weeding (Third)—October, 1919

At the end of the eleventh growing season a third weeding was made. Very little cutting was done, because the previous treatments were con-

sidered to have freed enough good trees to form the crop. Practically no white pine, except a few small groups in the southern portion of the stand, showed any promise of carrying through to the final harvest. The most thrifty individuals in these groups were released from overtopping hardwoods, but little hope was held for their survival.

Improvement Cutting and Thinning[3]*—February, 1933*

Fourteen years had elapsed since the previous treatment, the stand now

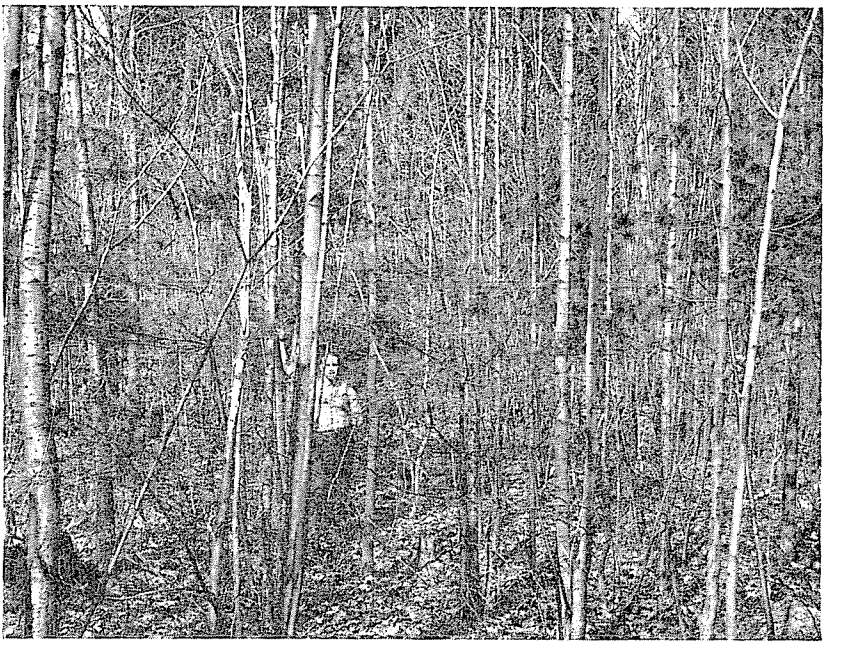


FIG. 9. SPRING, 1933. THE STAND AT TWENTY-FOUR YEARS OF AGE

The white pine is completely suppressed by the hardwoods, and the white ash is overtopped by the more aggressive red oak. Three weedings have been made.

having reached twenty-four years of age. The principal crop trees were red oak, white ash, paper birch, and hard maple. Associated with these were red maple, black and yellow birch, elm, basswood, white oak, and white pine. Red oak and paper birch were dominant in the well-drained portions of the area, white ash in the swales. Only two small groups of white pine remained. Elsewhere it had died, or persisted only in a hopelessly suppressed condition.

[3]For a description of improvement cutting and thinning, see "Improvement Cutting and Thinning" (Cline, 1935).

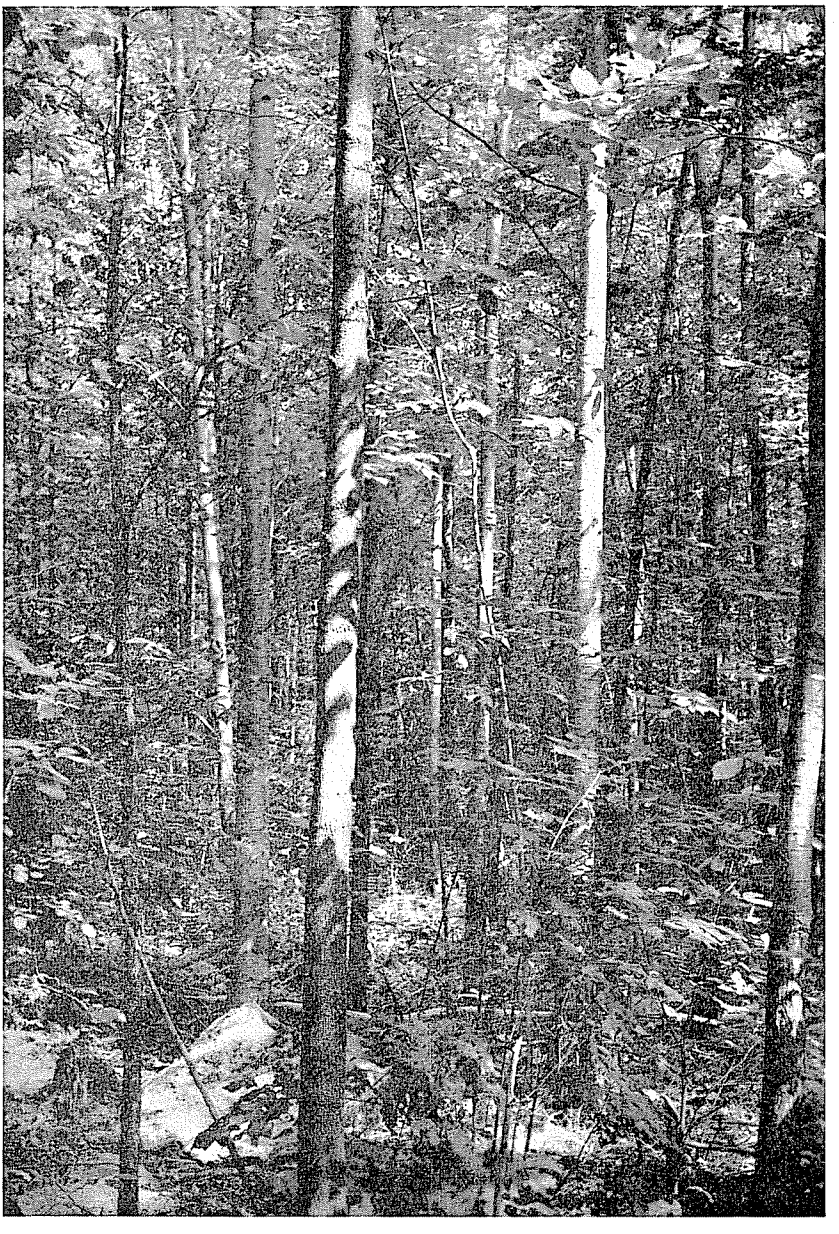


FIG. 10. SUMMER, 1935. THE STAND AT TWENTY-SEVEN YEARS OF AGE

On the better drained portions of the area, red oak and white ash are the leading crop trees. Certain individuals have reached 55 feet in height and 7 inches in diameter. Clear length of bole already nears 30 feet.

The stocking was fairly uniform over the entire area, ranging from 700 trees (2 inches and over in d.b.h.) per acre in places where red oak was most abundant to 864 where white ash was in the lead. The average height for all trees was 35 feet, and the average diameter 3.3 inches. Some of the largest red oaks, however, were 45 feet high and over 5 inches in diameter; and a few favorably located ashes were even taller. The boles of these best trees were clear of limbs for upwards of 1½ logs.

It was evident that the long delay between the last weeding and the present treatment had permitted some of the more aggressive trees, especially red oaks, to attain positions of extreme dominance in which they had developed crooked boles and large branches. In the drier portions of the area, groups of red oak were so well established and had so suppressed their less aggressive associates that appreciable change in the composition was no longer possible. The markedly different growth habits of red oak and white ash had now become well known through previous studies of these species by Patton (1922) and Kempff (1927). Patton characterized the oak as space-demanding, and the ash as crowd-enduring. Kempff adopted the terms crown-resistant for oak and crown-sensitive for ash. Because of the local prevalence of these two valuable species, much of the cultural treatment in the young hardwood stands described in this series of case histories is concerned with adjusting the competition between them.

The treatment was a combined improvement cutting and crown thinning (thinning from above) to better the composition where possible and give the selected crop trees more room. Most of the work was confined to the removal of whips (tall, slim individuals) and inferior trees in dominant positions. Thinning was confined to a few small areas, particularly ash groups, where the stocking was too dense. About 180 trees per acre were removed, of which 50 percent were red oak, 30 percent white ash, and the remainder yellow birch, red and hard maple, and paper birch. Although some of the trees were large enough for cordwood, the difficulties and expense of extracting the small quantities produced, and the fact that doing so would have necessitated removal of some of the desirable understory of trainers,[4] influenced the decision to limit disposal to lopping the tops and scattering the slash. At this age, clear length of bole in the crop trees was still short of that desired, and hence continued action of the trainers was needed. The method of thinning adopted for this stand, the so-called Danish modification of crown thinning, has been described by Holsoe (1933).

[4]Overtopped trees which, through their shading and abrasive action, hasten natural pruning of the crop trees.

FIG. 11. SPRING, 1933. A GROUP OF WHITE ASH GROWING IN A SWALE

In the thinning, just completed, the density of the main story was considerably reduced, to increase diameter growth. The boles are clear of branches for nearly 25 feet. The trainers (the small, overtopped trees) were left to aid natural pruning.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours Total*	*Man-hours Per Acre*
Weeding	10/1912	4.5	4	40.5	9.0
Weeding	Fall/1916	4.5	8	45.0	10.0
Weeding	10/1919	4.5	11	9.0	2.0
Improvement Cutting and Thinning	2/1933	4.5	24	22.5	5.0
Total				117.0	26.0

Stand Condition—September, 1938

The stand is now 30 years of age. White ash is the leading species along the water courses, and red oak on most of the well-drained area. An abundance of paper birch in the southeast corner is attributed to a nearby source of seed in the adjacent stand to the south. Scattered more or less throughout the entire stand are hard maple, white oak, black and yellow birch, and an occasional black cherry and black oak. White ash growing in the swales has shown the greatest height growth, certain individuals having reached 65 feet. Red oak has the best diameter development; the largest trees are 9.5 inches, d.b.h., with a height of 58 feet and a clear length of 30 feet.

The following table shows stand composition in a well-drained area, where red oak predominates:

WELL-DRAINED AREA
COMPOSITION BY CROWN CLASSES

	Dominant	*Codominant*	*Intermediate*	*Suppressed*	*Total*
	(*Number of stems per acre*)				
Red Oak	136	128	64	36	364
White ash		20	124	76	220
Yellow birch			68	16	84
Hard maple		4	20	8	32
Red maple			12	8	20
Paper birch	4		4	4	12
White pine				12	12
Black birch			8		8
White oak				4	4
Total	140	152	300	164	756

Red oak now forms the dominant crown class, almost to the exclusion of other species. Subsequent thinnings undoubtedly will favor some of the best trees of these other species now in the lower classes, and the ultimate main stand composition will be broadened somewhat.

The following table shows stand composition in a moist area, where white ash is the leading species:

MOIST AREA (SWALE)
COMPOSITION BY CROWN CLASSES

	Dominant	*Codominant*	*Intermediate*	*Suppressed*	*Total*
		(Number of stems per acre)			
White ash	40	140	60	40	280
Red oak		20			20
Red maple		10	40	40	90
Elm			10	10	20
White oak				10	10
Gray birch				10	10
Paper birch			10		10
Basswood				10	10
Total	40	170	120	120	450

White ash comprises 100 percent of the dominant crown class in the moist places.

The average size of the crop trees, for the stand, is between 50 and 55 feet in height and from 5.5 to 6.5 inches, d.b.h. The clear length averages 25 feet, and the dead length,[5] above clear length, about 3 feet.

Of all the white pine present in the beginning, only two small groups remain. There are some 60 trees in these groups, only a few of which appear thrifty; and it is unlikely that even these much longer can compete successfully with the hardwoods.

The soil has been transformed from a relatively inactive mor under the previous pine stand to a true mull beneath the hardwoods (Fisher, 1928). The former organic layer has been completely decomposed and merged with the mineral soil. Soil biota are numerous, and the leaf litter in any given year, except for oak leaves, which are the least attractive food of earthworms, is almost completely incorporated into the mineral soil before the succeeding fall.

Discussion

The early aim to develop a mixed pine and hardwood stand has not been attained. On good sites such as this, where hardwoods are rapid-growing,

[5]That portion of the bole, beneath the living crown, where dead limbs persist.

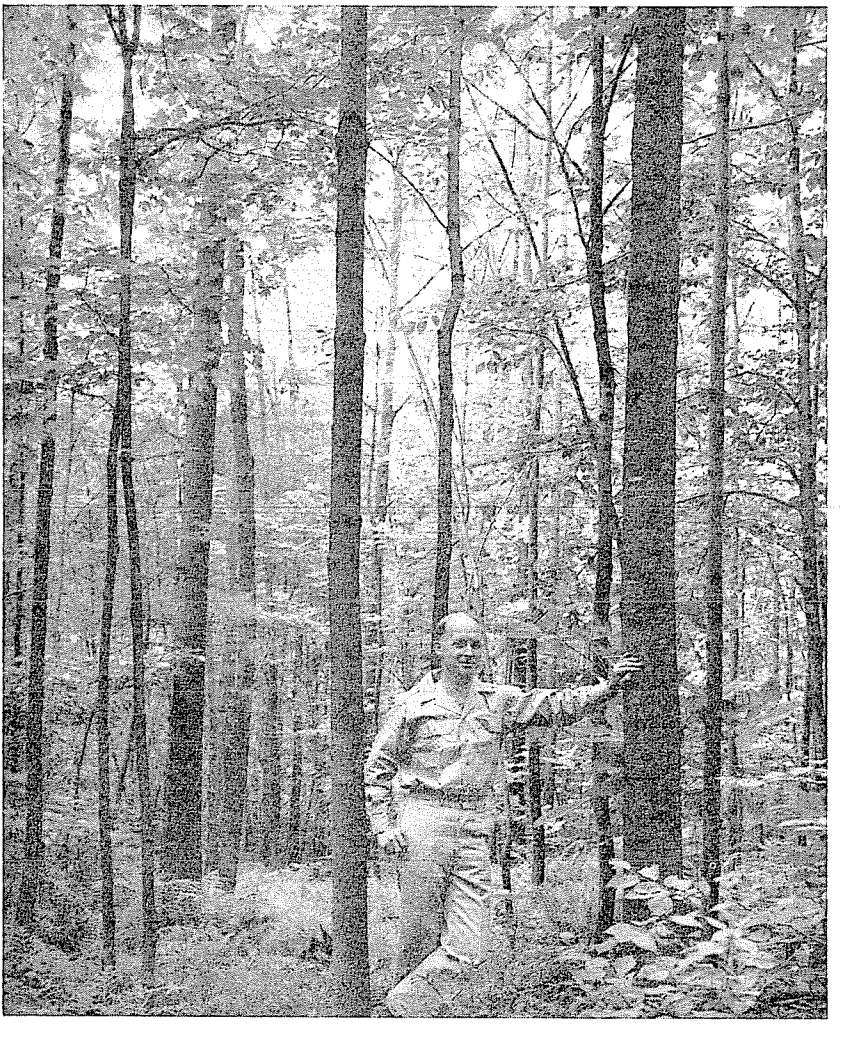


FIG. 12. JUNE, 1946. THE STAND AT THIRTY-SEVEN YEARS OF AGE

The best red oaks have now reached a diameter of over 10 inches and a height of nearly 65 feet.

white pine is greatly handicapped. In this case, a very dense pine reproduction was available as a result of the 1908 seed year, and the early weedings strongly favored it as part of the crop. Yet it was found impracticable to bring it through even to 30 years.

With greater knowledge in the beginning of the inability of pine to keep pace with hardwoods, a much better stand could have been developed. At the outset many of the good hardwood stems were repeatedly cut back to favor pine; by the time the weakness of this policy was discovered, their quality was seriously impaired. Similarly, the lapse of fourteen years between the third and fourth treatments permitted coarse and fast-growing red oaks and other inferior elements to gain a dominant position in the stand, crowding out more valuable individuals; even one treatment for the special purpose of removing trees of inferior form from the main canopy would have accomplished much in the way of improved quality.

There are more than enough well-formed crop trees to form a full stocking at maturity, but the early failure to appreciate fully the aggressiveness of red oak will lengthen the period required to bring the better-formed individuals to merchantable size. Also, from the standpoint of security against gypsy moth damage (Baker and Cline, 1935) and improvement of soil fertility, the present preponderance of red oak is not in accord with the best silvicultural practice. Oak leaves constitute the largest source of highly favored food of the gypsy moth larvae, and gypsy moth infestations have steadily grown in intensity in this part of New England. At the same time, oak leaves are among the least favored food of earthworms, and, therefore, in an area supporting only oak, the highly desirable earthworm activity is reduced.

CASE NO. 2

Pine and Hardwoods Following Uniform Shelterwood Cutting in Old Field White Pine

Block: Tom Swamp History to May, 1940

Compartment: I

Stand: P-Hd-3, 22.5 acres (Southern Portion, 8.5 acres)

In contrast to clear-cutting, the shelterwood method of obtaining natural reproduction is one by which the stand is gradually removed in a series of cuttings extending over a period of years, usually a decade, more

or less. The first cuttings are for the purpose of improving seedbed conditions on the forest floor and stimulating abundant seed production. As soon as a good seed year comes along, a "seeding cutting" is made, which permits more light to reach the ground, reduces root competition for soil nutrients, and in other ways aids the establishment of reproduction. The seedlings get their start under the shelter of the parent trees, the overwood; hence the term shelterwood. Subsequent partial cuttings provide the newly established reproduction with additional light and nutrients. Finally, when the reproduction is well rooted and able to shift for itself, the remainder of the stand is cut clean in one operation.

This stand was among those treated in 1908-09, the first year of operations in the Forest. Here the aim was to obtain natural white pine reproduction, and it was decided to try out a simplified form of the uniform shelterwood[6] method, using only two cuts. The first cutting was designed to encourage the start of pine reproduction. After the seedlings had become established, the second cutting would be made and the new generation completely freed.

Not only was this the first attempt to secure natural reproduction by the shelterwood method, but the type to which it was applied was a temporary one and the site especially favorable for hardwoods. It is not surprising, therefore, that the outcome was not all that was hopefully anticipated by those who planned the cuttings.

Site and Land History

The area is situated on the upper portion of the slope which extends westerly from the village of Petersham to the Tom Swamp bottomland. The elevation is about 1,100 feet. The soil is a Charlton stony loam, one of the most highly productive in the region.

This was "first division" land, directly adjacent to one of the original house lots. Presumably, the forest was cleared soon after settlement, in 1733, and the land devoted to agriculture. Certain portions of the area were put into crops; but others, too rough and stony for cultivation, undoubtedly were pastured. Abandonment took place around 1850, and the land seeded in to white pine and a scattering of hardwoods.

First Shelterwood Cutting—Winter, 1908-09

At 60 years of age the stand was dense and contained about 40,000 board feet per acre. Associated with the white pine, particularly in the wetter and more poorly drained places, were scattered hardwoods, chiefly red maple, black birch, and red oak. Because of the extremely high density

[6]In this method, the preliminary cuttings are applied uniformly throughout the entire stand, thus differing from the group and strip shelterwood methods.

of stocking, the pine was slow-growing and of poor quality. Red rot was common, and many trees showed evidence of advanced decay. There was very little ground cover, and only a light stocking of advance growth hardwoods, including white ash, hard maple, black cherry, red oak and chestnut.

Inasmuch as 1908 was a good pine seed year, it was thought that opening the stand and breaking up the organic layer in the logging would create conditions favorable for pine reproduction.

All dead and overtopped pines and a good many of the intermediates were cut, along with an occasional large-crowned, poor-quality dominant.

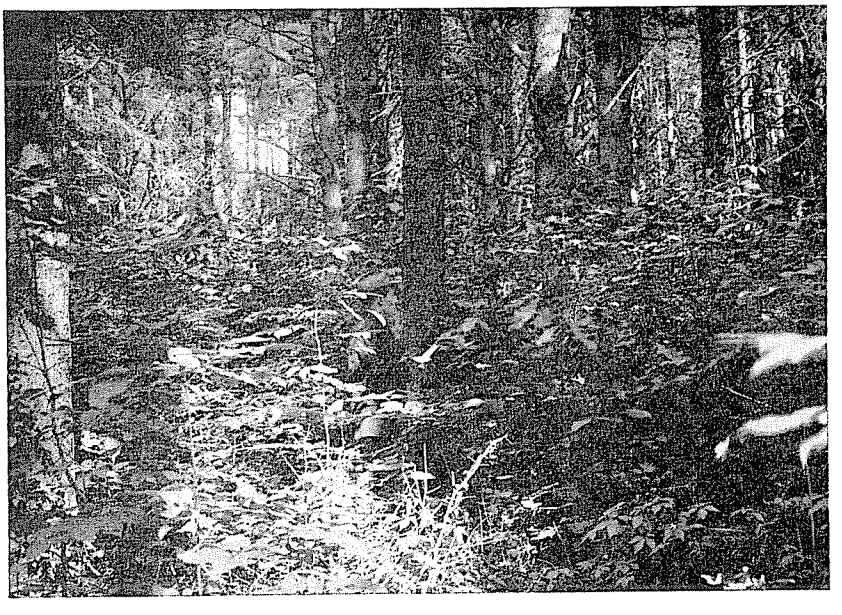


FIG. 13. JUNE, 1912. THE STAND IN THE FOURTH GROWING SEASON AFTER THE FIRST SHELTERWOOD CUTTING

A dense hardwood undergrowth has developed, completely overtopping the white pine reproduction.

All hardwoods, except a few whose removal would result in large breaks in the canopy, also were cut. About 7,000 board feet per acre were removed. This reduced the number of trees to less than 50 percent of those in the original stand, but the density of the main canopy was only slightly lowered. As the light slash from the small-crowned trees was not heavy enough to warrant burning, it was lopped and scattered, and left on the ground to rot. (Fisher, 1911, p. 2)

Condition of the Reproduction—Autumn, 1909

At the end of one growing season, pine seedlings were found to have come in abundantly over almost all of the area. In a series of seedling counts taken on plots 8 feet square, the lowest number was 16 and the highest was 65. The condition of the plants was not thrifty, however, owing to the heavy main canopy and a thick organic layer.

Condition of the Reproduction—May, 1911

In spite of the unpromising condition of the pine seedlings at the time of the previous inspection, many of them, especially those whose roots had succeeded in reaching mineral soil, had survived. Reproduction apparently had been successfully established. The effect of removing the remaining stand, with the attendant damage from logging and losses from insect attack, had yet to be learned.

Condition of the Reproduction—Autumn, 1913

Following the heavy white pine seed year of 1908, another moderately heavy one occurred in 1911. A sampling of the pine reproduction showed about 11,000 seedlings per acre from the combined seed crops of 1908 and 1911. However, their general condition was poor, because of competition with the old stand and the advance growth hardwoods. Only in places where the seedlings had become rooted in the mineral soil did they appear to be thrifty. On the other hand, the hardwood advance growth had responded to the increased freedom; growth was accelerated and the stocking much denser. It consisted chiefly of red oak, white ash, black and paper birch, black cherry, hickory, red maple, and basswood.

After an investigation of stand conditions, the recorder (Wyman, 1913) reached the following conclusions:

(1) Pine reproduction does best where an abundance of light is available.

(2) Sufficient reproduction of both hardwood and pine is now on the ground to secure a satisfactory new stand, provided the overstory is removed in a short time.

(3) In regard to the pine seedlings, it would have been better to clear cut the area at the time the thinning (first cutting) was made, because the shade of the overstory during the intervening years has weakened them.

Final Cutting—Winter, 1914-15

A mixed reproduction of hardwoods and white pine completely covered the ground. Since the first cutting (1908-09), many of the pine

seedlings had survived, but they had grown slowly and become less and less vigorous. Even under the larger openings in the canopy, where the best growth had occurred, a maximum height of only 1½ feet had been reached during the 6-year period. Under heavy shade, the seedlings seldom were higher than 6 inches. Stump sprouts from hardwoods cut in 1908 were 6 feet tall in the shaded places and 10 to 12 feet in the openings. The hardwood advance growth had grown rapidly, ranging upwards to 7 and 8 feet. It was plain now that when the overwood was finally removed little of the pine could be counted on to survive.

FIG. 14. FALL, 1915. THE NEW STAND AT THE END OF THE FIRST GROWING SEASON FOLLOWING THE FINAL CUTTING OF 1914-15

Seedling sprouts of white ash, red oak, black cherry and chestnut cover the ground. One-year white pine seedlings were abundant but completely overtopped by the hardwoods.

Since 1914 was a good pine seed year, it was decided to make the final removal cutting without further delay, in the hope that additional pine reproduction would result. In order to favor the pine, the hardwood advance growth was cut back before logging. By June of 1915, the area was cleared of logs and slash, and left clear for the new crop. The cut yielded about 38,500 board feet per acre of round-edge lumber.

Condition of the New Stand—July, 1915

Most of the area was well stocked with one-year pine seedlings and

seedling sprouts of white ash, red oak, black cherry and chestnut. The new (1914) pine reproduction was abundant and well distributed, but many of the older seedlings, from the seed years of 1908 and 1911, were damaged in logging. Those that survived this ordeal were later attacked and killed by the pales weevil.

Condition of the Stand—September, 1918

An examination of a number of small plots, regularly distributed over the area, showed the following distribution of species:

	4-Year-Old Seedlings and Seedling Sprouts	*Stump Sprouts*	*Total*
	(*Number of stems per acre*)		
White ash	630	20	650
Red oak	340	5	345
Chestnut	30	50	80
Red maple	420	20	440
Black cherry	270		270
Hard maple	15		15
Poplar	40		40
Hickory	15		15
White oak	20		20
Basswood		15	15
Birch	220	10	230
White pine	4,100		4,100
Total	6,100	120	6,220

At the end of the fourth growing season, an average of 4,100 pine seedlings per acre, all from the crop of 1914, survived. In spite of a dense cover of hay-scented fern and hardwood sprouts, they appeared fairly thrifty; but the hardwood sprouts were 6 to 8 feet tall, while the height of the pine seedlings rarely exceeded one foot. White ash was the most abundant hardwood species, followed in order by red maple, red oak, and black cherry.

Weeding (First)—October, 1919

The first weeding was delayed until the end of the fifth growing season. By this time many of the pine seedlings observed in 1918 were hopelessly overtopped by the faster growing hardwoods; others showed

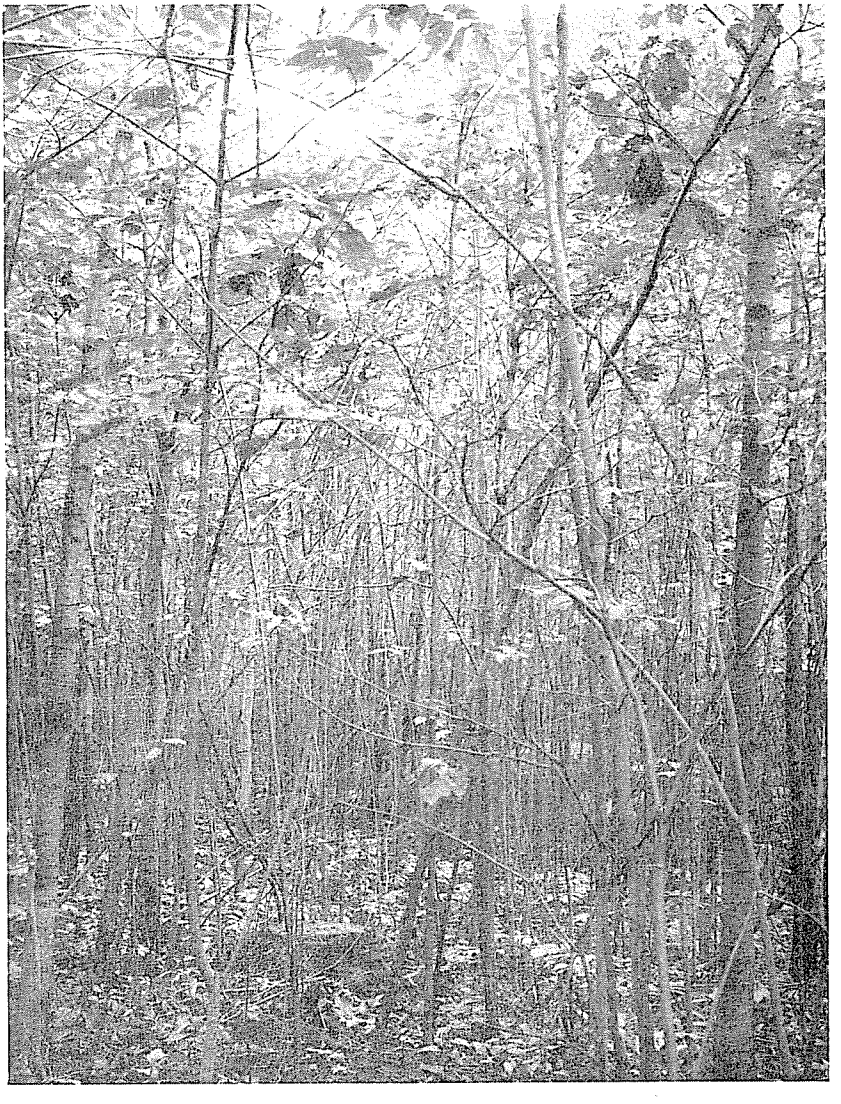


FIG. 15. JULY, 1934. THE YOUNG STAND IN ITS TWENTIETH YEAR

Red oak has outgrown white ash, paper birch and all other associates. A dense white ash group appears in the background.

promise of a favorable response to release. Most of the treatment was with the aim of improving the hardwood composition, because it was now evident that hardwoods would form the greater part of the ultimate crop. A few promising groups of pines were released, in places where the overtopping hardwoods were of poor species or form.

Weeding (Second)—October, 1927

At the time of this treatment, 13 years after the final cutting and 8 years after the first weeding, only scattered weed trees remained to be cut. For the most part, the stand appeared to be in good condition and made up very largely of desirable hardwoods. Most of the white pine had lost out in the competition; only a very few groups were worth releasing. The stand was considered to be of acceptable composition and density, in shape to go ahead without much more treatment until the thinning period. (For relative early growth rates of white pine and hardwoods, see Cline and Lockard, 1925, p. 23).

Improvement Cutting and Thinning—October, 1935

The stand at this time was 21 years old and composed chiefly of red oak, white ash, and paper birch crop trees. Red oak formed nearly pure groups over a considerable part of the area, and many individuals were coarse and limby, through having too much room. This fact, together with the high susceptibility of oak to attack by the gypsy moth, made it desirable to combine an improvement cutting and a gypsy moth control cutting in one. Considerable reduction in the quantity of red oak was made solely through the cutting of poorly formed individuals. White ash was generally favored, owing to its high value, its freedom from gypsy moth attack, and its beneficial effect upon the soil. Dense ash groups were thinned. A special effort was made to eliminate gray birch, poplar, and white oak, all relatively inferior species and favored foods of the gypsy moth. The cutting was heavier than ordinary, because of the rather drastic reduction in moth-favored species. However, in no case was a tree cut or girdled unless a more desirable tree was in a position to take its place, and no large gaps were made in the canopy.

An average of 186 trees per acre, 2 inches, d.b.h. and over, were removed, equivalent to 150 cubic feet, or nearly 2 cords. Red oak made up 55 percent of the number of trees cut and 70 percent of the volume. No attempt was made to utilize the cuttings, because of the expense of handling such small-sized material. Instead, the tops were lopped and scattered.

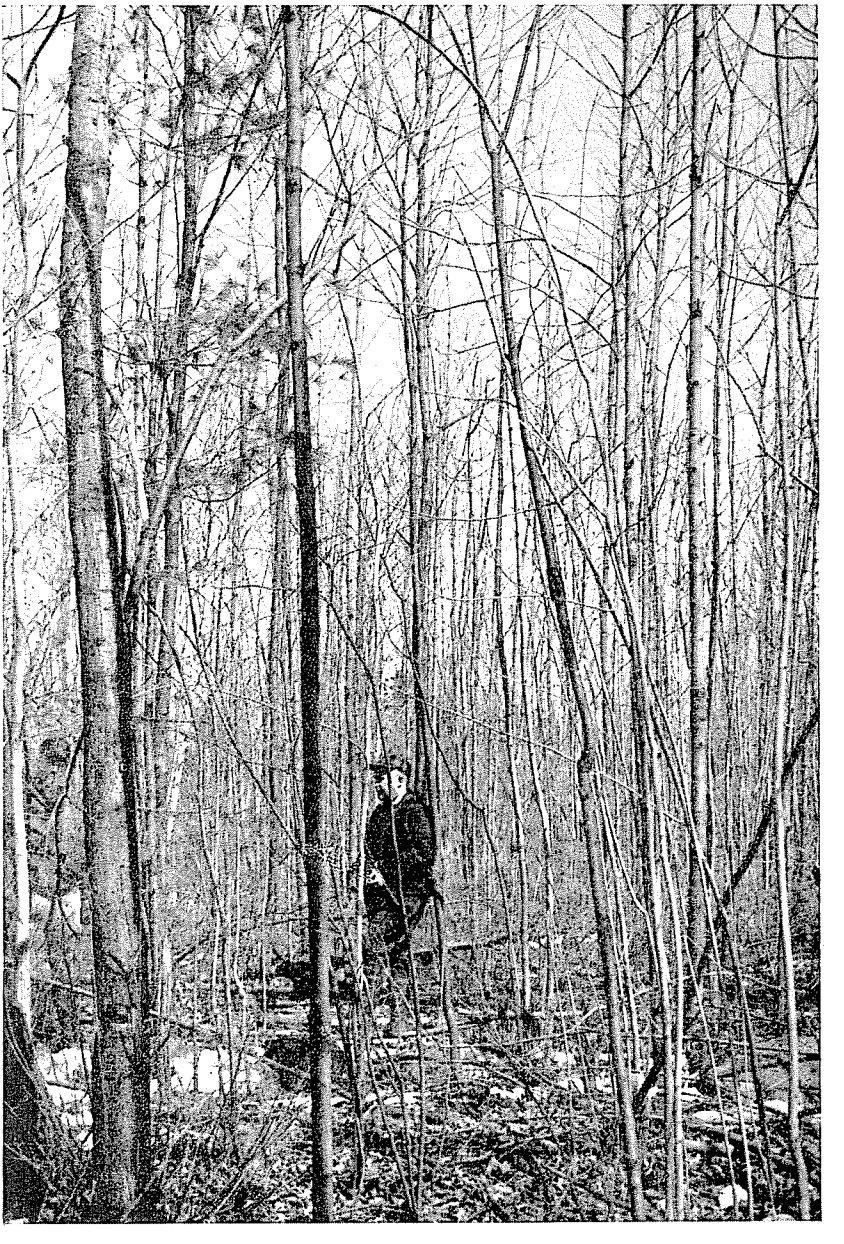


FIG. 16. SPRING, 1938. THE STAND AT TWENTY-THREE YEARS OF AGE

In the combined improvement cutting and thinning made three years previously, white ash was favored in this particular place. The red oak was girdled because of its isolated and dominant position.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	10/1919	8.5	5	25.5	3.0
Weeding	10/1927	2.0	13	4.0	2.0
Improvement Cutting and Thinning	10/1935	8.5	21	52.7	6.2
Total				82.2	

Condition of the Stand—May, 1940

The stand is 25 years old, a mixture of hardwoods, with two or three small groups of white pine from the seed crop of 1914 which may form a part of the final crop. The largest pines are 25 to 30 feet tall and 4 to 6 inches in diameter. Since they started out in dense groups of natural reproduction, they are relatively free from white pine weevil damage, straight, small-limbed, and of good quality (MacAloney, 1932, p. 23). Elsewhere, scattered individuals or groups of white pine are completely suppressed and not worth trying to save.

The main hardwood canopy is made up mainly of three species—red oak, paper birch, and white ash. Of these, red oak is the most abundant as well as the largest in size; next comes paper birch, with white ash a poor third. Red maple occurs commonly in the lower crown classes. Other species, such as black and yellow birch, hickory, basswood, hard maple, and black cherry, are present as minor associates, rarely occupying a dominant position. Although red oak comprises only about 25 percent of the total number of trees, it makes up over 40 percent of the main canopy. The density of crop trees in the two leading crown classes averages 450 stems per acre. The density of the trainers amounts to about 1,500 stems; and seedlings, sprouts from recent cuttings, and badly suppressed trees comprise an added density of about 2,000 stems per acre. The dominant trees range up to 45 feet in height and 7 inches in diameter.

The soil is a crumb mull with a high earthworm population. Particularly in areas where white ash is abundant, the worm action is very noticeable. By midsummer the forest floor is nearly bare.

Discussion

While this case does not illustrate the best use of the uniform two-cut shelterwood method in old field white pine, it is questionable whether

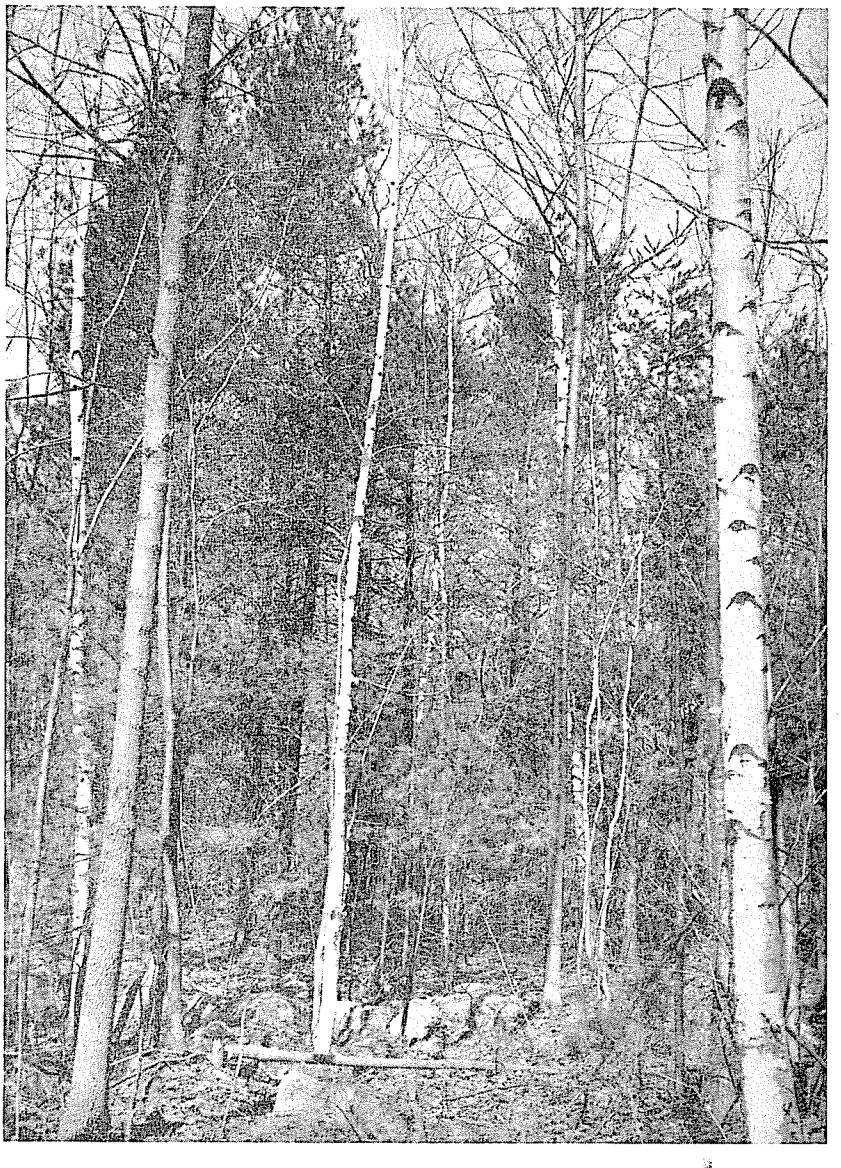


FIG. 17. APRIL, 1946. ONE OF THE FEW WHITE PINE GROUPS WHICH WILL FORM PART OF THE FINAL CROP

The comparatively good form of the trees is due largely to the high density of stocking at the start.

any other plan of cuttings would have materially bettered the outcome. The results obtained, although favorable in the beginning, have since proved the difficulty of reproducing old field pine stands on good hardwood sites. The timing of the cuttings was ideal from the standpoint of starting pine reproduction. The first cutting, in 1908-09, gave rise to an abundant seeding of pine, but conditions were not favorable to its survival beyond a few years. Seedlings from the 1911 crop also started in some abundance, but unfavorable ground cover conditions and competition with the residual trees made them very feeble. Nearly all of the pine seedlings remaining on the area at the time of the final cutting in 1914-15 were destroyed by one agency or another before 1918. The seed crop of 1914—just before the final cutting—gave rise to still another stocking of pine; but the hardwood advance growth had become so dense by this time that the pines later lost out in the strong competition, despite efforts in the early weedings to save them.

It would be interesting to know whether better success would have resulted from a heavier cutting in the beginning (1908-09), or from making an additional partial cutting to increase the size and vigor of the pine reproduction before completely freeing it. The probabilities are that, on a Charlton soil, any efforts to increase or strengthen pine reproduction would have had a similar stimulating effect upon hardwoods and nothing would have been gained.

The quality of some of the leading trees, particularly red oak, is not the best that can be produced on such good sites, but the aggressive habits of red oak were not fully appreciated at the time of the weeding treatments. The more scattered occurrence of red oak, as compared with the strongly groupwise tendency of white ash, became recognized more fully —a fact which adds to the difficulty of growing high quality oak where isolated individuals are surrounded by the more slowly growing and crown-sensitive ash. At the same time, the high density of the ash thickets calls for early and frequent thinnings to avoid stagnation. The difference in spatial occurrence of the two species is related to the means of seed dissemination under old field pine stands; acorns are carried chiefly by rodents, while ash mostly rests where it falls, in the immediate vicinity of seed trees.

CASE NO. 3

Softwoods and Hardwoods Following the Clear-cutting of Old Field Pine and the Planting of White Pine and Norway Spruce

Block: Slab City — History to June, 1940

Compartment: X

Stand: P-Hd-3, 3.6 acres

This case has special historical interest in that it deals not only with one of the very first plantings on cut-over land but also with the area where investigations were first made (1914) to discover the causes of heavy losses of white pine seedlings following the removal of old field white pine. Under the direction of E. E. Carter, then a member of the Forest staff, an experimental planting was made with white pine and Norway spruce following a clear-cutting. The planting was spread over a period of two years in order to learn whether there was any relation between mortality and time of establishment of the plantation (Carter, 1916).

The planting of the entire area resulted in the eventual development of a mixed stand of conifers and hardwoods in which, because of peculiar circumstances, the planted conifers formed the major part of the new stand.

Site and Land History

The area borders the east branch of the Swift River, at an elevation of 800 feet, with steep hills arising on either side. The elevation is the lowest and the site the coolest and most sheltered of any described in these cases. The soil is made up of glacial till and glacial outwash, the two forming a complex association of irregular distribution. The till is difficult to assign to any soil type, because its constituent parts are made up of basic materials of two or three distinct types; in fertility it approaches a Gloucester fine sandy loam. Large surface and sub-surface boulders are characteristic of the till, but they are generally absent in the outwash soil. The soil moisture conditions vary greatly over the area as a whole; certain spots influenced by outseepage from underlying strata are moist the year round, while others are quickly drained.

The early forest was cleared in the first stages of settlement. Because of the steepness of the slopes and the rough character of the ground, it is

likely that this area was used as a pasture. Abandonment as farm land took place around 1855, and the ground seeded in to white pine along with some red maple, black cherry, and other hardwoods.

Clear-cutting—Winter, 1913-14

At this time the old field pine stand was 55 years old and contained an average of 24,500 board feet per acre, including the hardwoods.

The advance growth consisted principally of red maple with a light admixture of black and yellow birch, red and white oak, chestnut, and white ash. This was mowed down with brush scythes, and the main stand clear cut. After clearing, there remained a mat of pine litter and duff on top of the soil, except where the piles of brush had been burned. In some places a layer of fine brush and broken limbs several inches thick had been added as a result of the logging.

Planting—May, 1914

A planting was made with 561 2-1 white pine and 100 2-1-1 Norway spruce transplants, covering about half an acre in the southern portion of

FIG. 18. JUNE, 1914. GENERAL VIEW OF THE CUTTING AREA ONE MONTH AFTER FIRST PLANTING

Only a sparse stocking of sprouts from the stumps of the hardwood advance growth is visible. The fresh cutting attracted pales weevils, and the white pine stand in the background afforded an abundant source of white pine weevils.

the area. Four rows of Norway spruce were planted under the partial shade of the neighboring stand to the south, and then 15 rows of white pine under full exposure. The spacing was as near 6 feet as the stumps and rocks permitted. The mattock-hole method of planting was used, and a great deal of care exercised in doing a good job. Small scalps to remove the heavy organic layer were made before planting.

Inspections—1914 Area

Several inspections (Carter, 1916), dating from June 1914 to September 1915, were made of the plantation.

The first inspection showed that there had been a very small loss, 88 percent of the plants being classed as thrifty. The second inspection showed 83 percent of the plants thrifty, with only 11 percent dead. The third inspection showed a 20 percent loss, with many more dying. It was on this inspection that a number of snout beetles were found feeding on the seedlings. Professor C. T. Brues, of the Department of Entomology at Harvard, identified these as *Hylobius pales* Herbst. This discovery came as a surprise, because heretofore the beetle had never been considered a primary pest on young pines.

At each subsequent inspection beetles were collected in the act of feeding on the seedlings. The loss unmistakably attributable to this source increased steadily, until in September 1915 it amounted to 62 percent. And an additional 10 percent were so severely injured that death seemed inevitable.

The full results of the examinations appear in the following table:

Condition of White Pine Plants	*Dates of Inspection*						
	6/26/14	8/3/14[7]	9/3/14	11/4/14	5/19/15	6/18/15	9/3/15[8]
	Percent						
Not Attacked by Pales Weevil							
Thrifty	88	83	55	45.9	35	21.0	9.1
Weak	10	6	3	1.6	5	3.6	.7
Dead	2	7	7	7.1	8	8.2	10.6
Attacked by Pales Weevil							
Thrifty	—	—	3	3.8	5	5.2	8.4
Dying	—	—	12	6.8	5	16.0	9.5
Killed	—	4	20	34.8	42	46.0	61.7
	100	100	100	100.0	100	100.0	100.0

[7]Inspection covered rows 5 to 13 only.
[8]Inspection covered rows 5 to 12 only.

Similar examinations made of the Norway spruce showed that the death of only one seedling could be attributed to the weevil. About 10 to 15 percent of the spruces had been chewed to some extent but had recovered.

Planting—May, 1915

The remainder of the cutting area was planted at this time. The same species from the same seed sources were used as in the planting of 1914, and the method of planting and the spacing were also the same. An isolation strip about 20 feet wide was left between the two plantings. About 2,200 white pine and 800 Norway spruce were set out.

Inspections—1915 Area

On June 18, 1915, a sample count was made of 100 trees in the middle rows of this area to determine the extent of pales weevil damage. Of this number, 15 had been attacked but not killed, and 3 had died of other causes.

One year later (June 2, 1916) 9 rows of white pine were examined. The results of this examination showed:

	Number of White Pine Plants	*Percent*
Normal and uninjured	186	55.5
Chewed in 1915 but healing	17	5.1
Chewed in 1916	19	5.7
Missing	38	11.3
Killed by weevil	75	22.4
	335	100.0

Additional deaths, from 5 to 10 percent, were experienced during the remainder of the 1916 season, which brought the total losses from weevil damage to nearly 30 per cent. This figure compares with the 70 percent mortality experienced in the 1914 planting area. From this it was concluded that damage by the pales weevil is considerably reduced if planting is delayed for one year.

No counts were made during the third growing season in either area, but cursory inspection revealed that further damage from the weevil was negligible. An important discovery had been made, however, establishing the importance of the pales weevil as a serious insect pest, building up large populations in freshly cut stumps and slash, and girdling and killing pine seedlings for a period of two years following logging.

Weeding (First)—November, 1920

Seven growing seasons had passed since the clear-cutting in the winter of 1913-14. Enough white pine and Norway spruce had survived attacks by the pales weevil to form, with an advance growth of red oak, black cherry, and white ash, a fairly uniform cover over the entire area, apparently providing an abundance of trees for full stocking. The conifers averaged 3 to 4 feet in height, and the hardwoods ranged up to 15 feet.

All overtopping hardwoods of inferior form or species, such as red maple stump sprouts and gray birch, were cut, leaving the selected crop trees free to grow.

Weeding (Second)—June, 1923

At the beginning of the third season after the first weeding, the conifers were again overtopped by inferior hardwoods of stump sprout origin. In general, the hardwood element appeared much less promising than at the start, so the conifers were given preference where there was a choice between the two. A few thrifty red oaks were left, even where they overtopped the conifers, but little hope was held for their producing high quality timber. They were 3 to 4 feet taller than the other species, and widely spaced.

Weeding (Third)—May, 1924

This treatment was very light. Only an occasional overtopping tree, overlooked in the previous weeding, was cut.

Weeding (Fourth)—June, 1928

The stand at this time was about 17 years of age. Scattered poorly formed red oaks and other weeds, such as gray birch and red maple, which were overtopping some of the promising conifers, were removed. Special effort was made to release the Norway spruce around the edges of the stand, where it was being crowded both by trees within the stand itself and by trees in adjacent older stands.

Weeding (Fifth) and Pruning—March, 1930

The stand was now about 19 years old. The eastern portion of the area had a much better composition than the central and western portions; here, white pine, Norway spruce and hardwoods occurred in fairly well-defined groups. Elsewhere the stand ran strongly to hardwoods, largely of inferior species or form, with scattered white pines. Severe damage had been caused by the white pine weevil. This resulted, it is now evident, from the nearness of extensive stands of older white pine, which supported

an abundant population of the insect, the wide spacing of the plantation, and too drastic weeding. Keeping the pines free to grow by cutting back overtopping hardwoods resulted in heavy attacks by weevils, even where pine groups were surrounded by hardwoods.

In the eastern portion of the area, the weeding was aimed at developing the groupwise form of conifers and hardwoods. In the hardwood sections, red oak, paper birch, white ash, and good quality red maple were favored for the crop where stems of sawtimber form were available. However, most of the hardwood sections gave promise of producing only a cordwood-grade crop. Besides the weeding, a few selected pines were pruned in a narrow strip parallel to the state highway.

Improvement Cutting and Pruning—July, 1934

At the time of this treatment, many of the pine tops had been damaged by a heavy snow and in places the hardwood weeds had again reached a position of dominance in the pine groups.

Hardwood groups were improved by cutting and girdling rank-growing individuals, chiefly "wolf" red oak, gray birch, and red maple. The favored trees were red oak of good form, white ash, paper birch, and an occasional red maple.

The pruning of 1930 was extended to include all promising crop trees in the pine groups. At the same time, hardwood weeds overtopping selected pine crop trees were cut.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-Hours Total*	*Man-Hours Per acre*
Planting	5/1914	0.5	3	18.0	36.0
Planting	5/1915	2.75	4	72.0	26.0
Weeding	11/1920	3.6	10	20.0	5.5
Weeding	6/1923	3.6	12	9.0	2.5
Weeding	5/1924	3.6	13	2.0	0.5
Weeding	6/1928	3.6	18	8.0	2.2
Weeding and Pruning	3/1930	3.6	19	10.0	2.8
Improvement Cutting and Pruning[9]	7/1934	3.6	24	43.0	11.9
Total				182.0	

[9]The labor cost for the 1934 treatment was equally divided between the improvement cutting and the pruning.

FIG. 19. JANUARY, 1942. WHITE PINE PLANTED IN 1915

Repeated weeviling has severely damaged most of the trees. Hardwoods which would have been useful in controlling weeviling, by partial suppression, were removed early. The few treees that escaped severe damage, because of their subordinate position, have been pruned (Cline and MacAloney, 1931).

A pine group of later seeding containing trees too small to prune was released in order to recover the area from a dense growth of gray birch, blue beech, and alder. In general, the softwood group areas were increased at the expense of the hardwood groups.

The Norway spruce around the margins of the stand was again released.

In judging the cost of treatment due allowances should be made for the unusually high planting cost. Extreme care was taken to avoid any losses which could be charged against poor planting. The individual weeding costs were low, but collectively they approximate the average total for such treatments in similar stands elsewhere in the Forest.

Stand Conditions—June, 1940

The stand is 30 years old, and composed of a groupwise distribution of white pine, Norway spruce, and hardwoods. The conifer groups occupy nearly two-thirds of the area. The white pine is found principally on the 1915 planting area, where it occupies the ground to the exclusion of other species, with the exception of the border of Norway spruce. The white pine in the 1914 planting area, in the southern portion of the stand, has largely disappeared as a result of early attacks by the pales weevil, and to a lesser extent through suppression by the faster growing hardwoods. White pine weevil attack has been very severe, and many of the trees are extremely forked and crooked. The largest pines average about 35 feet in height and 8 inches, d.b.h., which is indicative of a fairly productive site. The evidence of the snow damage reported in 1934 is still plainly visible, but, because of the much more severe weevil damage, it is of relatively little account.

The Norway spruce which was planted under the cover of older stands has not proved satisfactory. That planted (in 1915) beyond the influence of older trees, along the state highway, has made good growth, though repeatedly attacked by the white pine weevil.

Red oak occupies a dominant position in the hardwood groups, but is mostly coarse and limby. Some individuals have reached 50 feet in height and 8 inches, d.b.h. Other hardwoods mentioned in earlier observations, such as white ash, black cherry, and paper birch, have lost ground. The subordinate element is now made up chiefly of red maple and northern hardwoods—beech, yellow birch, and hard maple.

Discussion

The course and outcome of the treatments applied to this area were determined largely by the experiment undertaken to find out what caused the death of coniferous seedlings on fresh white pine cuttings. The

FIG. 20. JANUARY, 1942. FREE-TO-GROW RED OAK IN A HARDWOOD GROUP

Unless crowded, red oak tends to develop a large crown with heavy branches. In this particular place, there were no better trees to favor.

discovery that the pales weevil was responsible led to further studies of this insect and the development of appropriate control measures for general application (Peirson, 1921).

Probably for reasons of site quality, not yet fully understood, the volunteer hardwoods most abundant at the start did not measure up to expectations. Despite several weedings, the hardwood groups are not satisfactory in either composition or tree quality. Furthermore, the white pine groups are disappointing, because of severe and repeated attack by the white pine weevil. The scrubbiness of so many of the pines is due to repeatedly cutting back overtopping hardwoods in order to give the pine freedom to grow. In localities where the white pine weevil population is high, this case demonstrates the need for a more conservative type of weeding—one in which freedom from weevil attack is minimized through partial suppression of the pine, even though early growth is thus retarded.

Judging from nearby remnants of old growth forests it would now appear that the stand composition best adapted to such a cool, moist site would run strongly to hemlock and white pine and certain of the northern hardwoods. Trees of these species, not present to any extent in 1913, have gradually increased in numbers. A conversion to this more suitable association can be effected by handling the present hardwood portions of the stand on a cordwood rotation, removing older trees as the needs of the newer elements may require.

CASE NO. 4

Pine and Hardwoods Following the Clear-cutting of Old Field White Pine and the Supplementary Planting of White and Red Pine

Block: Tom Swamp History to May, 1940

Compartment: I

Stand: P-Hd-3, 22.5 acres (Northern Portion, 14.0 acres)

Supplementary planting on old field pine cuttings was first resorted to for the purpose of making up apparent deficiencies in the volunteer growing stock. The planting of conifers was influenced by the prevalence of pure pine stands throughout the region, and the assumption, based on market conditions, that the growing of white pine and others coniferous species would continue to be profitable. The local demand for hardwoods

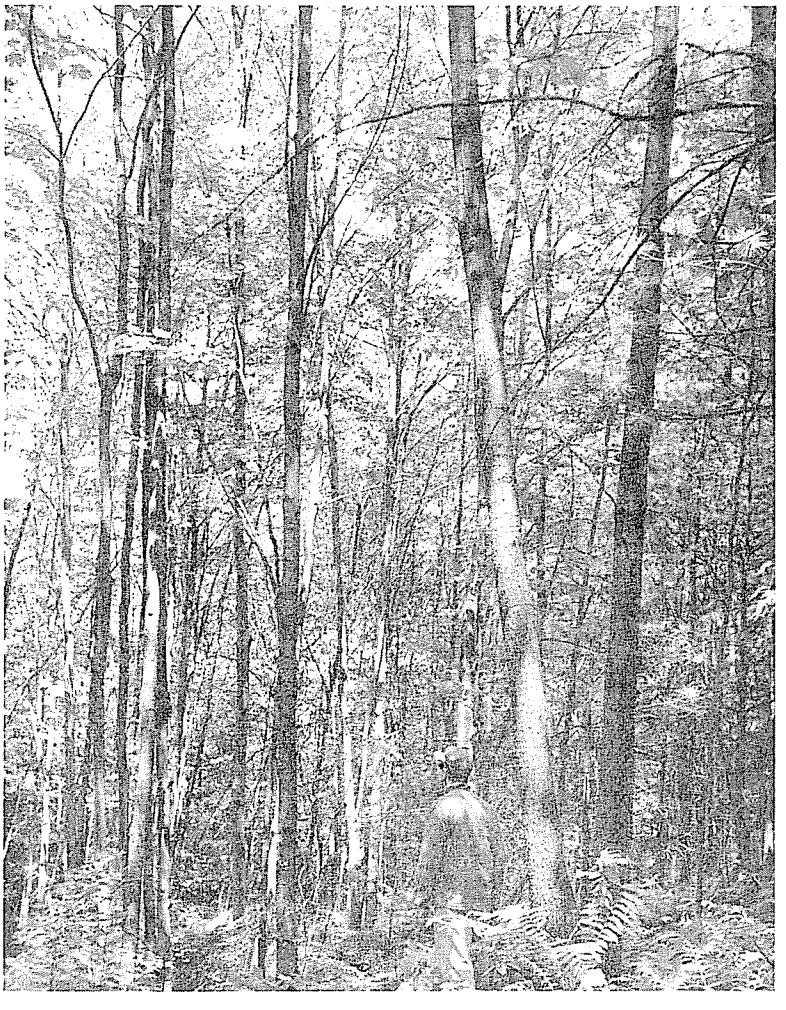


FIG. 21. JUNE, 1946. PORTION OF A HARDWOOD GROUP

Time has improved the stocking of the hardwood areas. Red oak is dominant but generally of poor form. Trees forming the subordinate element are chiefly of northern hardwood species.

was comparatively poor. Departures from the exclusive use of white pine for planting were prompted chiefly by the hope of finding equally or more rapid-growing species free from both white pine weevil attack and the white pine blister rust. At first, the conifers were planted uniformly throughout the cutting area, except where dense groups of advance growth hardwoods were present, with the intention of developing a stemwise mixture with volunteer hardwoods in which the conifers would gain to the maximum extent the benefits of such association.

The original aim in this case was to develop a mixed stand of white pine and hardwoods of natural origin following an old field pine stand. Because of some previous success in obtaining white pine reproduction through partial cuttings, a preliminary cut was made, at that time called a thinning, which was expected to result in natural restocking. When natural regeneration proved unsuccessful, an attempt was made to supplement the softwood stocking by planting. The feeding habits of the pales weevil were understood, and planting was delayed two seasons following the final cutting. Not yet fully appreciated, however, was the severity of the competition that the planted conifers would receive from the volunteer hardwoods on a highly fertile site.

Site and Land History

The area is located on a gentle westerly slope which extends from Petersham village to the floor of Tom Swamp. Its elevation is approximately 1,050 feet. The soil is a well-drained loam belonging to the stony phase of the Charlton series, and the site is one of the most fertile in the Forest. This land has had an agricultural history dating back to early colonial times. It was included in the first division of the town, in 1733, and it is likely that the original forest was cut not long thereafter and the land cleared for farming. Because of the extreme stoniness of the soil, use probably was limited to pasturage. Abandonment took place around 1850, and the ground seeded in densely to white pine with a scattering of hardwoods.

Thinning—Winter, 1910-11

The stand was 60 years old, nearly pure pine, with a high density of stocking and narrow-crowned trees. The volume of the pine ran about 35,000 board feet per acre. Scattered among the pine were hardwoods, mostly red maple, black birch, red oak, chestnut, and white ash. An advance growth of hardwoods included white ash, hard maple, black cherry, red oak, and chestnut, the white ash comprising about 80 percent of the whole.

Although the main stand had reached merchantable size, the decision

was made to remove it in two cuts; the first, a light "thinning" for the purpose of encouraging pine reproduction, and a final cutting to free the young pine completely. A heavy seed crop was in prospect for the fall of 1911, and it was hoped that opening up the stand in advance would aid in the establishment of seedlings. This first cutting removed chiefly overtopped and defective trees—a volume of about 5,000 board feet per acre. The hardwood advance growth was left undisturbed except in places where it interfered with logging.

Condition of the Reproduction—Fall, 1912 and 1913

In 1912, an examination of the ground revealed a patchy distribution of 1-year-old pine seedlings resulting from the seed crop of 1911. It was believed there were enough, together with hardwoods, for a fully stocked

FIG. 22. WINTER, 1916-17. THE MILL WAS SET ON THE AREA AND THE LUMBER PILED IN THE SOUTHERN PORTION.

new stand. Since the advance growth hardwood appeared stunted as a result of suppression, and many of the stems were injured during the thinning operation, it was planned to cut back to the ground all the hardwood advance growth when the final harvest was made.

By the fall of 1913, the white pine reproduction that was reported the previous season had largely disappeared. The only surviving seedlings

were those that had succeeded in getting their roots anchored in the mineral soil. It was now recognized that the thinning had been too light to be effective in the establishment of pine reproduction.

Clear-cutting—Winter, 1916-17

During the six years since the thinning, the rate of growth of the residual stand increased somewhat, and a good seed crop in 1914 augmented what little remained of the 1911 pine reproduction. White pine seedlings occurred in patches throughout the area.

The main stand was clear cut and, with the exception of some of the more vigorous seedlings, notably dense groups of white ash, the hardwood advance growth also was clear cut, to produce good seedling sprouts and to facilitate the logging. The slash was burned after the logs were removed. A portable mill was set up on the cutting area and the lumber piled in the southern portion. Some of the pine seedlings were unavoidably killed or damaged during the operation, but it was thought that enough would survive to form the basis for a good mixture with the hardwood seedling sprouts that were soon to follow.

Condition of the New Stand—Fall, 1918

The organic layer had not entirely disappeared at this time and, as usual, hay-scented fern had come in abundantly.

A count of stems made on small plots distributed over the area showed the following stocking:

	Seedlings and Seedling Sprouts (*Number of stems per acre*)	*Stump Sprouts*	*Total*
White pine	350 (4-year)		350
White ash	1,440	20	1,460
Red oak	250		250
Hard maple	170		170
Chestnut	110	5	115
Poplar	85		85
Red maple	20	50	70
Black cherry	60		60
Birch	50	5	55
Basswood	25		25
White oak	20		20
Hickory	10		10
Total	2,590	80	2,670

White ash was the most abundant species, comprising over 50 percent of the total number of stems. Red oak and hard maple were well represented, but the remaining hardwoods occurred very sparingly. The sprout reproduction averaged from 4 to 5 feet in height, and the seedlings less than 2 feet. Of the fairly abundant pine reproduction present at the time of clear-cutting, only 350 seedlings per acre remained. All of these were from the 1914 seed crop.

Planting—April, 1919

The scattered distribution of the natural reproduction, both pine and hardwood, made supplementary planting appear advisable. In the south

FIG. 23. AUGUST, 1918. A PORTION OF THE CUTTING AREA DURING THE SECOND GROWING SEASON FOLLOWING CLEAR-CUTTING

A count of stems showed 2,670 per acre. But distribution was very irregular; in some places there were dense groups of seedling sprouts, and in others only beds of hay-scented fern.

end of the cutting area, where the lumber was piled, only scattered white ash, hard maple, oak, black cherry, and gray and paper birch were present. In the western and northwestern portions the density was very high, in places averaging more than 17,000 stems per acre, over half white ash; planting was considered unnecessary in such places. In the more open places, 2,525 red pine and 1,125 white pine 5-year-old transplants were set out. Both species were planted in pure blocks of large size, the white pine in the northern and southern ends of the area, the red pine in the center. The plan was to restock portions of the area where the volunteer repro-

duction was scanty or absent. The mattock-hole method was used throughout, with 6′ x 6′ spacing.

Weeding (First)—July, 1921

This treatment was carried out during the third growing season after planting and was confined to the planted areas. Rank-growing sprouts of red maple and red oak overtopping and damaging the pines were cut with machetes. In the unplanted areas very little work was needed, because of the high proportion of good hardwoods. Only occasional coarse stump sprouts and rank-growing trees of inferior species were cut. A few promising groups of volunteer white pine were freed, which sometimes meant the sacrifice of desirable hardwood stems.

Weeding (Second)—October, 1923

The second weeding, made at the end of the fifth growing season after planting was, like the previous one, for the chief purpose of releasing the planted pines and regulating the hardwood composition. Because the growth rates of the two elements differed widely, it was necessary to cut back many promising, but taller, hardwoods growing within and around the margins of the planted areas in order to free the pines. A study of the height growth of the planted red pines in relation to exposure to light (Reed, 1926, p. 8) showed a maximum height of from 5 to 6 feet for trees having the greatest freedom. Those with the least freedom from suppression were only 2 or 3 feet high. Reed concluded that "although red pine grows rapidly on cut-over land, the plantation must be weeded early and often."

Weeding (Third)—March, 1930

Six years had elapsed since the previous weeding. During this interim, scattered sprout clumps and fast-growing weed hardwoods from seed had outgrown the better hardwoods and conifers desired for the crop. In spite of the earlier attempts to favor pine, all that remained of the extensive plantings were a few relatively small groups of white and red pine, mainly in the northern and central portions. The original distribution of the conifers had been everywhere obscured by the more rapidly growing hardwoods; and in the southern end only an occasional pine remained free to grow, the others having been suppressed by the hardwoods. The hardwood composition ran strongly to red oak, white ash, and paper birch.

Rank-growing stump sprouts of red maple and red oak, and weed species such as poplar, gray birch, and pin cherry were cut in places where better trees were overtopped. The most promising groups of white and red pine were released. Except for a few understocked places along the

eastern edge, the stand was now considered in good condition to develop without further treatment until thinning should become necessary.

Improvement Cutting and Thinning—October, 1935

At this time, nineteen years after clear-cutting, only a very small portion of the planted pines had succeeded in avoiding complete suppression by the hardwoods, and it was evident that the planting of conifers on such a site had been a mistake.

Among the hardwoods, red oak was the leader, but unfortunately the

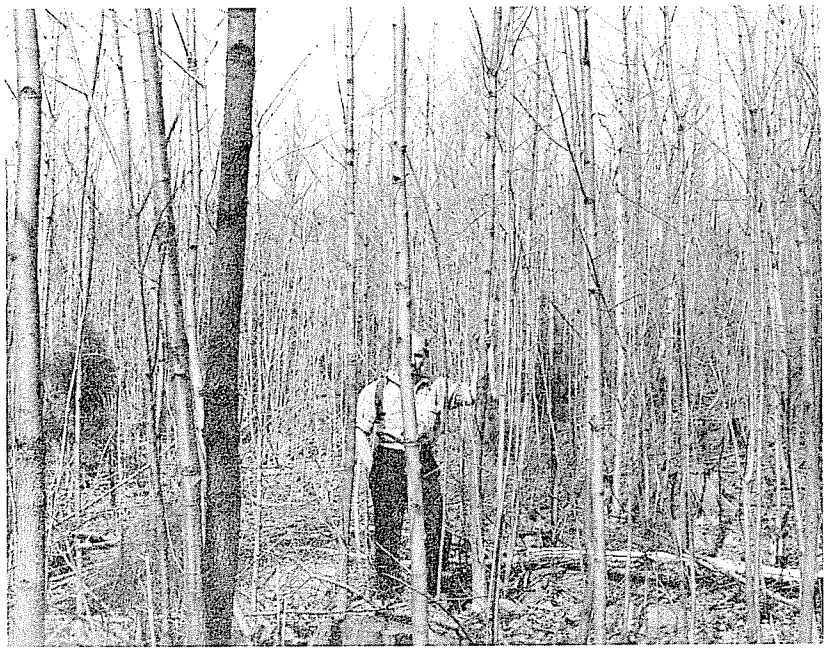


FIG. 24. APRIL, 1933. A WHITE ASH GROUP AT SIXTEEN YEARS

Ash characteristically occurs in small groups of high density. Several suppressed red pines appear in the picture.

quality of many of the largest individuals was poor. This, together with a high susceptibility to gypsy moth defoliation, made reduction of the proportion of oak desirable. The treatment was, in effect, a combination of thinning and gypsy moth control cutting.

A special effort was made to favor white ash, where it occurred in mixture with oak, because of its freedom from gypsy moth attack and its beneficial effect upon the soil. In general, all dominant trees of inferior species or form were cut or girdled to favor better-formed individuals of

the most desirable species. Because of the large size and heavy crowns of many of the red oaks, they were girdled rather than cut. Well-formed multiple-stemmed sprouts of desirable species from small stools (1″-3″)

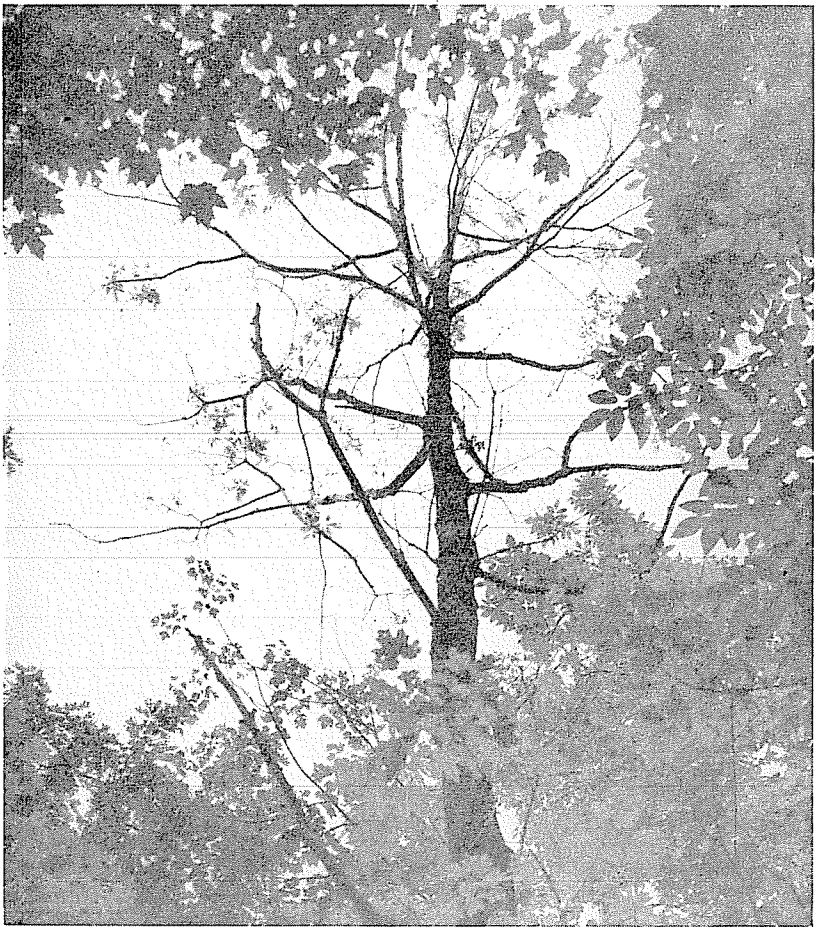


FIG. 25. RED OAK DEFOLIATED BY THE GYPSY MOTH
The foliage of neighboring ash and maple trees has barely been touched by the caterpillars.

were thinned by cutting the poorest stems and saving the best. For the purpose of reducing the proportion of favored gypsy moth foliage, some coarse red oak sprout clumps from large stools were thinned, where this could be done without unduly opening up the stand. The dense white ash thickets were especially in need of thinning and these were opened up considerably. The few promising red and white pine groups were freed

from overtopping hardwoods, and only crown-sensitive species favored for the marginal belt. Gray birch, poplar, and white oak were cut heavily because of their attractiveness to the gypsy moth (Behre, Cline and Baker, 1936).

The cut, including trees 2 inches and over, d.b.h., amounted to nearly two cords per acre. Red oak made up 55 percent of the number of trees cut and 70 percent of the volume. The felled material was lopped, to bring it in close contact with the ground and hasten decay.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Planting	4/1919	4.0	2-5	92.0	23.0
Weeding	7/1921	4.0	5-8	4.0	1.0
Weeding	10/1923	14.0	7-10	28.0	2.0
Weeding	3/1930	14.0	13-16	32.2	2.3
Improvement Cutting and Thinning	10/1935	14.0	19-22	86.8	6.2
Total				243.0	

Condition of the Stand—May, 1940

Of the dozen or so hardwood species included in the composition, only three are prominent, and these occupy about 80 percent of the main crown area. Most abundant and largest in size is red oak, followed by paper birch and white ash. Associated hardwoods include red and hard maple, black cherry, yellow and black birch, basswood, hickory, and white oak, confined largely to the lower crown classes. The hardwoods are now 23 years of age, and some of the dominant trees have reached 7 inches in d.b.h. and 45 feet in height. The density of crop trees is high, averaging 300 to 400 stems per acre, and the trainer element is composed of nearly five times as many trees.

The average clear length of the dominant crop trees of the three principal species is 10 feet for red oak, 11 feet for paper birch, and 8 feet for white ash. Many dominant red oaks are so crooked and heavy-limbed that they will produce only cordwood. The ash groups which originated as advance growth not cut back at the time of clear cutting in 1916-17 stand out in striking contrast to those of sprout origin; the trees are slow-growing and heavy-limbed.

Among the hardwoods are remnants of the pine groups planted in 1919. Probably less than 10 percent of the trees originally planted are now in a free-to-grow position. The white pine in the south end has been largely subordinated and forced out, only an occasional single tree remaining in the main canopy. The red pine in the center of the area has done better; five or six small, but well established, groups remain.

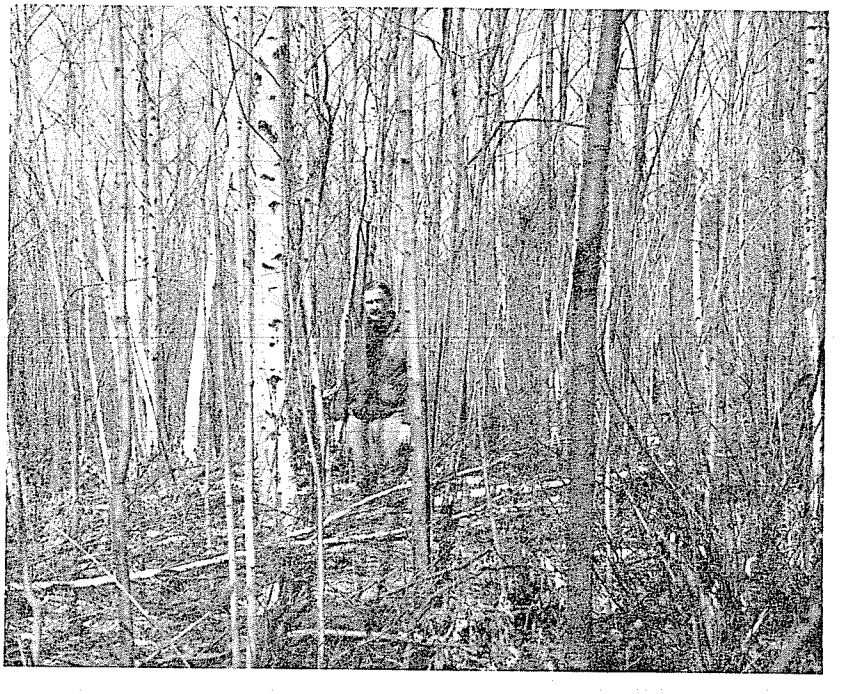


FIG. 26. MARCH, 1938. A PAPER BIRCH GROUP TWO YEARS AFTER THE FIRST THINNING

All of the weed trees have been removed, but many of the subordinate trees have been left as trainers.

Occasionally, dominant red pines occur in a stemwise mixture with the hardwoods, as lone survivors of a former group; they are 35 to 40 feet tall, 6 to 7 inches, d.b.h., and have well-developed crowns.

Occasional groups and single trees of white pine in the northern portion have also survived. The groups are small, like the red pine groups, each one containing from two to a dozen trees that can be made a part of the final crop. The white pine has grown less rapidly than the red pine, the average height of the tallest trees being only about 30 feet, and the

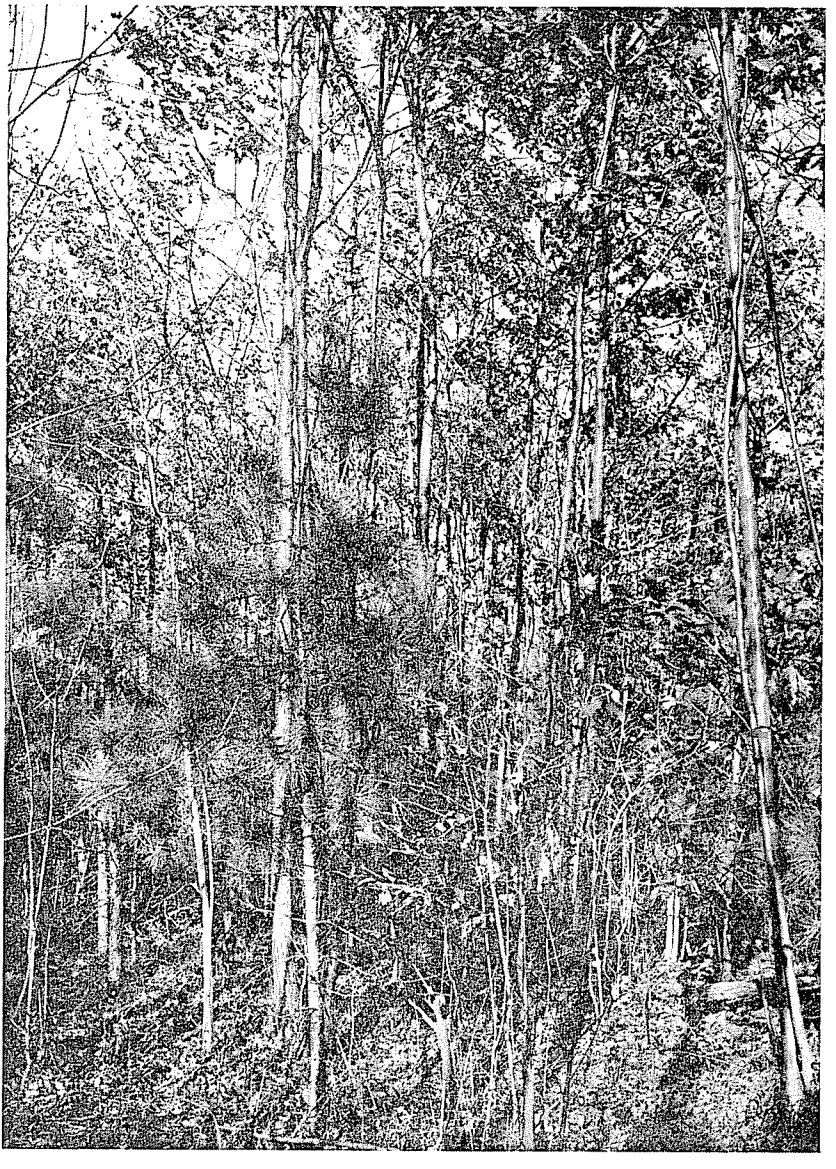


FIG. 27. OCTOBER, 1941. RED PINE PLANTED IN 1919 IS COMPLETELY OVERTOPPED BY HARDWOODS

The pine is too weak and the hardwoods too vigorous to warrant a release cutting.

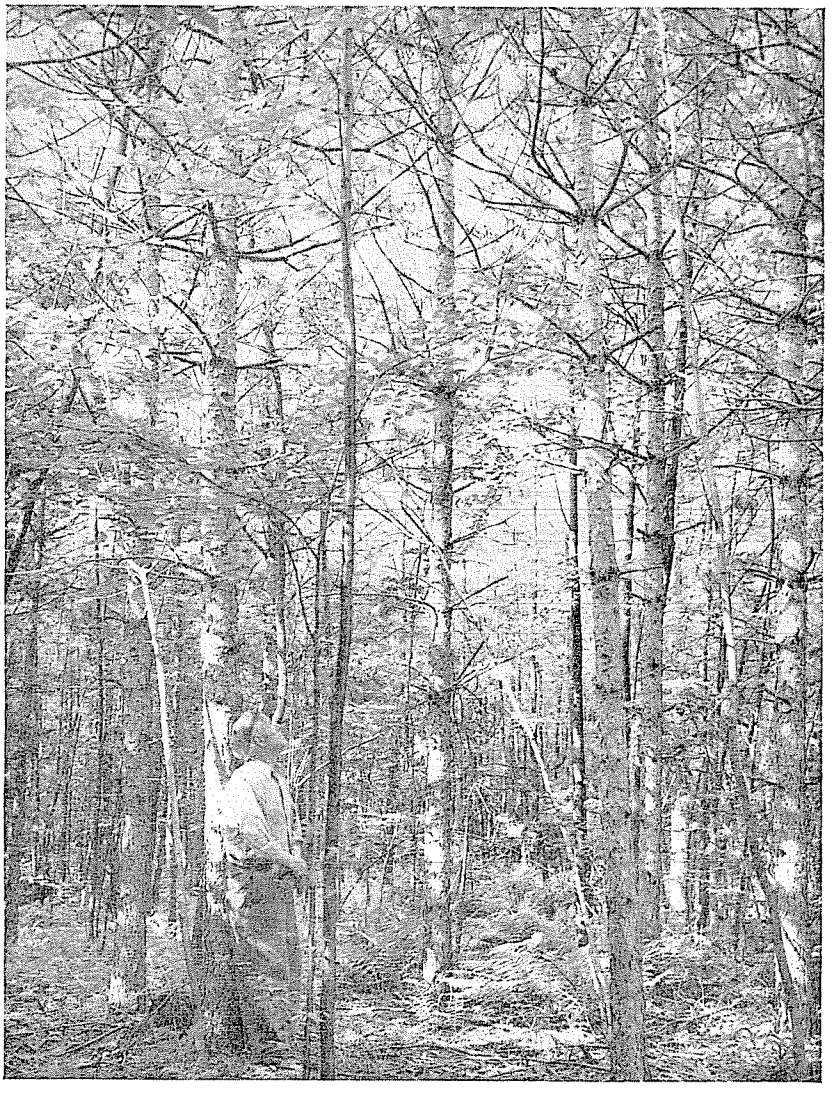


FIG. 28. JUNE, 1946. ONE OF THE FEW GROUPS OF PLANTED RED PINES WHICH WAS BROUGHT THROUGH

diameter 5 to 6 inches. Many of the white pines have been attacked by the white pine weevil.

Discussion

This case illustrates the difficulty of attempting to grow pine, either red or white, in mixture with hardwoods on the best hardwood sites. Even with seemingly poor stocking in the beginning and the apparent need of supplementary planting, complete stocking by natural means was practically everywhere attained within a few years after logging. In spite of three weedings to favor the planted pines, which were thrifty 5-year-old transplants, scarcely 10 percent of them give promise of coming through. Even saving this small number necessitated sacrificing many good-quality hardwoods. In such cases, any possible increased value of the final crop because of the addition of pine is offset by the reduced quality of the hardwoods and the greater expense in handling.

If, during the course of treatment, greater attention had been given to composition control within the hardwood areas and greater emphasis placed on tree quality rather than vigor, the number of poor quality hardwoods now present in dominant positions would have been reduced. Permitting vigorous red oaks to remain unchecked for an extended period of time not only produced poor quality in the oaks themselves, but also caused the loss, through suppression, of other valuable hardwoods. Better results would have been obtained in the white ash groups if the advance growth had been cut back at the time of logging.

The quality of the trees in the white pine groups could have been made better by more careful early weeding. Competing hardwoods can be used to good advantage in partially suppressing and crowding the pines on the sides to lessen weevil damage, particularly in plantings at the usual 6′ to 7′ spacing; but more frequent treatment is required than in the case of weedings to give the pine full freedom from the start. Where the first log length is spoiled by forks or crooks, it is hardly worth while expending further effort to bring through a small group.

While red pine is not attacked by the white pine weevil and outgrows white pine in early life, it is less shade-tolerant than white pine, and its use does not lessen the need for regulating competition with hardwoods.

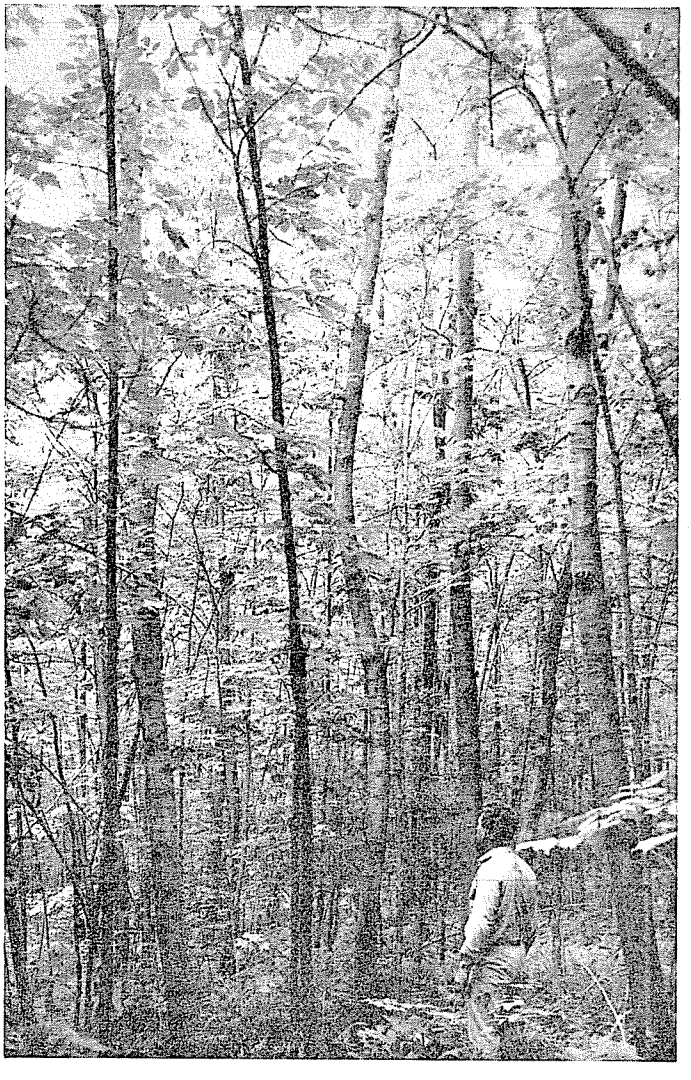


FIG. 29. JUNE, 1946. A GROUP OF POOR-QUALITY RED OAKS

These can be removed in thinnings, but it would have been better to get rid of them during the weeding period.

CASE NO. 5

Pine and Hardwoods Following the Clear-cutting of Old Field Pine and Supplementary Planting of Red Pine

Block: Tom Swamp — History to January, 1939
Compartment: IV
Stand: P-Hd-1, 7.8 acres (Northern Portion, 4.8 acres)

This case is similar to the previous one to the extent that here again an attempt was made to establish a coniferous plantation on a highly productive site well suited to growing a mixture of valuable hardwoods. The date of planting is the same in both cases (1919) but the subsequent course of treatment differs. In Case No. 4 the site was quite the same throughout the entire area, whereas in the case herein described there are marked differences in site caused by a succession of low rounded knolls with intervening poorly drained flat areas, or swales, extending across the full width of the area—a condition which gives rise to differing composition and requires varying treatment.

By using large (5-year-old) transplants of red pine, a species not subject to attack by the white pine weevil, it was thought that comparatively little difficulty would be experienced in bringing through the planted stock in a stemwise mixture with hardwoods.

Site and Land History

The area is located on a gentle westerly slope at an elevation of about 950 feet. The soil is a "complex" in which different soil types occur on limited areas varying slightly in surface relief. Well-drained, low rounded knolls are separated by imperfectly drained flat areas. The soil in the flats is either Whitman or Sutton stony silt loam, and that on the knolls a Gloucester stony fine sandy loam. The former are highly productive hardwood soils, the latter less favorable for exacting hardwoods.

This was "second division" land, granted in 1738, and cleared at some later date for agricultural use. Abandonment as farm land took place around 1850, followed soon thereafter by a dense seeding in of white pine and hardwoods.

Condition at Time of First Treatment—Winter, 1911-12

The old field stand was even-aged, about 55 years old. On the well-

drained knolls white pine formed nearly pure groups. In mixture with the pine, and occurring particularly in the low, wet areas, were hardwoods of several species. Stand composition was approximately 40 percent white pine, 30 percent red maple, 25 percent red oak, and the remainder hemlock, white ash, black cherry, chestnut, birches, basswood, white and black oak, beech, and poplar. White pine, however, made up over 80 percent of the total volume. There was a moderately dense advance growth of hardwoods including red and white oak, white ash, black cherry, black birch and chestnut.

FIG. 30. NOVEMBER, 1911. THE OLD FIELD WHITE PINE STAND BEFORE THINNING

Thinning—Winter, 1911-12

This was a "low" thinning, or thinning from below, to increase the growth rate of the residual stand. A secondary object was to take advantage of the abundant pine seed crop of 1911, by which it was hoped that enough pine seedlings would become established to form part of the next stand, along with the hardwood advance growth. Thus the treatment was in part a reproduction cutting. The cutting was confined entirely to white pine, a volume of about 10,000 board feet per acre being removed.

Clear-cutting—Winter, 1917-18

A large number of pine seedlings had started on the area the season after the cutting of 1911-12, but only a few had survived. The high mortality was charged to the pales weevil and unfavorable weather conditions. A second seeding of pine, however, followed the seed year of 1914 and resulted in a stocking of some 6,000 seedlings per acre at the time of clear-cutting.

The hardwood advance growth was cut back to the ground with brush scythes just before the overwood was cut. The trees were felled in windrows and the slash burned in place directly after the logs had been removed.

Condition of the New Stand—August, 1918

An examination of the pine reproduction showed 2,450 seedlings per acre present from the seed year of 1914, or less than half the number reported at the time of clear-cutting. The pales weevil was still actively feeding at the time of the examination, and it was evident that the high mortality was due to this insect. Only a few seedlings from the crop of 1917, averaging 150 per acre, were found; these were not being attacked by the weevil.

The following table shows the reproduction present at the end of the first growing season:

	Seedlings and Seedling Sprouts	*Stump Sprouts*	*Total*
	(Number of stems per acre)		
White pine	2,600		2,600
Red maple	1,380	140	1,520
Black cherry	1,425	15	1,440
White ash	1,230	50	1,280
Red oak	810	5	815
Chestnut	355	85	440
Birch	200	10	210
Poplar	70		70
White oak	55	5	60
Elm	25	5	30
Basswood	15	5	20
Sugar maple	5		5
Total	8,170	320	8,490

White pine led all other species in numbers, followed by red maple and black cherry. The sprouts averaged 3 to 4 feet in height at this time and the seedlings less than 1 foot. The oaks, chestnut, basswood, hard maple and black cherry occupied the drier portions of the area; and ash, red maple and gray birch the wetter portions. White pine was fairly well distributed throughout the new stocking.

Planting—May, 1919

Red pine was planted to supplement the natural stocking and to provide a further test of the adaptability of this species to planting on such sites. Its freedom from attack by the white pine weevil was considered an especially advantageous feature. Although the volunteer stems numbered over 5,000 per acre, there appeared at the time to be plenty of room to interplant; and the belief was that the red pine could be brought along with the hardwoods without too much difficulty. About 1,950 good-sized red pine transplants (2-3 stock) were set out at irregular intervals. The spacing depended upon the density of the volunteer stocking, both white pine and hardwoods, and was aimed at leaving no spacings of more than 6 feet, all desirable species included. Planting was done by the mattock-hole method.

Weeding (First)—November, 1920

At the end of the second growing season some of the red maple stump sprouts were so rank-growing that their removal was considered necessary. Particular attention was given to releasing planted red pine and volunteer white pine. Very little work other than cutting stump sprouts was needed at this time.

Weeding (Second)—November, 1921

At the end of the next growing season the red pines were again showing ill effects from the hardwood competition. Regardless of species or form, all hardwoods overtopping red pines were cut back. It already was evident that the pines were being subjected to extremely heavy competition by the hardwood element.

Weeding (Third)—November, 1926 and June, 1927

At the end of the eighth growing season there was sufficient growing stock either of white and red pine combined, or of better hardwoods, to form a fully-stocked stand. This high density, together with the more or less stemwise distribution of the two elements and the greater height of the hardwoods, caused uncertainty as to which should be favored. Had the decision in the beginning been to develop a groupwise mixture of pine

and hardwoods, the subsequent treatments would have been greatly simplified. But now the hardwoods had occupied the area so completely and had so overtopped the pines that any further attempt to favor the pines might prove disastrous. Only two or three groups of red pine, on knolls near the western edge of the area, showed any real promise of surviving without drastic weeding. So, unlike the first two weedings, which were aimed at freeing the pine, it was decided to favor good individuals of all desirable species and to abandon most of the pine. The few promising pine groups were completely freed, by the removal of all overtopping hardwoods, and crown-sensitive hardwood species were fa-

FIG. 31. APRIL, 1925. THE YOUNG STAND SIX YEARS AFTER THE RED PINE PLANTING

Many good hardwood stems have been spoiled for crop tree production by weedings to favor the red pine.

vored in the zone immediately surrounding each group. Elsewhere, dominant hardwoods of poor species or poor form were removed to favor more desirable individuals.

White ash was the leading species in the swales. Here it was of excellent form and making rapid growth.

Improvement Cutting (First)—April, 1933

This treatment was made the fifteenth growing season after clear-cutting. Very few trees of inferior species that came in after logging, such

as gray birch, poplar, and pin cherry, had survived the weedings. In places where the composition ran strongly to red oak, the knolls, many individuals had developed forks and large crowns; these were removed to favor better trees wherever possible. Where more desirable trees were absent, these coarse individuals were left as fillers. Some of the sprouts from the larger stumps had again reached a dominant position, and these also were cut. The red pine groups were liberated again, and it appeared that they were permanently free from hardwood competition. Elsewhere, both red and white pines existed only as scattered single trees, occasionally in a free-to-grow position, but more often overtopped and rapidly dropping out. Some of the isolated red pines were extremely coarse and heavy-crowned.

Improvement Cutting (Second) and Thinning—April, 1938

At the time of the first improvement cutting (1933), the gypsy moth had not developed to the point of demanding consideration, and no special effort was made to reduce the quantity of oak. This cutting was aimed principally at a reduction in oak, particularly trees of poor quality in places where there were unfavored food species available to take over the space. The density of stocking of the ash groups in the swales had reached the point where thinning was needed. The more slender stems, the whips, were cut back to provide more room for better-developed individuals.

Most of the trees removed were large enough for cordwood; but, because of the small quantity per acre and the difficulties of extraction, the stems were left on the ground. An average cut of 400 trees per acre, 2 inches d.b.h. and over, amounted to nearly three cords. Red oak made up 32 percent of the total number of trees cut and 40 percent of the volume.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Planting	5/1919	4.8	1-5	48.0	10.0
Weeding	11/1920	4.8	3-7	14.4	3.0
Weeding	11/1921	4.8	4-8	24.0	5.0
Weeding	11/1926-6/1927	4.8	9-13	13.4	2.8
Improvement Cutting	4/1933	4.8	15-18	12.5	2.6
Improvement Cutting and Thinning	4/1938	4.8	20-23	33.1	6.9
Total				145.4	30.3

Condition of the Stand—January, 1939

The present stand is essentially of 21-year-old mixed hardwoods. Only two or three small groups and an occasional single red pine remain, on the drier portions of the area, representing numerically less than 5 percent of the original quantity planted. Practically no white pine is left, the entire early stocking having lost out in competition with the hardwoods. The distribution of the hardwood species varies with slight changes in topography, imperfectly drained areas being dominated by white ash, the drier ones by red oak. The density of stocking is more or less uniform over the entire area, but in places where red oak is the leading element there is a smaller choice of trees suitable for the final crop than in places where white ash predominates.

Because of marked irregularities in species distribution due to soil differences, the sample plots taken to show composition were grouped according to the two main site conditions. The following table shows stand composition in the poorly drained flat portions of the area:

POORLY DRAINED FLAT AREA

Diameter (inches)	*Crop Trees*					
	WA	*BB*	*RO*	*RM*	*HM*	*BC*
	(*Number of stems per acre*)					
1	30	30				
2	360	180		20		10
3	190	60	10		10	
4		30	30			
Subtotal	580	300	40	20	10	10
Total — 960						

Diameter (inches)	*Inferior Elements*									
	BB	*WA*	*RM*	*RP*	*RO*	*WP*	*PB*	*WO*	*HM*	*BC*
	(*Number of stems per acre*)									
1	80	40	10					10		
2	430	240	50	50	20	20	10	30	30	10
3	180	100	10	10	10		10			
4				10						
Subtotal	690	380	70	70	30	20	20	40	30	10
Total — 1,360										

The flats have a good stocking of potential crop trees. Of these, white ash constitutes 60 percent and black birch 31 percent, the remainder being red oak, red maple, hard maple, and black cherry. The average height of the dominant trees is 40 feet. Red oak and black birch share leadership in diameter. The inferior elements are made up chiefly of trees of good species, but because of poor development or form their main usefulness will be to serve as trainers and fillers.

Stand composition in the well-drained portions of the area, the knolls, where red oak is the dominant species, is as follows:

WELL-DRAINED AREA

Diameter (inches)	*Crop Trees*			
	RO	*HM*	*WA*	*BB*
	(Number of stems per acre)			
Up to 1				
1		120	40	
2	120			40
3	80			80
4	40			
Subtotal	240	120	40	120
Total — 520				

Diameter (inches)	*Inferior Elements*				
	HM	*WA*	*RO*	*BB*	*RM*
	(Number of stems per acre)				
Up to 1	560	40		40	
1	1,040	40	40	120	40
2	120		40	40	
3			120		
4			40	40	
Subtotal	1,720	80	240	240	40
Total — 2,320					

There is an average total stocking of 500 trees more per acre than in the flat areas, but 440 fewer crop trees. The smaller number of crop trees is due to the large space demands of red oak, as compared with white ash. Of the entire stocking on a stem-count basis, red oak constitutes only

17 percent, but it makes up 70 percent of the dominant trees. The average height of the dominants is 30 feet, ten feet less than in the wetter portions.

The red pine groups appear to be permanently free from hardwood suppression and are making rapid growth. The largest trees average 5 to 6 inches, d.b.h. and 30 feet in height. A few of the single trees are as large as 8 inches and 35 feet tall.[10]

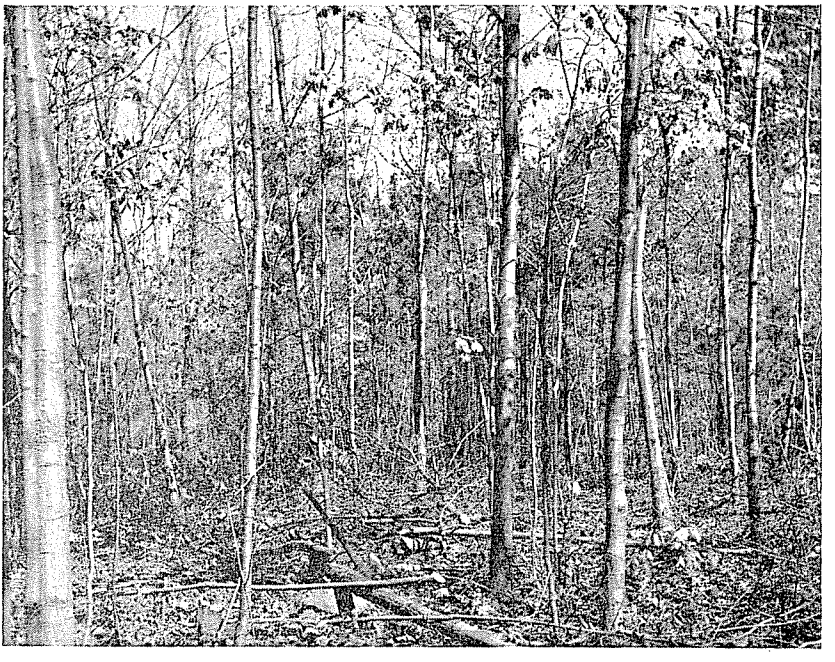


FIG. 32. MAY, 1938. A RED OAK GROUP AT THE TIME OF THE IMPROVEMENT CUTTING

On the knolls, such as this, red oak completely dominates in the composition and there is little possibility of broadening the variety of species.

A comparison between the general stand composition at present and in the first growing season, in 1918, shows what significant changes have taken place. White pine, which was the most abundant species then, has largely disappeared. Black cherry, which was next in order, has suffered the same fate. Chestnut, poplar, and gray birch, which were only minor constituents, have been eliminated by the blight or by cutting. The other species now present are essentially the same as in 1918, the main difference

[10]Many of these heavy-crowned isolated red pines were uprooted by the hurricane.

being in distribution. White ash now holds a relatively higher position in numbers, as do hard maple and red oak, red maple having been reduced in abundance through cutting.

Discussion

The chief mistake in the early handling of the stand was the more or less uniform planting of red pine over the entire area and the subsequent efforts, during the first two weedings, to keep it free. How much permanent loss in stand quality resulted from these weedings cannot be estimated, but it is likely that the form of the red oaks on the well-drained portions of the area would have been improved by the maintenance of the highest possible density of stocking from the start. While the treatments were effective in bringing out a high proportion of valuable species, the form of the dominant red oaks, in particular, is definitely not first class.

Beginning with the third weeding, eight years after planting, the treatments have been in accord with presently considered good silvicultural practice. Selected crop trees of crown-sensitive species, such as white ash and paper birch, have been released from suppression and side pressure; others that have a tendency towards coarseness, such as oak and maple, have been crowded, where the stocking permitted. The choice of species to favor in a given place has been influenced by considerations of adaptability to the site, maintenance of soil fertility, and stand security. White ash has been favored in the swales, where it is making excellent growth. The strong predominance of red oak on the well-drained portions of the area, the knolls, is not so desirable and will be difficult to correct. As in the previous cases, the extreme aggressiveness of red oak was not taken into account at the time of the first weedings, when noticeably coarse individuals could have been eliminated without difficulty. Furthermore, its susceptibility to recurrent defoliation by the gypsy moth makes its presence in almost pure groups on the knolls objectionable.

This case has further demonstrated the inadvisability of planting red pine on cut-over old field pine land well suited to the growth of hardwoods, as well as the difficulties of bringing through a stemwise mixture of two elements having widely different early growth rates.

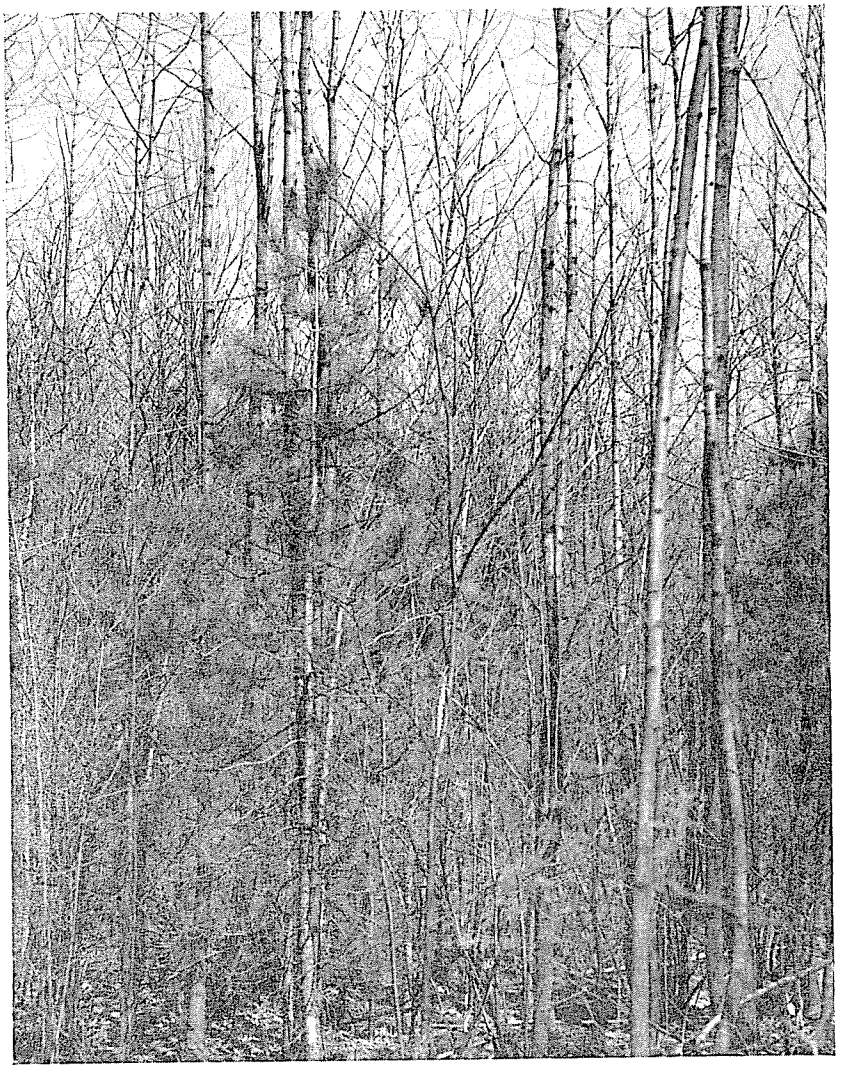


FIG. 33. APRIL, 1946. A WHITE ASH GROUP IN A MOIST FLAT AREA

The ash is well-formed and growing rapidly but thinning is needed. The planted red pine is unable to compete with the hardwoods on such sites.

CASE NO. 6

Softwoods and Hardwoods Following the Clear-cutting of Old Field Pine and Supplementary Planting of White, Red and Scotch Pine and Norway Spruce

Block: Tom Swamp
Compartment: I
Stand: P-Hd-5, 9.0 acres

History to July, 1938

In this case no attempt was made to obtain natural reproduction of white pine. The old field stand was clear-cut in a nonseed year and dependence for new stocking placed largely on the hardwood advance growth. After completion of the logging operation, stocking varied between extremely heavy in the vicinity of scattered ash seed trees in the former stand and little or none in a sizable area at the southern end of the cutting, where lumber and cordwood were piled. There were also a few scattered bare spots in other parts of the cutting area, occupied only by hay-scented fern.

Because earlier attempts to establish coniferous plantations on good hardwood sites invariably had resulted in almost complete failure, it was decided to limit any planting to the openings. This marked a notable advance over the practice of uniformly planting a cutting area with the aim of developing a stemwise mixture of conifers and hardwoods.

Site and Land History

The area is located at the point where a broad-topped ridge gives way to a long gentle slope to the west. The elevation is approximately 1,100 feet. In the better drained portions the soil is a Charlton stony fine sandy loam; in the imperfectly drained portions, a Sutton stony fine sandy loam. The water table is fairly high, and soil moisture generally abundant at all seasons of the year. In places there is outseepage from underlying strata, a condition favorable to white ash. Both soils are particularly well suited to growing hardwoods.

This was "first division" land, which was presumably cleared for agriculture soon after the first settlement, in 1733. The farm was continued until about 1850, at which time it was abandoned and the land reclaimed by forest. At the time the Harvard Forest was established, in 1908, the old field stand had reached an age of 60 years. It was solid white pine,

except for patches of hardwoods, chiefly red maple and white ash, in the wet places, and scattered individual hardwoods elsewhere.

Clear-cutting—Winter, 1922-23

Prior to clear-cutting, two minor treatments were carried out in parts of the area. A light thinning was made in 1911 in the extreme northern end. In 1919, a cutting was made to salvage the chestnut which had been killed by the blight. However, neither of these cuttings had any marked effect on the residual stand.

FIG. 34. APRIL, 1923. THE CUTTING AREA AFTER COMPLETION OF LOGGING AND SLASH BURNING

The advance growth hardwood was cut prior to logging.

At the time of clear-cutting, the stand was a little over 70 years old. There was a very abundant advance growth of white ash in the central portion of the area, due to scattered ash seed trees in the main canopy. At the northern end, the advance growth was more spotty and composed mostly of less desirable species. Elsewhere, there were a few small areas where it was extremely sparse or absent.

The advance growth was mowed just prior to logging, and the main stand felled in the customary manner, by windrows, the slash being burned in piles early the following spring. Lumber and cordwood were

piled at the southern end of the area, and their presence there during the period of drying killed most of the advance growth hardwood stools.

Planting—April, 1925

At the beginning of the third growing season after logging, there still remained several small openings in addition to the large one where the lumber and cordwood had been piled. In other places the hardwood composition and stocking appeared at least fairly satisfactory. The sprouts from the small advance growth stools were being supplemented by seedlings of a number of light-seeded species, especially paper birch.

FIG. 35. MAY, 1925. A GROUP OF VOLUNTEER HARDWOODS SEGREGATED BY AN ENCIRCLING STRING FROM THE AREA TO BE PLANTED

A few weeks before planting, a pine stand on an adjoining ownership was logged. It was recognized that coniferous seedlings set out so close to a fresh cutting would be subject to pales weevil attack. However, it was decided to go ahead with the planting regardless, with the thought that more might be learned about the feeding habits of this insect.

The small openings to be planted, amounting to about 15 percent of the total area, were segregated from the surrounding well-stocked areas by strings. In these openings, 3-year-old white pine, Scotch pine and Norway spruce seedlings of small size (4″ to 6″) were set out in groups

FIG. 36. MAY, 1925. A RED OAK IN A WHITE ASH GROUP

The differing growth habits of the two species become evident at an early age. In the absence of treatment, the space-demanding oak crowds out the crown-sensitive ash.

of a single species, totaling 3,500 plants. In the large opening at the southern end, covering about two acres, 2,500 red pine transplants (2-2 stock) were set out at a uniform spacing of 6 feet.

Replanting—April, 1927

As might be expected, the pales weevil caused considerable damage to the planted conifers in the southern portion of the new stand, nearest the adjoining fresh cutting. Some were killed outright, while others, the majority, were only partially girdled and showed evidence of recovering. However, because of a strong seeding in of paper birch since the original planting, it appeared unnecessary to replant more than a small part of the large red pine area, which was the only planting attacked by the weevil to a serious extent.

Weeding (First)—June, 1927

At this time the better elements, both conifers and hardwoods, were overtopped by sprouts from stumps of trees which had formed part of the previous main stand, and by fast-growing trees of weed species which had originated since logging. Extremely dense thickets of gray and paper birch, poplar, willow, and sumac had claimed the charcoal beds resulting from slash burning. Even at this date it was evident that the smaller planted softwood groups would be only partially successful, due to the rapid development of the surrounding hardwoods and insufficiently large and vigorous plants. Had thrifty 4-year transplants of white and Scotch pine and Norway spruce been used, better results undoubtedly would have been obtained. In the southern end, the red pine plantation was very successful. Losses from pales weevil attack were much lighter than originally estimated. Here, all hardwoods of inferior species or form were cut. Occasional good hardwood stems were left, with the aim to develop a pine and hardwood mixture. In other planted softwood groups, of small size, already largely taken over by hardwoods, the treatment favored only a very few of the most promising pines or spruces. On the remainder of the area, the hardwood portion, weeding was directed toward the removal of trees of inferior species or poor form, whether of sprout or seedling origin, that had gained dominant positions in the stand.

Weeding (Second)—June, 1929

This treatment was applied chiefly to the extreme northern end of the area, where a stand of relatively light density and inferior composition had developed. Many red oaks had already taken on wolf-tree form and these were cut. The remainder of the area required nothing more than the setting back of an occasional sprout clump. Black cherry stump

FIG. 37. JANUARY, 1934. THE SOUTHERN END OF THE STAND (FOREGROUND), WHERE RED PINE WAS PLANTED AT A UNIFORM SPACING

Hardwoods, especially paper birch, seeded in to such an extent that the planting was unnecessary for full stocking. Beyond the red pine is the hardwood section shown in Fig. 40.

sprouts were especially vigorous. It had now become certain that the planted Scotch and white pine groups had failed completely, and they were abandoned. In spite of comparatively thin stocking, the hardwoods in these group areas were more promising than the pines. Two or three of the best Norway spruce groups were released.

White ash, red oak, hard maple, and paper birch were favored for the crop tree element in all portions of the stand, except where the red pine was planted. Only in the northern end was it necessary to accept some less desirable species, such as black birch, hornbeam, and red maple.

In the southern end, the thickets of gray and paper birch on the charcoal beds had been supplemented by a more general seeding of these species. Gray birch was more prominent than paper birch, but almost enough of the latter had seeded in to form the basis of a new stand. Some red pines already had been killed in the densest thickets. Where paper birch had gained dominance over the pine, both in numbers and position, it was retained; otherwise, it was brought along in a stemwise arrangement with the pine.

Weeding (Third)—April, 1933

This treatment, made at the beginning of the ninth growing season after planting, was confined to the red pine in the southern portion of the stand. Only a light weeding was necessary, the majority of trees being in a free-to-grow position. A selective type of weeding was applied in which most of the release was effected by lopping only the tops of the weed trees. A dense hardwood filler was thus maintained between the pines to hasten natural pruning and to improve bole form.

Weeding (Fourth)—June, 1934

One year after the previous weeding in the red pine, it was evident that the top-lopping treatment had been too conservative. The trees that had been topped put out new leaders which quickly recovered their former dominant position. Further release was needed at once. Special consideration was given at this time to the reduction of trees favored by the gypsy moth, namely, gray birch, poplar, and oak. Trees of these species were cut regardless of position. In certain places, especially in the northern end of the red pine planting, where it adjoined the hardwood area, the pines were doing poorly because of extreme hardwood competition. These places were turned over completely to white ash and paper birch. Elsewhere, in places where it was certain that the pine would come through, all large-crowned hardwoods, too high to fit well with the pines, were cut regardless of species.

Weeding (Fifth) and Thinning—1934-35

During September and October, 1934, and October, 1935, a combined weeding and thinning treatment was applied to the hardwood portion of the stand, which was then 12 to 13 years old. For the first time, attention was given to the reduction of stems in sprout clumps from the smaller stools (1 to 3 inches). In most cases the clumps were reduced to a single stem—the best-formed and most vigorous one, with due regard to its point of origin on the parent stool. Dense thickets of ash saplings, established in the neighborhood of former seed trees, were heavily thinned, and coarse red oaks, especially where surrounded by ash, were eliminated by girdling with a chain saw.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per acre*
Planting	4/1925	3.5	2-4	87.0	24.8
Replanting	4/1927	2.0	4-6	9.0	4.5
Weeding	6/1927	9.0	5-7	25.0	2.8
Weeding	6/1929	9.0	7-9	36.0	4.0
Weeding	4/1933	2.0	10-12	6.0	3.0
Weeding	6/1934	2.0	12-14	10.0	5.0
Weeding and Thinning	10/1934-35	7.0	13-15	28.0	4.0
Total				201.0	

Stand Conditions—July, 1938

The hardwood portion of the stand, now 16 years of age, is, even after three treatments, generally densely stocked. The "natural" composition has been modified by the elimination of the species considered to be of little or no value, by a reduction in the proportion of red oak, and an increase in that of white ash. In the dense white ash groups, response to the thinning of 1934-35 was unsatisfactory. The reason for this continuing poor growth on a highly productive site is not definitely known. The extremely high density in the beginning probably is not the explanation. It seems more likely that the trouble lies in the soil. On such moist situations the root systems are naturally shallow and, unless a protective organic covering is maintained, they are subject to exposure through frost heaving and erosion. Here, a high earthworm population, encouraged by the abundance of highly favored food (ash leaves) has prevented

the accumulation of such a protective organic cover. It has been noted that the earthworm feeding oftentimes strips the ground of all leaf litter by midsummer, leaving it fully exposed until the next leaf fall. Heavy rains result in the washing away of the bare top soil and the exposure of

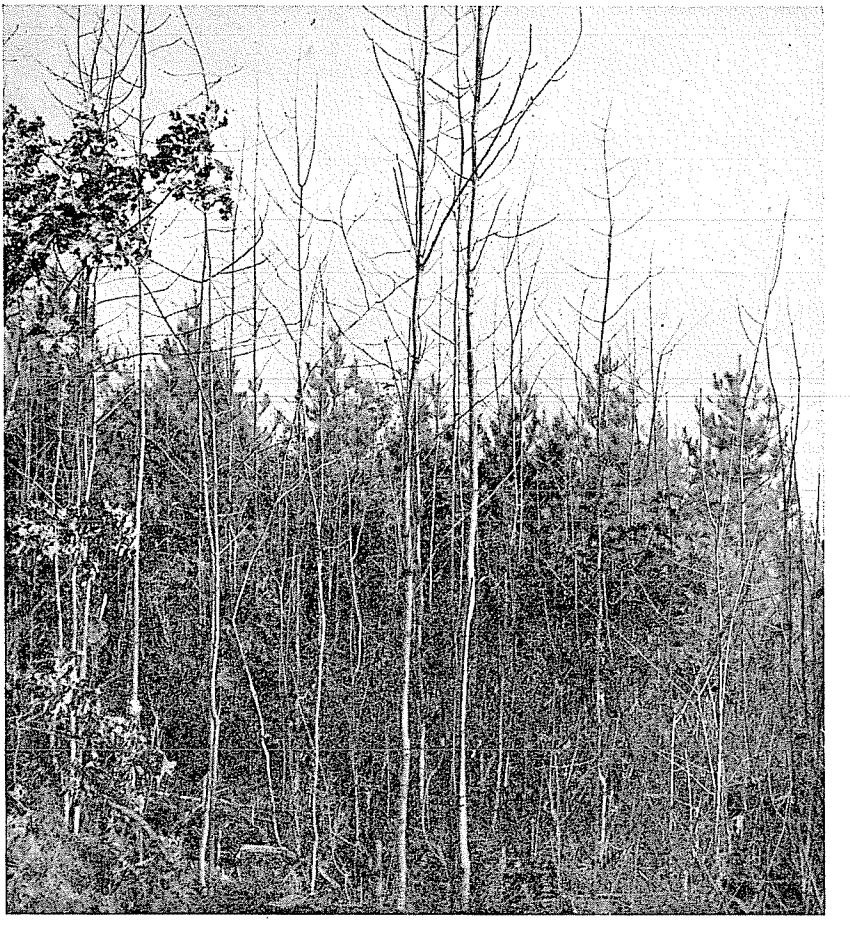


FIG. 38. WHITE ASH AND RED PINE GROUPS

The white ash is slow-growing despite thinning. Apparently, erosion of the soft and porous soil is an important factor.

the roots. Freezing temperatures occurring while snow cover is absent cause frost heaving and increased root exposure.

Besides the ash groups, the stand is now composed of a mixture of hardwoods, in such proportions as it was possible to develop from the

FIG. 39. EXPOSED BASSWOOD ROOTS

A large earthworm population under ash and basswood develops an extremely soft and porous soil lacking a protective organic top layer. Heavy rains and frost heaving result in exposure of the roots.

available material, giving consideration to soil fertility, stand security and value of the final products. The following composition table is representative of much of the hardwood portion of the stand:

D. B. H. in Inches	*WA*	*RO*	*RM*	*HM*	*PB*	*WO*	*BB*	*GB*	*Pop*	*WP*
	(Number of stems per acre)									
Less than 1	120									
1	500	60	370	80	340	130	60	80		10
2	200	90	20	30	100	50	70		10	
3	30	110			40		20			
4		20			20					
Subtotal	850	280	390	110	500	180	150	80	10	10
Total — 2,560										

White ash, paper birch, and red maple are most abundant, in the order named, but red oak leads in number of larger stems. The dominant oaks are 35 feet in height, with an average dead length of 10 feet; the leading paper birches are equally high, with a slightly greater dead length; and the white ash is 30 feet, with an average dead length of 8 feet.

The planted white and Scotch pine and Norway spruce groups have largely failed to compete with the surrounding hardwoods. Only two or three small groups of Norway spruce, located in places where the hardwood competition is comparatively feeble, can be made part of the final crop. The once poorly stocked northern end of the area has improved with time, by the addition of certain light-seeded species, such as paper and black birch. A sufficient number of good stems is now present in this section to insure good stocking at maturity. The coarse red oaks which were girdled in 1935 have since died. A marked change has taken place in the soil, its present crumb mull structure contrasting with the mor type of profile which developed during occupancy of the land by the previous old field stand.

The planted red pines, now 18 years of age, average 20 feet in height and 4 inches in d.b.h., with the largest trees 25 feet high and 6 inches in diameter. Nearly one-fourth of the red pines have been eliminated by hardwood competition, mainly around the borders of the plantation. Small hardwood groups, composed chiefly of white ash and paper birch, have been developed, the recessive crown habits of both species making them ideally suited to association with red pine, especially in groups. The red pines are of unusually good form, having had the advantage of a hardwood filler almost from the beginning. Already the dead length

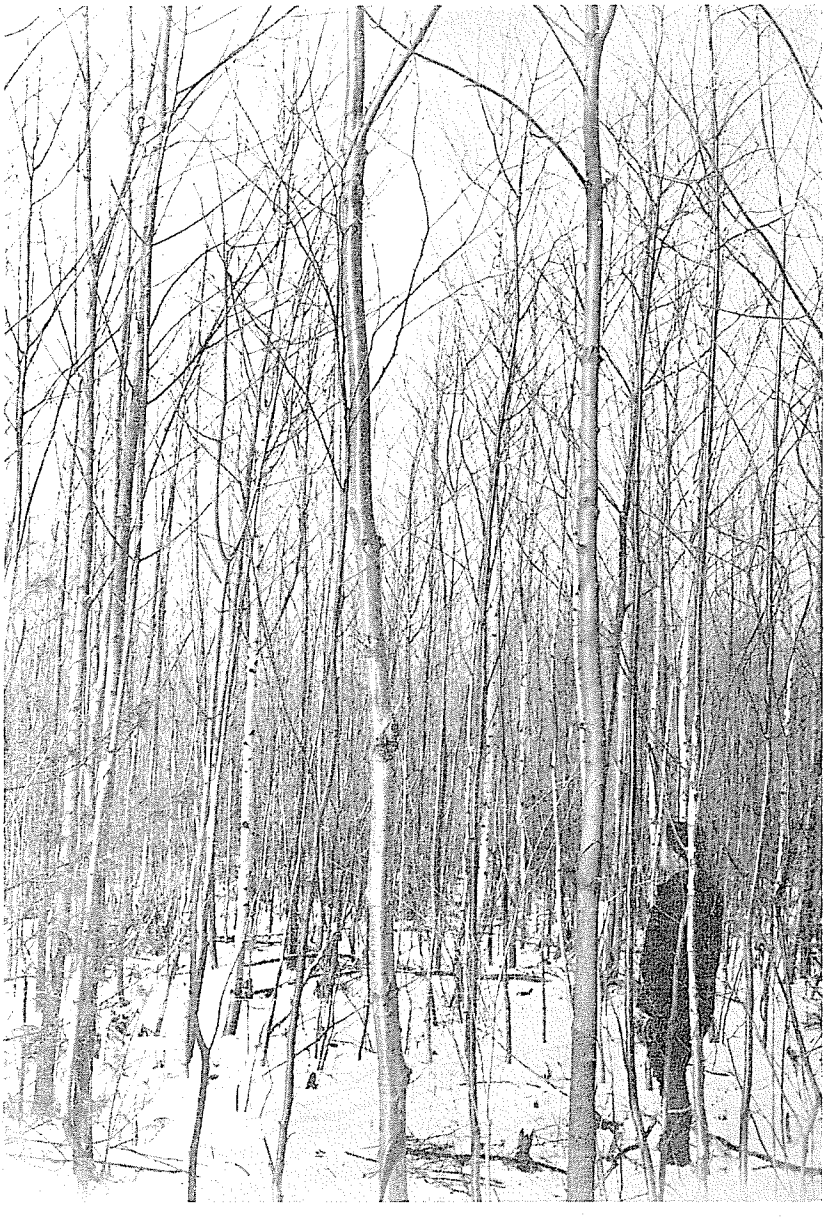


FIG. 40. DECEMBER, 1938. MIXED HARDWOODS ON A PORTION OF THE AREA NOT PLANTED

White ash, paper birch and red oak are the leading crop tree species. Three treatments have served to eliminate the weed trees.

FIG. 41. APRIL, 1946. RED PINE AND HARDWOODS IN THE SOUTHERN PORTION OF THE STAND

Good bole form and small branches are the result of side pressure by the surrounding hardwoods.

extends upward to 8 feet. The average branch size for the first 6 feet is less than ½ inch and about ¾ of an inch for the next 6 feet.

Discussion

By virtue of experience gained in planting conifers on similar sites, greater discrimination was used in this case in choice of places requiring supplementary planting, with the result that fewer losses in planted stock were sustained than in the earlier cases. However, time again has shown that what appear to be openings two years after clear-cutting old field pine on heavy soil are later claimed by volunteer hardwoods. Natural seeding would even have completely stocked the large opening, where red pine was planted, within a few years.

White ash occurring in dense groups on the moister parts of the area has presented an especially difficult problem. Although the reasons for such slow growth and poor development, despite thinning, are not definitely known, it appears that the combination of slope and a very loose soil has resulted in erosion and frost heaving. Probably it would be desirable to work for a mixture of hardwoods in such places, including those whose foliage is less favored as food by earthworms, and to make early and repeated thinnings. In this way the ground might be made somewhat more firm and root anchorage strengthened.

CASE NO. 7

Hardwoods Following the Clear-cutting of Old Field Pine

Block: Tom Swamp — History to November, 1940
Compartment: I
Stand: Hd-5, 1.4 acres

As a result of long experience in attempting to establish plantations of conifers on old field pine cuttings, in order to supplement the seemingly deficient volunteer stocking, it had been thoroughly learned by the time treatment of this case was begun, in 1926, that much of such planting was unnecessary. Here, on a site well adapted to hardwoods, supplementary planting was intentionally dispensed with, and reliance placed entirely on restocking by natural means. The cutting was made in an off-seed

year for pine, and little, if any, pine seeding was expected. Furthermore, the hardwood advance growth was decidedly not dense enough to meet the requirements of full stocking for the new stand.

The lapse of only 14 years since cutting has shown what may be expected by way of increased stocking on such areas without recourse to planting.

Site and Land History

The area is located midway on a long westerly slope, at an elevation of 1,000 feet and with a gradient of about 10 percent. The soil is a highly productive Charlton stony loam. Drainage is mostly internal, but during periods of continued or heavy rains there is considerable surface run-off. Under such conditions soil erosion becomes an important consideration.

The original lot was granted at the time of the first land division, in 1733, and clearing of the land for agriculture is believed to have taken place shortly thereafter. Because of the extreme stoniness of the soil, use must have been limited to pasturage. The farm was abandoned around 1870 and white pine soon seeded in on the open ground.

Clear-cutting—Winter, 1926-27

The stand was white pine, 50 to 60 years old and of fairly high density, with some scattered hardwoods, chiefly white ash, red maple, red oak, and basswood. Beneath the old stand was a rather thin stocking of advance growth hardwoods, consisting mostly of white ash, hard maple, red and white oak, and basswood.

The pine stand was clear-cut in the usual manner, by windrows, and the slash burned as logging progressed. All of the advance growth hardwoods were cut back to the ground before logging, except a small group in the southeastern corner of the stand. This group was left because it seemed adequately stocked and the trees appeared strong enough to make a favorable response to full exposure. The trees in this group appeared older than the rest of the advance growth, presumably having become established earlier by virtue of the advantages of location at the edge of the stand.

Weeding (First)—April, 1931

This treatment was made just before the fifth growing season following the clear-cutting. Coarse sprouts from stumps of trees in the former stand were overtopping and rubbing good trees of seedling or seedling sprout origin. Such sprouts were cut back with a machete. The principal trees favored were white ash, basswood, red oak, and hard maple, most of them seedling sprouts originating as advance growth

under the old field pine. The stocking was still considered deficient, but new seedlings of paper birch and white ash had come in and the density of stocking was noticeably improved. Most of the spots where slash had been burned had seeded in to sumac, willow, gray birch, poplar, and pin cherry. These trees were not yet tall enough to interfere with the surrounding seedling sprouts of the better species.

Weeding (Second)—October, 1933

Within the short space of three growing seasons since the first weeding, many more trees of inferior species, that had seeded in after the clear-cutting, had gained overtopping positions. Also, some of the sprout clumps cut at the time of the first weeding were again in need of cutting, to free desirable crop trees. The density of stocking had so increased in this short time that there no longer was any doubt about the possibility of developing a high quality crop. There were, however, rather greater than ordinary irregularities in both the horizontal and vertical distribution of stems.

Weeding (Third)—November, 1936

At the end of another three-year period, only a small area near the center of the stand needed attention. Elsewhere, trees previously selected for the crop were generally in a free-to-grow position. Again, the main cause of interference was sprouts from large stumps and fast-growing weed species. These were weeded out to free desirable crop trees. Certain of the red oaks, formerly thought of as potential crop trees, had developed wolf tree tendencies, and these also were cut where better formed trees were available to take their places.

Weeding (Fourth)—May, 1939

At the time of the fourth weeding, the density had become so high in places, as a result of increased tree size and additional natural seeding, that many crop trees were actually suffering from crowding. At the same time, certain red oaks which had been free to grow from the start had become extremely coarse and spreading; it was now clear what part such individuals would play in the stand if not promptly removed. Only well-formed red oaks not extending above the general canopy level were saved for the crop. The treatment was largely a thinning out of dense white ash groups and a reducing of the number of stems in multiple-stemmed white ash and basswood from small stools.

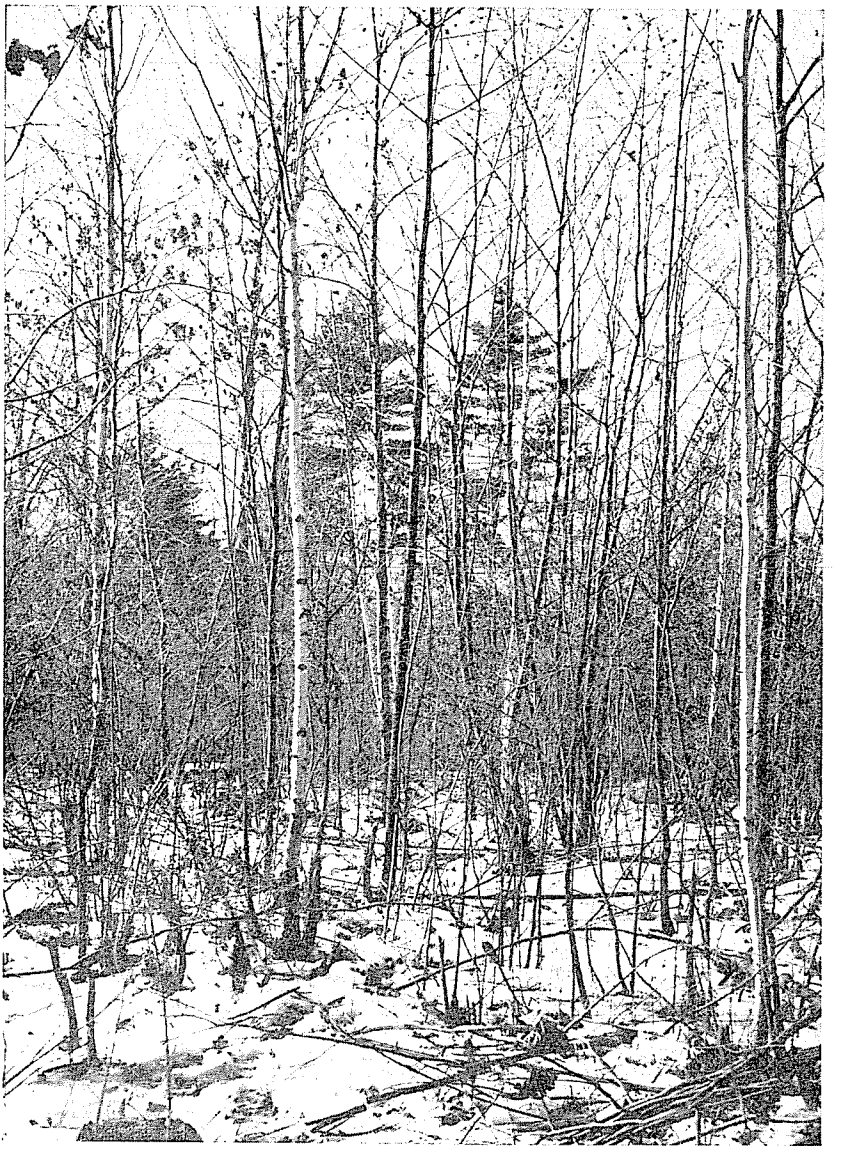


FIG. 42. JANUARY, 1942. THE STAND AT FIFTEEN YEARS OF AGE

Through timely treatments the weed trees have been eliminated and the growing space turned over to well-formed white ash, red maple, paper birch, basswood and other desirable species.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	4/1931	1.4	4	6.0	4.3
Weeding	10/1933	1.4	7	6.0	4.3
Weeding	11/1936	0.8	10	6.0	7.5
Weeding	5/1939	1.4	12	3.0	2.1
Total				21.0	

Condition of the Stand—November, 1940

The stand is now fourteen years of age, and made up chiefly of white ash, red maple, paper birch, and red oak.

The following tally of composition was taken in a representative portion of the area:

	WA	*RM*	*PB*	*RO*	*BB*	*Bswd.*	*Hky.*	*WO*	*HM*	*Total*
	(Number of Stems Per Acre)									
Small saplings	1,320	590	420	210	130	80	60	30	30	2,870
Large saplings	80	—	60	160	10	40	—	20	—	370
Total	1,400	590	480	370	140	120	60	50	30	3,240

White ash leads in point of numbers, but red oak in size. Of the 370 trees in the largest size class, 160, or more than three-quarters, are red oak. Many of the oaks are coarse and branchy. Basswood is uncommonly abundant, owing to a source of seed in a nearby stand.

With the exception of those trees that seeded in after logging, and the small group of uncut advance growth in the southeastern portion of the stand, many of the ash and basswood crop trees are multiple-stemmed in form, originating as sprouts from advance growth stools. Starting, as it did, under conditions of deficient stocking and walled in on the downhill side by a dense high forest, the new stand was particularly susceptible to frost damage. Most severely injured were white ash and red oak. Frost has probably contributed more than any other agency to the poor quality of many of the trees, in the form of stem crooks and excessive branching. However, there are more than enough single-stemmed trees and well-formed sprouts to assure in time full stocking of high quality. At present

FIG. 43. RED OAK DAMAGED BY FROST

The frequent occurrence of twig die-back in young oaks apparently is due to late spring frosts. The resultant forked and crooked trees are of major concern in developing a high quality crop.

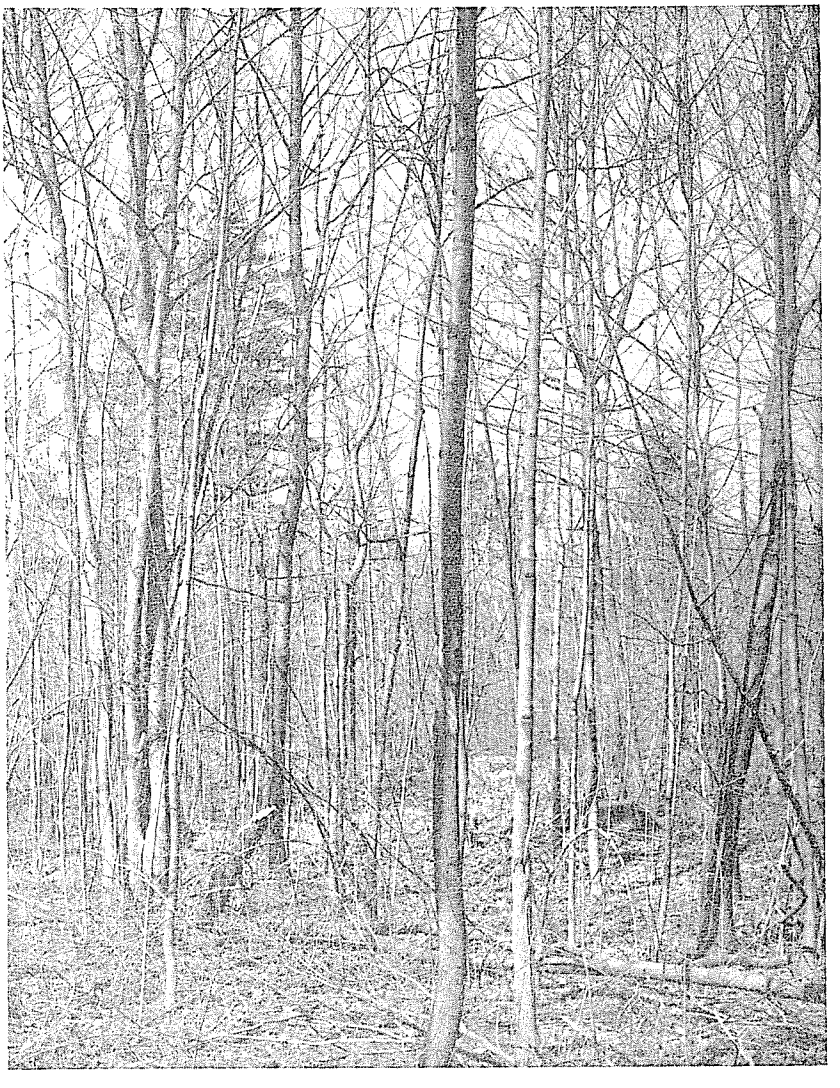


FIG. 44. APRIL, 1946. A GROUP OF HARDWOODS OF ADVANCE GROWTH ORIGIN NOT CUT BACK AT TIME OF LOGGING

The trees are crooked and very coarse-branched. Seedlings subjected to long periods of suppression do not produce high quality trees when released.

the stand has a density of 3,240 stems per acre, including an abundance of trees whose foliage is highly favored by earthworms.

The high earthworm population has produced an excellent crumb mull structure but the soil is so soft, and so easily eroded and heaved by frost, that many trees have their roots exposed, particularly white ash and basswood (see Fig. 39).

FIG. 45. EARTHWORM MIDDENS

Under portions of the stand where white ash predominates, the leaf litter is almost entirely consumed by earthworms by mid-summer.

The group of advance growth hardwoods not cut back at the time of logging in 1926-27 stands out in marked contrast to the rest of the stand. The trees are larger in size, averaging 5 to 6 inches in diameter and 30 feet in height, but almost without exception they are very crooked and limby; few, if any, will produce high quality timber.

Discussion

This case has demonstrated that, following the clear-cutting of old field

white pine on the best soils, even a decidedly low volunteer hardwood stocking at the start may be expected to thicken up to such an extent during the first decade that a satisfactory final crop is assured without resort to supplementary planting. With seemingly deficient stocking in the beginning, an overabundance of trees later became available through additions by natural seeding. This case has further shown that hardwood seedlings originating as advance growth and subjected to long periods of suppression do not produce high quality trees after being released.

In this stand, located on a slope and containing an abundance of white ash and basswood, whose foliage is highly favored by earthworms, a soil condition has developed which is detrimental to stand security. As brought out in the preceding case, where soil conditions under white ash thickets are similar, it would seem desirable to favor more of those species, like oak, whose foliage is less palatable to earthworms, thus perhaps developing a permanent organic layer as a protective cover over the mineral soil.

STANDS FOLLOWING THE CUTTING OF OLD FIELD WHITE PINE ON MEDIUM SOILS

CASE NO. 8

Pine and Hardwoods Following the Clear-cutting of Old Field Pine

Block: Tom Swamp History to September, 1938

Compartment: IV

Stand: P-Hd-1, 7.8 acres (Southern Portion, 3.0 acres)

This case deals with the clear-cutting of a stand of old field white pine growing on a medium site inclined towards dryness. Through unusual circumstances, there was advance reproduction of pine on the ground at the time of logging, resulting from a seed year which occurred three years previously. In striking contrast to the cases on heavy soils, where almost complete failure resulted from efforts to bring through white pine reproduction, in this instance comparatively little difficulty was encountered in developing a mixture of the two elements.

In the beginning, both pine and hardwoods were present in sufficient numbers to form the basis of a well-stocked new stand, and some uncertainty existed as to which to favor. When the time came for silvicul-

tural treatments, the natural inclination was to favor desirable individuals of both pine and hardwoods, in a stemwise distribution. Not until the latter part of the weeding period did the greatly differing early growth rates of the two elements make evident the advisability of segregating them into groups, in which each might grow at its own rate with a minimum of interference from the other.

Site and Land History

The area is situated midway on a gentle westerly slope at an elevation of about 950 feet. The soil is chiefly a well-drained Gloucester stony fine sandy loam, not as moist and fertile a soil as the Charlton.

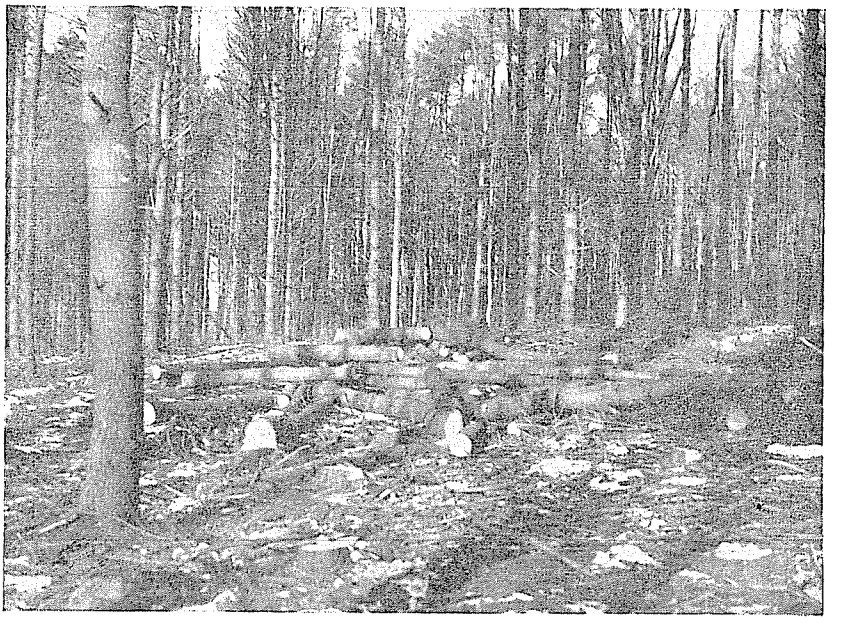


FIG. 46. WINTER, 1917-18. THE OLD FIELD WHITE PINE STAND DURING LOGGING

The advance growth hardwood was cut just before felling the trees.

The land was formerly in agricultural use, probably pasture, because its rockiness would have prohibited cultivation. Abandonment as farm land took place around 1850, and the open land soon seeded in to white pine and some hardwoods.

Clear-cutting—Winter, 1917-18

The stand consisted of even-aged white pine, 60 to 70 years old, with a

scattering of red oak, red maple, chestnut, and other hardwoods. The pines were about 70 feet tall, fairly straight, and with persistent dead limbs extending from the green crown to near the ground. In volume, the stand was reported to contain nearly 45,000 board feet per acre, round-edge lumber scale. Advance reproduction under the main stand included both white pine and hardwoods. White pine was the most abundant, with an estimated 6,000 seedlings per acre, followed in order by white ash, red oak, and black cherry. The pine originated from the seed crop of 1914;

FIG. 47. SUMMER, 1919. THE CUTTING AREA DURING THE SECOND GROWING SEASON AFTER LOGGING

Hardwood seedlings and seedling sprouts and white pine seedlings are the leading elements in the new stand.

favorable moisture conditions were very likely responsible for its persistence in such numbers. A moderately good crop of pine seed was produced in the fall of 1917 and was on the ground at the time of logging.

The advance growth was mowed with brush scythes, the stand clear-cut, and the slash piled and burned as logging progressed.

Condition of Stand—August, 1918

A sample count of reproduction during the first growing season after logging showed the following number of stems according to origin:

	(Number of Stems Per Acre)			
	1 Year Old	*4 Years Old*	*Over 4 Years*	*Total*
White pine	150	2,430	20	2,600
	Seedlings	*Seedling Sprouts*	*Stump Sprouts*	*Total*
Hardwoods	3,165	2,405	320	5,890

Less than one-half of the pine seedlings survived logging, most of the loss being attributed to the pales weevil. Active feeding by this insect was still going on in August. The few seedlings which resulted from the seed crop of the fall of 1917 were too small to be attacked.

FIG. 48. MAY, 1924. THE YOUNG STAND AT FIVE YEARS OF AGE, AT THE TIME OF THE SECOND WEEDING

The natural groupwise tendency of white pine was becoming evident, but a stemwise mixture of white pine and hardwoods continued to be the aim. In the foreground, a red maple sprout clump has been cut.

Weeding (First)—November, 1920

The first weeding was made at the end of the third growing season. The most injurious weeds were red maple sprout clumps from large stumps. All of these were cut back. In addition, thrifty white pines were freed by cutting overtopping hardwoods, and the hardwood element itself

was improved by cutting trees of inferior species or form in overtopping positions.

In order to free any substantial portion of the pine, it was necessary to cut otherwise desirable hardwood stems, thus spoiling many of them for future use as crop trees.

Weeding (Second)—May, 1924

The second weeding was carried out just prior to the seventh growing season. By this time a great deal of the pine reproduction was hopelessly overtopped by the hardwoods despite the previous weeding. Only in places where the pines were in thick groups were they competing at all favorably. There was a natural tendency toward the groupwise distribution, the significance of which was not yet fully recognized; the treatment for the most part still gave preference to the individual tree rather than to groups. White ash was favored in a number of places. Because of its inability to compete successfully with the faster growing species, such as red oak, it was necessary to cut equally promising trees of other valuable species to give it needed room.

Weeding (Third)—November, 1926

At the time of the third weeding, the stand appeared denser than ever, and the faster height growth of the hardwoods compared to that of the pine was more marked than before. The pines averaged between 8 and 9 feet in height, and the hardwoods nearly 15 feet. At this point it was decided to abandon the stemwise form in favor of the groupwise. Where promising white pine occurred in groups large enough to form workable units (usually from 1/40 to 1/10 acre in size), they were released from overtopping hardwoods. All hardwood stems were cut from within the pine groups, and crown-sensitive species, such as white ash, were favored around the margins of the groups. The more scattered pine was neglected. In the hardwood areas, coarse, rank-growing individuals were cut to favor better-formed trees. It was now evident that a good many hardwood stems had been needlessly cut in a futile effort to save pines. The "bayonet" form of such hardwoods made them no longer suitable as crop trees.

Weeding (Fourth)—June, 1930

The fourth and final weeding was made during the growing season of the thirteenth year. In this operation the groupwise form was further accentuated. Special effort was made to identify promising groups and to limit their composition to either white pine or hardwoods. The operation otherwise was similar in character to the preceding one.

Improvement Cutting—April, 1933

The two previous weedings had been successful in establishing the groupwise form, but some of the pine groups were being crowded by surrounding hardwoods. In the hardwood groups, too, certain red oaks had broken through the general canopy level and developed coarse, wide-spreading crowns.

FIG. 49. SUMMER, 1928. PORTION OF A WHITE PINE GROUP FREED IN THE WEEDING OF 1926

After an unsuccessful attempt to develop a stemwise mixture of white pine and hardwoods, the groupwise distribution was adopted.

The pine groups were freed from overtopping hardwoods, and the hardwood groups were improved by removing poorly formed or defective individuals, chiefly red oaks with forked stems, cankers, or large crowns.

Improvement and Gypsy Moth Control Cutting—April, 1938

This treatment was carried out just prior to the twenty-first growing season.

At the time of the previous treatment (1933), the gypsy moth had not attained sufficient numbers to cause concern, and for that reason no special effort was then made to lessen the hazard through reducing the proportion

of red oak, a species highly favored by the caterpillars. In the present treatment, cutting was centered on red oak where the presence of other valuable species less favored by the moth permitted. The white pine groups were enlarged to the greatest possible extent, and gray birch and poplar—other highly favored food species—were eliminated. With few exceptions, the red oaks cut in the hardwood groups were of inferior form and quality.

This was the first treatment to yield material sizable enough for cordwood. An average of 207 cubic feet, or 2.6 cords, per acre was cut, 60 percent of which was red oak.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	11/1920	3.0	3	9.0	3.0
Weeding	5/1924	3.0	6	16.8	5.6
Weeding	11/1926	3.0	9	8.4	2.8
Weeding	6/1930	3.0	13	18.0	6.0
Improvement Cutting	4/1933	3.0	15	7.8	2.6
Improvement and Gypsy Moth Control Cutting	4/1938	3.0	20	20.7	6.9
Total				80.7	26.9

Condition of the Stand—September, 1938

The stand at this time (age 21) is a groupwise mixture of white pine and hardwoods. The pine groups, varying in size from 1/40 to 1/20 of an acre, occupy about 25 percent of the total ground area. They are densely stocked with trees ranging in height up to 25 feet, and in diameter up to 4 inches. Elsewhere some pines still persist throughout the hardwood groups, but in a subordinate position. The overtopped pines have not been attacked by the white pine weevil. What weeviling has taken place is confined to the thriftier individuals in the centers of the larger groups, where suppression is least. Even in such cases the resulting damage is minimized by the high density of stocking, which forces injured trees to straighten.

Of the total of 5,890 trees per acre in 1918, 1,700 remain in 1938, about one-third of them in the crop tree class. The hardwood element is made up of several species; among the most important in numbers are white ash, red oak, and paper and black birch. Those less common in occurrence

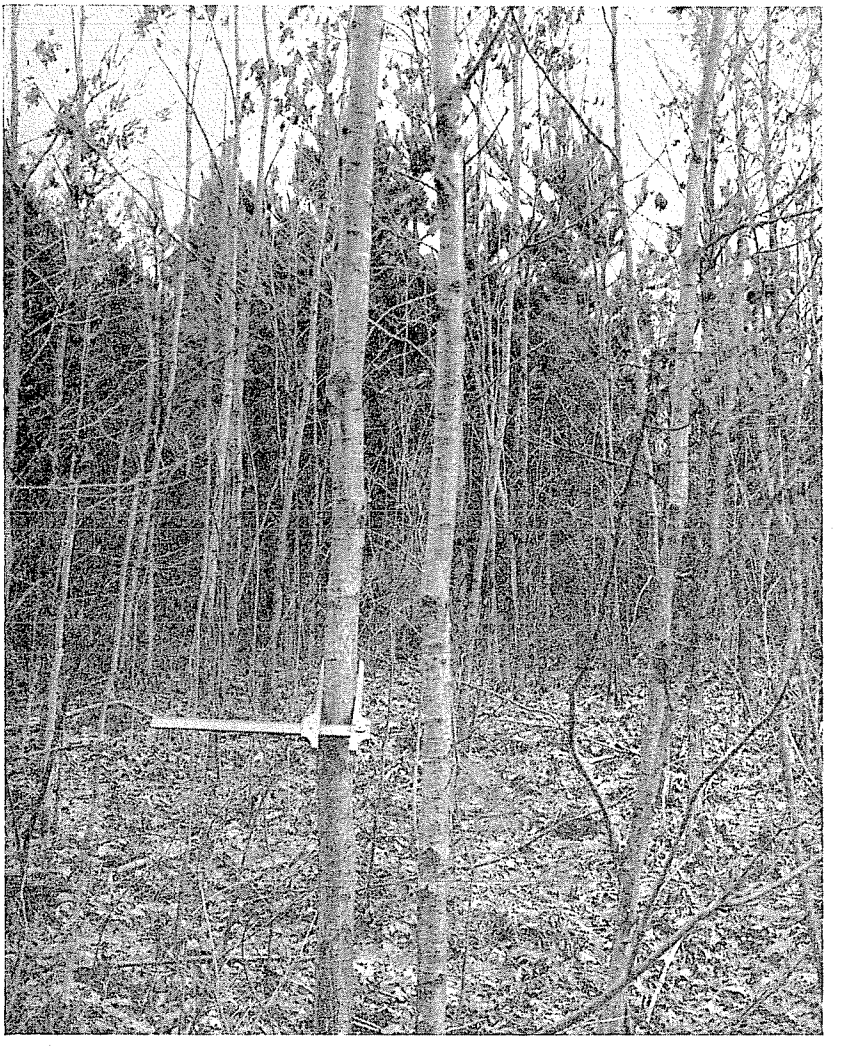


FIG. 50. DECEMBER, 1938. GROUPS OF HARDWOODS AND WHITE PINE ON THE DRIEST PART OF THE AREA

A well-defined groupwise arrangement of the two elements has been effected.

include red maple, white oak, black cherry, and yellow birch. In 1918, the leading species were red maple, black cherry, white ash, and red oak. The red maple has been drastically reduced through weedings, while black cherry has been diminished through natural causes. Frequently, cherry is abundant at the start, but suffers heavy losses with increasing age, occurring but rarely in older stands. Red oak has been reduced from 815 stems per acre in 1918 to about 300 in 1938. However, while the maximum d.b.h. of other hardwoods is 3 inches, 50 percent of the red oaks range between 4 and 7 inches. The height of the main canopy in the hardwood groups ranges from 35 to 45 feet.

Pure groups of red oak occur on the higher ground, the knolls. Here, the quality of the oak is inferior to that of trees growing on better sites; its bole form is poor, and the crowns are large-limbed and spreading. The period during which it is possible to regulate composition effectively is past, because the oak has completely suppressed the associated species.

The practice in past treatments of favoring crown-sensitive trees, such as white ash and paper birch, around the pine groups in order to reduce the competition between the two elements, was successful where followed through. In a few cases where red oak adjoins the pine, further cutting will be necessary to prevent the pine groups from becoming smaller.

The soil has improved under the hardwood cover. The mor condition found under the old field pine has been transformed to a mull. The development of mull is not as rapid here, because of the preponderance of oak, as in places where leaves of other species more palatable to the soil biota are more abundant. And, too, the soil moisture conditions are less favorable for biotic activity in Gloucester soils than in Charlton.

Discussion

In this case, white pine reproduction from the seed crop of 1914 was present at the time of clear-cutting the old field pine. Such a condition is of uncommon occurrence, because, although pine will germinate under pine, it usually dies from the drying out of the organic layer before its root system can reach the mineral soil. The seed crop of 1914 had the advantage of favorable weather conditions during the critical summer months of the following years, and persisted until the time of clear-cutting.

An example of how undependable is the establishment of pine seedlings by clear-cutting in a seed year is the small number (150 per acre) resulting from the good seed crop of 1917, the year of clear-cutting. Losses from the pales weevil following cutting accounted for more than half of all the pine seedlings present. Subsequent seed crops in adjoining stands added to the numbers of pines, but these gains were more than offset by

losses in competition with the hardwoods, leaving only a small part of the whole to carry through to the final crop. Where pine was once generally distributed over the entire stand area, it is now limited to about one-quarter of the area in the aggregate.

In bringing through pine in mixture with hardwoods, the groupwise distribution was shown to be much more readily established than the stemwise. Pine is much slower growing in youth than the hardwoods, and is soon overtopped. Although pines segregated in a group are free from suppression by hardwoods, and therefore subject to attack by the white pine weevil, the very fact that the groups are established where the pine reproduction is thickest assures straight stems and small branches despite weeviling. Furthermore, a groupwise distribution lends itself to fuller utilization of the ground in cases where there are minor variations in topography and soil moisture. The more exacting hardwoods may be advantageously favored in the moister places and white pine, along with oak, in groups, in the drier places.

As brought out in Case No. 6, in 1925, after a succession of failures in attempting to develop stemwise mixtures of conifers and hardwoods, a plan of groupwise planting was adopted; in the present case, in 1926, a groupwise distribution of white pine and hardwoods, of natural origin, became the settled policy. That attempts to establish the stemwise form should have persisted so long was due largely to the observed occurrence in remnants of old growth stands of single white pines surrounded by hardwoods. It was not until the study of mixed white pine and hardwood, made by Cline and Lockard in 1925, that evidence was brought forth showing that isolated white pines growing among hardwoods were generally the lone survivors of a former group of pines.

CASE NO. 9

Pine and Hardwoods Following Strip Shelterwood Cutting in Old Field Pine

Block: Tom Swamp — History to March, 1939
Compartment: V
Stand: P-Hd-3, 1.5 acres

In the one shelterwood case history included under "Heavy Soils" (Case No. 2), the final outcome was a few small groups of white pine in the midst of a stand of hardwoods. Such was the invariable result of

similar attempts to obtain pine reproduction by this method on the best soils. On the medium soils, the outcome, with respect to the survival of the pine, was much better. In fact, at one time the shelterwood method was the preferred means of converting old field white pine to a mixed stand of pine and hardwoods (Fisher, 1921, p. 13).

This case is referred to in the Forest records as "strip shelterwood" but, actually, much of the white pine reproduction was on the ground before any effort was made to obtain it. The heavy seed year of 1914 was followed by several years of timely precipitation. The large number of pine seedlings resulting from this favorable combination of factors prompted the employment of a simplified form of shelterwood method. (See Case No. 2 for description of the shelterwood method.)

Site and Land History

The area is located at an elevation of about 950 feet on a gentle westerly slope. The soil is a Gloucester stony fine sandy loam having internal drainage which is apt to be excessive during dry seasons. The site is considered favorable for growing white pine in mixture with the less exacting hardwood species.

The land was cleared for farming during the early stages of settlement, probably for pasturage. Abandonment as farm land took place around 1860, following which the area seeded in to white pine.

Thinning—Winter, 1911-12

The area at this time supported a dense, even-aged white pine stand about 50 years old. Ground cover was practically lacking, and advance reproduction was sparse.

The thinning was very light, amounting to only about 5,000 board feet out of a total of 35,000 board feet per acre. The main canopy was disturbed only to the extent of removing an occasional poorly formed or otherwise defective tree. Nearly all of the trees removed were from the suppressed and intermediate crown classes. The slash was burned in piles following logging.

Strip Shelterwood Cutting—Winter, 1917-18

After the thinning of 1911-12, an abundant reproduction of white pine from the seed crop of 1911 sprang up, but died within a short time. Much more pine reproduction started from the seed year of 1914, and a great deal of this was still present in 1917. Survival was highest along the northern edge of the stand. Except in the dense groups of pine reproduction, a moderately dense hardwood advance growth was present, composed chiefly of red and white oak, chestnut, red maple, and black birch.

Because of the unusually abundant pine reproduction along the edge of the stand, it was decided to clear-cut a marginal strip, 50 feet wide, at the same time opening up (in a seeding cutting) an adjoining strip, to the south, of equal width. It was hoped that the seed crop of 1917 would serve to augment the pine reproduction already present.

The hardwood advance growth was cut just prior to logging and care taken to fell the trees away from the pine reproduction. Heavy snow covered the area at the time of logging. After the logs were removed the slash was burned in place. Counts taken of the white pine reproduction showed 28,000 seedlings per acre in the cleared strip, and 60,000 under the

FIG. 51. APRIL, 1921. DENSE WHITE PINE REPRODUCTION ON THE SHELTERWOOD STRIP CLEAR CUT IN 1917

A weeding in 1920 removed overtopping hardwoods, mostly red maple seedlings.

partial canopy, all from the 1914 seed crop. The difference was attributed to losses caused by logging and slash burning.

Inspection of Cleared Strip—First Season, 1918

During the summer of 1918, the seedlings in the cleared strip were attacked by the pales weevil. In September, a count showed a survival of 60 percent, nearly all the remainder having been killed by the weevil.

Observations in the fall showed that the seedlings from the 1914 seed crop were small for their age and as yet unresponsive to freedom; in fact, seedlings in the cleared strip averaged slightly less in height than those

in the partially cut strip. Older hardwood seedlings and seedling sprouts were relatively scarce, but year-old red maples had seeded in abundantly from an adjoining stand. The scattered older seedlings averaged about a foot in height, and seedling sprouts from 3 to 4 feet. From the seed crop of 1917 only 11 pine seedlings were found on the entire area.

Weeding (First), Cleared Strip of 1917-18—August, 1920

The hardwoods had grown rapidly, and in many places the pine reproduction was overtopped. It was now evident that the dense pine reproduction was concentrated in the middle and western sections of the strip, and that the eastern end should be given over to hardwoods. All

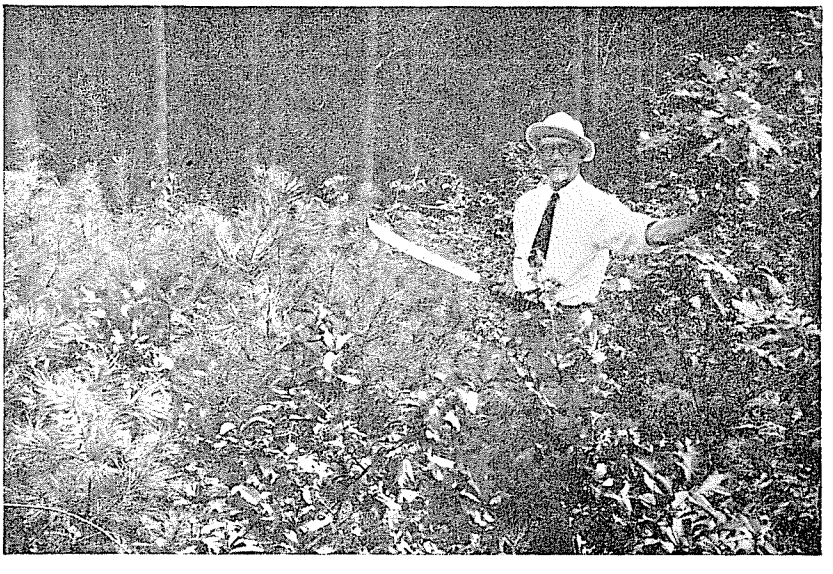


FIG. 52. SECOND WEEDING IN THE FIRST STRIP

Director of the Harvard Forest, R. T. Fisher, freeing the margin of the white pine group in the center of the strip.

hardwoods were cut in the pine section, but no weeding was required in the hardwood section.

Clear-cutting of Second Strip and Partial Cutting of Third Strip—Winter, 1922-23

The strip which was partially cut in 1917-18 was now clear-cut. Sprouts from the hardwood advance growth, cut back five years previously, together with hardwood seedling reproduction, had proved to be strong competition for the young white pine. This along with pales weevil attack

caused heavy losses. It was evident that only a part of the stocking of this strip would be pine.

In addition to the clear-cutting of the second strip, an adjoining strip, to the south, was opened up.

Inspection of First Strip—Winter, 1922-23

The reproduction freed in 1917-18 was now making rapid growth. In the extreme ends of the strip, the hardwoods had crowded out the white pine, but elsewhere the stocking was pure pine with a density of nearly 30,000 stems per acre.

FIG. 53. SUMMER, 1928. WHITE PINE AND HARDWOOD GROUPS ON THE SHELTERWOOD STRIP CLEAR CUT IN 1917-18

Dense white pine reproduction occupies the center of the strip, with hardwoods at either end.

Weeding (Second) of First Strip—May, 1924

This strip was now composed of white pine in the middle section and hardwoods on the ends. In the pine section all overtopping hardwoods were cut regardless of species or origin. In the hardwood sections overtopping trees of inferior form or species were cut.

Weeding (Third) of First Strip, and (First) of Second Strip—June, 1931

The current treatment was the first one to cover both strips. Only a single small section of pine remained in the center of the second strip, which elsewhere had been completely taken over by hardwoods. The

hardwood sections in both strips were especially in need of weeding; rank-growing individuals of black birch, red maple, white oak, and gray birch were the principal weeds. Within the pine group in the first strip, scattered hardwoods had again overtopped the pines, while surrounding hardwoods were pressing the margins of the group.

The hardwood groups were weeded to free the best-formed individuals of desirable species, and the pine groups were freed from all overtopping hardwoods, within and around the margins, regardless of species.

Thinning (First) of First Strip—November, 1934

An unusually heavy, wet snowfall on April 12, 1933, bent over most of the dense white pine reproduction on this strip, now 6 to 10 feet tall and long in need of thinning. Many of the trees had been forced down almost to the ground, but were still living and had started to straighten. The pines around the margin, which had escaped snow damage, were being whipped and overtopped by hardwoods.

The treatment consisted of freeing the white pines which had escaped snow damage and generally reducing the density of stocking in the pine group. Leaning pines which were interfering with straight ones, and hardwoods around the margins of the pine group were cut. A number of coarse red and white oaks were girdled.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Pine Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	8/1920	0.25	6	1.0	4.0
Weeding	5/1924	0.25	9	0.3	1.2
Weeding	6/1931	0.5	17	4.0	8.0
Thinning	11/1934	0.07	20	3.5	50.0
Total				8.8	

The first, second, and fourth treatments were confined to the 1917-18 strip cutting, and the third treatment covered both the 1917-18 and the 1922-23 strips. The cost of the fourth treatment, made in the dense pine group in the center of the 1917-18 strip, was extremely expensive, but the high density of stocking and the heavy snow damage were bound to make any restoration treatment expensive. Such damage might have been avoided through timely thinning.

Stand Conditions—March, 1939

Only two strips are to be considered, since the plan of treatment was

not completely carried through in the third strip. The first strip (1917-18 final cutting) is composed mostly of white pine, while the second strip (1922-23 final cutting) is made up chiefly of hardwoods, with only one small group of pine, from the seed crop of 1914, remaining. In the first strip there are two groups of hardwoods, now 21 years old, occupying the ends of the strip; their composition, shown in the following table, is of interest by way of contrast with that of hardwoods on the best sites.

HARDWOODS IN THE FIRST STRIP

D.B.H.	*Crop Trees*[11]			*Inferior Trees (Trainers, Weeds, etc.)*									
Inches	*RO*	*WO*	*RM*	*RM*	*WP*	*WO*	*RO*	*WA*	*YB*	*BB*	*PB*	*Be*	*Total*
				(Number of Stems Per Acre)									
Up to 1				128	320								448
1		16		320	160	16	16	16			16		560
2	32	16	32	192		80	48	16	32	32			480
3	224	48	16	48		16	32					16	400
4	48						48			32			128
5	16						16			32			64
Total	320	80	48	688	480	112	160	32	32	96	16	16	2,080

[11]Only sound single-stemmed trees were included.

Of the crop tree element, red oak is the leading species, followed by white oak and red maple. White ash is notably absent. Dominant red oaks average about 30 feet in height and 4 inches in diameter.

The white pine group in the 1917-18 clear-cut strip is now 24 years old; dominant trees average between 20 and 25 feet in height and nearly four inches in diameter. White pine weevil damage has been negligible, due to the extremely dense stocking.

The hardwood section in the 1922-23 clear-cut strip is 16 years old, and its composition is as follows:

HARDWOODS IN THE SECOND STRIP

D.B.H.	*Crop Trees*						*Inferior Trees (Trainers, Weeds, etc.)*									
Inches	*RO*	*PB*	*WO*	*RM*	*BC*	*BB*	*WO*	*RM*	*WP*	*YB*	*WA*	*Hem*	*BB*	*PB*	*RO*	*Total*
							(Number of Stems Per Acre)									
Up to 1									240			40				280
1			40				340	360		100	40					880
2	60	80	60	20	20	20	120	60					20	20	40	520
3	100	60		20										20		200
4	20	20											20			60
5													20			20
Total	180	160	100	40	20	20	460	420	240	100	40	40	60	40	40	1,960

Red oak leads among the crop trees, followed by paper birch and white oak.

The hardwood sections of the two strips differ mainly in the areal distribution of the species rather than in composition; both are representative of hardwood stockings on medium quality soils.

Because of the low density of the white pine group in the second shelterwood strip, it escaped snow damage. The dominant trees are somewhat larger than those in the first strip. With continued treatment the group will form part of the final stand.

FIG. 54. THE RESULT OF SNOW DAMAGE

When eighteen years of age, in 1933, the dense white pine group in the center of the first strip was bent over by heavy snow. This picture was taken in 1945.

Discussion

The decision to apply strip shelterwood cuttings was due to the presence of a marginal strip of especially thrifty pine reproduction established voluntarily through an abundant seed crop in 1914, a succession of favorable growing seasons, and side light. The freeing of the marginal reproduction was successful, but the usual competition with hardwoods was encountered when partial cuttings were applied to the inner strips. Here

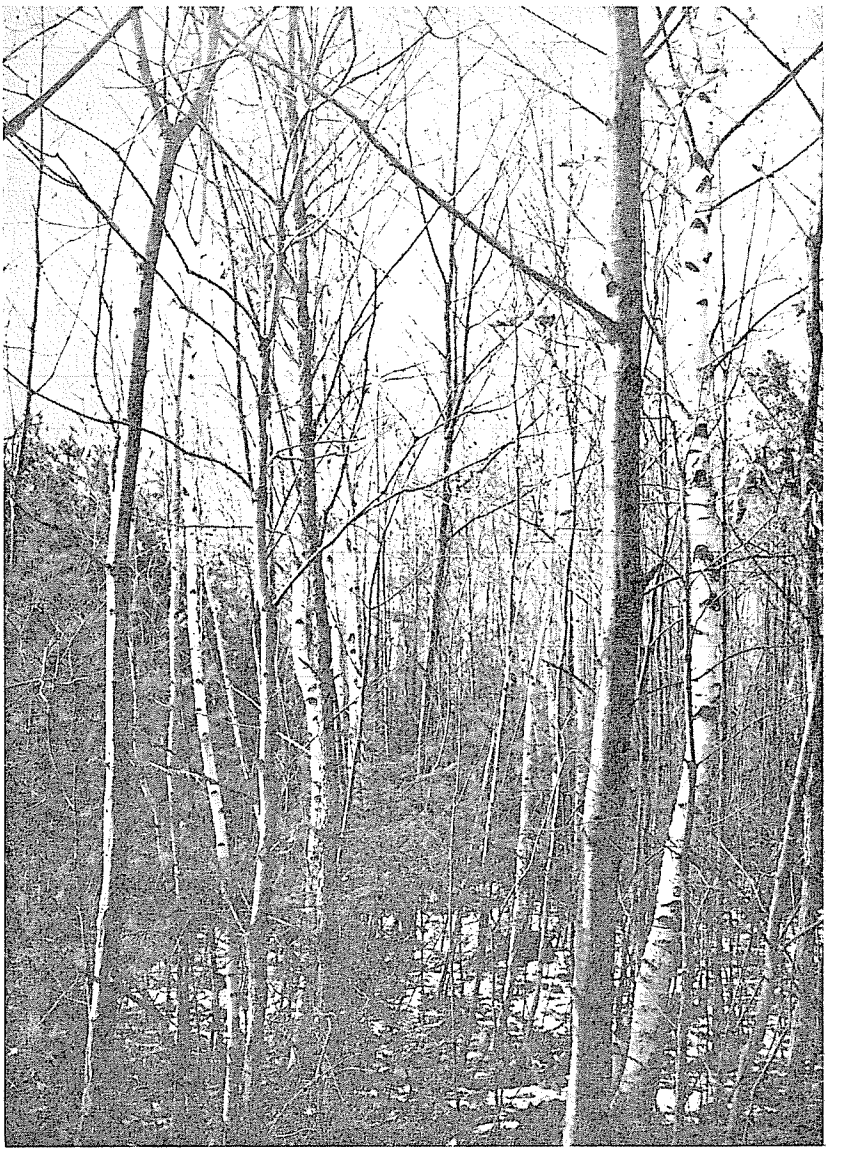


FIG. 55. JANUARY, 1942. HARDWOODS IN THE SECOND SHELTERWOOD STRIP CLEAR-CUT IN 1922-23

The density of stocking was not sufficiently high to produce straight, clear stems.

the opening up of the canopy stimulated the hardwood advance growth, and doubtless added to its abundance, so that in the second strip white pine eventually formed only one small group; and in the third strip, hardwoods completely dominated the new generation.

On medium soils such as this, where white pine once established can compete with the hardwoods on fairly even terms, the policy might well be to encourage a mixed reproduction, preferably in groups. This might have been carried out by clear-cutting the entire old field pine stand in 1917-18, for at that time there was abundant white pine reproduction everywhere. While some of it doubtless was rather weak, except in the marginal strip, and a considerable proportion would have been lost through logging and the pales weevil, yet the reproduction was so abundant that at least some groups could have been brought through to form a mixture with hardwoods.

Although this case carries with it no endorsement of the strip shelterwood method, and presumably, successful reproduction could have been secured simply through a single clear-cutting, it does bring out the applicability of a shelterwood method on medium sites. The shelterwood method reduces the risk common to clear-cutting in a seed year of losing pine reproduction by sudden exposure of the ground to drying out before the seedlings can become established.

(For an analysis of the growth and development of the shelterwood reproduction in relation to radiation, the reader is referred to the study of this case by Gast, 1930.)

CASE NO. 10

Pine and Hardwoods Following a Shelterwood Type of Cutting in Old Field Pine

Block: Slab City — History to December, 1939
Compartment: II
Stand: P-Hd-1, 2.7 acres

The observed ability of white pine to compete on more nearly even terms with hardwoods on soils of medium fertility and the hazards involved in securing satisfactory pine reproduction by clear-cutting in a seed year prompted renewed interest in the use of the shelterwood method of reproduction. It was by now realized that the failures of the early years

were due chiefly to the fact that this method happened to be tried out in old field pine stands growing on heavy soils highly favorable to hardwoods.

While this case does not properly illustrate the full use of the shelterwood method, since establishment of the pine reproduction antedated the first cutting by several years, it does resemble the group shelterwood method[12] in a number of respects, and the results furnish evidence that this method may be applied with fair assurance of success to even-aged white pine stands growing on medium quality sites.

Site and Land History

This area is located on relatively high (elevation 1,000 feet), level land, exposed in all directions. The soil is a Brookfield stony loam; drainage is rapid, and there is a marked tendency toward dryness. On such sites white pine frequently occurs in mixture with less exacting hardwoods, such as the oaks and red maple.

The original forest was cleared soon after the settlement of the town in 1733, and the land was put to agricultural use. Since the terrain is smooth and the ground relatively free from boulders, it is likely that the area was cultivated, at least for a time. Later on, it was used as a pasture. Upon abandonment as farm land, around 1860, the area seeded in to white pine with a scattering of hardwoods, forming an even-aged stand.

First Shelterwood Cutting—Winter, 1923

The stand was 70 years old, predominantly white pine, with a small proportion of red maple and red oak, well stocked and of exceptionally good form. Pine reproduction occurred in groups throughout the southeastern portion of the stand, originating from the seed crop of 1920. An abundant advance growth of hardwoods included chestnut, black cherry, black birch, red, white, black and scarlet oak, and red and hard maple. The presence of so many species of oak is indicative of the dryness of the site.

The cutting was limited to the southeastern portion of the stand and was aimed especially at stimulating the growth of the groups of pine reproduction. Since only scattered reproduction was present on the rest of the area, it was decided to delay cutting there until such time as additional seeding took place. The hardwood advance growth was cut prior to logging. About half the trees were removed, or nearly a third of the

[12]In contrast to the uniform and strip shelterwood methods, the group shelterwood method is aimed at developing groups of natural reproduction, occurring either voluntarily in natural openings in the stand or brought in by preparatory group cuttings. With the occurrence of subsequent seed years, the groups are expanded by "ring" cuttings. Thus regeneration spreads centrifugally around each group center until the groups eventually meet and the new stocking is completely freed, forming an essentially even-aged new stand.

total volume, in a more or less uniform opening up of the canopy. The cutting took out largely trees in the subordinate crown classes, with an occasional coarse individual from the dominant class. The slash was lopped and scattered. Care was taken to avoid damaging the groups of pine reproduction.

Winter, 1925-26

On the remainder of the area, the somewhat higher and drier portion, pine reproduction now occurred in dense patches, as a result of the seed crop of 1923. There were but few seedlings from the 1920 crop. The hardwood advance growth varied from scanty to moderately dense, mostly 6 to 8 feet tall, and was composed of the same species as occurred in the southeastern part of the area, but with a larger proportion of the oaks. There was a fairly heavy ground cover of lycopodium, blueberry, wintergreen, dwarf raspberry, and other plants.

The remainder of the stand was thinned in much the same way as the southeastern portion, the aim again being to encourage the development of the groups of white pine reproduction which had voluntarily become established. About one-third the volume was removed. The tops were lopped and the slash scattered, as in the 1923 cutting, to keep the ground clear for subsequent seeding.

Final Cutting—Winter, 1931-32

The stand was 79 to 82 years old, with an occasional hardwood, chiefly red maple. Form and quality were far above the average. Growth rate (expressed in ring widths) had doubled since the preliminary cuttings. Six well-stocked groups of pine reproduction, located chiefly on the lower (eastern) side of the area, covered approximately a fourth of the total ground area. Elsewhere pine seedlings occurred scatteringly. The hardwood advance growth was moderately abundant and consisted chiefly of red maple, white and red oak, black cherry, black birch, chestnut, and hard maple.

The ground cover had increased in density, as a result of opening up the stand, in places forming a mat of lycopodium, blueberry, wintergreen, and other plants common to the drier sites. The depth of the organic layer varied from 2 to 3 inches.

The final cutting, covering the entire area, removed all the overwood, together with all hardwood advance growth, except that within the groups of pine reproduction. This came eight growing seasons after the partial cutting of the first area and six years after that of the remaining area, the ages of the pine reproduction being 7 and 11 years. The slash was piled

and burned during the course of logging, care being taken to protect the pine groups.

Following cutting, this small cutting area was completely surrounded by a high forest.

Weeding (First)—May, 1934

The six groups of white pine reproduction now occupied an aggregate area of slightly less than a half acre. During the two years immediately following logging, the pales weevil killed many of the smaller pines; and the branches of the larger pines were fed upon, retarding the growth of

FIG. 56. MARCH, 1932. A PORTION OF THE AREA DURING THE FINAL CUTTING

Two groups of white pine reproduction, just beyond the windrows of logs, were later freed from overtopping advance growth hardwoods. In the foreground, where there was no pine reproduction, the hardwood advance growth was cut prior to logging.

the trees, but in most cases not killing them. At the same time, the scattered hardwoods in the pine groups were beginning to interfere with the pines. These were cut, regardless of species, and the pine completely freed.

No treatment was needed outside of the pine groups at this time. In general, the hardwood area was poorly stocked. Most of the black birch sprouts failed to survive under complete exposure, and the growth rate of all species was noticeably poorer than that on the better sites. Despite the

closely surrounding high forest, only a few birch and maple seedlings had come in between the advance growth sprouts. The leading elements in the new stand were red and white oak sprouts.

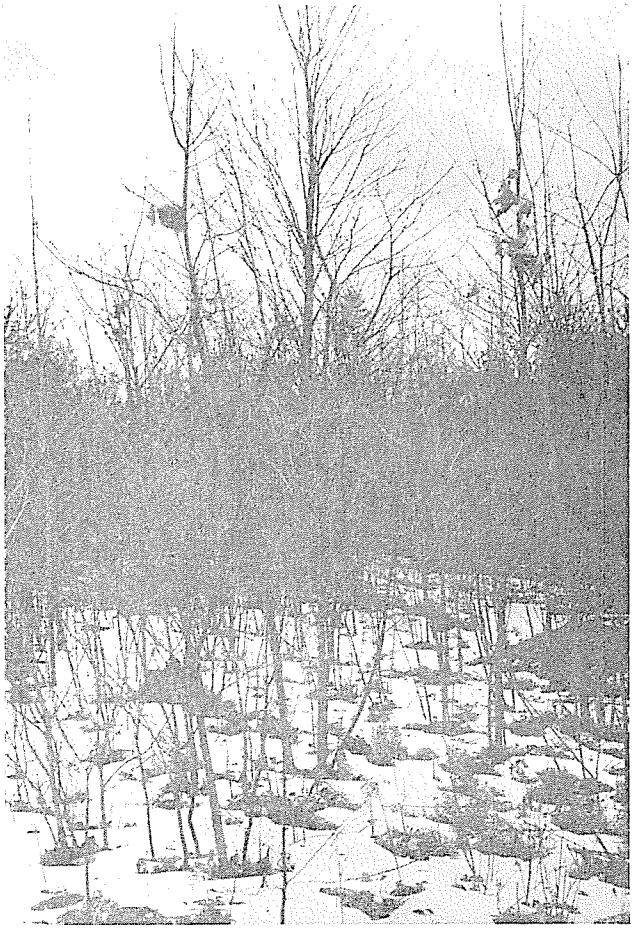


FIG. 57. JANUARY, 1942. A HARDWOOD GROUP AT TEN YEARS

The stocking is poor and many of the oaks are forked and crooked, due to twig die-back. White pine groups appear on either side in the background.

Labor Summary

Since only a single treatment, weeding, has been made on this area since clear-cutting, the regular labor tabulation is omitted. The weeding was done at a rate of 4 man-hours per acre, for the white pine groups.

Inspection of the Stand—Spring, 1935

The prevalence of twig die-back and excessive forking, particularly in the oak sprouts, prompted a special study (MacAloney and Hansbrough, 1936) of the area. Apparently, the damage was caused by late spring frosts, which blackened the foliage and killed the tender new shoots. Stems of seed origin seemed to be less severely injured. Located, as it is, hemmed in by old stands, the area was recognized as being a "frost pocket." The spring of 1935 was especially unfavorable, with extremes in temperature ranging from 86° F. to 23° F. during the month of April (see Fig. 43).

The generally poor stocking of the hardwood area, together with so much frost damage to the oaks, raised doubts as to the possibility of producing a crop of sawtimber.

Condition of the Stand—December, 1939

The stand is a groupwise mixture of white pine and hardwoods. The hardwoods, principally sprouts from the stools of the advance growth that were cut at the time of the final cutting in 1931-32, are 8 years of age. Most of the older pine reproduction is 16 years old. The small white pine groups have been further reduced in size, due to the encroachment of the hardwoods; they are densely stocked and the trees are well formed. Heights run up to 12 feet; this is slow growth in comparison with that of white pine in the best sites. As always, the tallest individuals are in the centers of the groups, the shortest near the edges, where competition with the surrounding hardwoods is most severe.

The hardwood areas vary considerably in density of stocking, from poor on the higher and drier ground in the western portion to medium in the eastern portion. In general, the dominant trees occur scatteringly, forming less than a third of a complete canopy. In all parts of the area, the leading trees, now ranging in height from 12 to 17 feet, are red and white oak and red maple. The oaks tend to be coarse-limbed and forked, and the maples are largely multiple-stemmed sprouts. The only other species occurring in the dominant class are pin cherry, black oak, and paper, gray and yellow birch.

In between the scattered taller hardwoods is a well-defined subordinate stand of thin to moderate density of stocking, including many seedlings 3 to 7 feet high. Its composition runs strongly to red maple, both single- and multiple-stemmed, black cherry, hard maple, and white oak. Pin cherry and red, black, and scarlet oak are less abundant. The form of the subordinate trees is generally better than that of the dominants, but with such an inadequate stocking and slow growth rate, the prospects of developing a good sawtimber crop continued to appear remote. The only

favorable observation, as compared with that at the time of the weeding, was an increasing amount of pine reproduction among the hardwoods, particularly along the western side of the area.

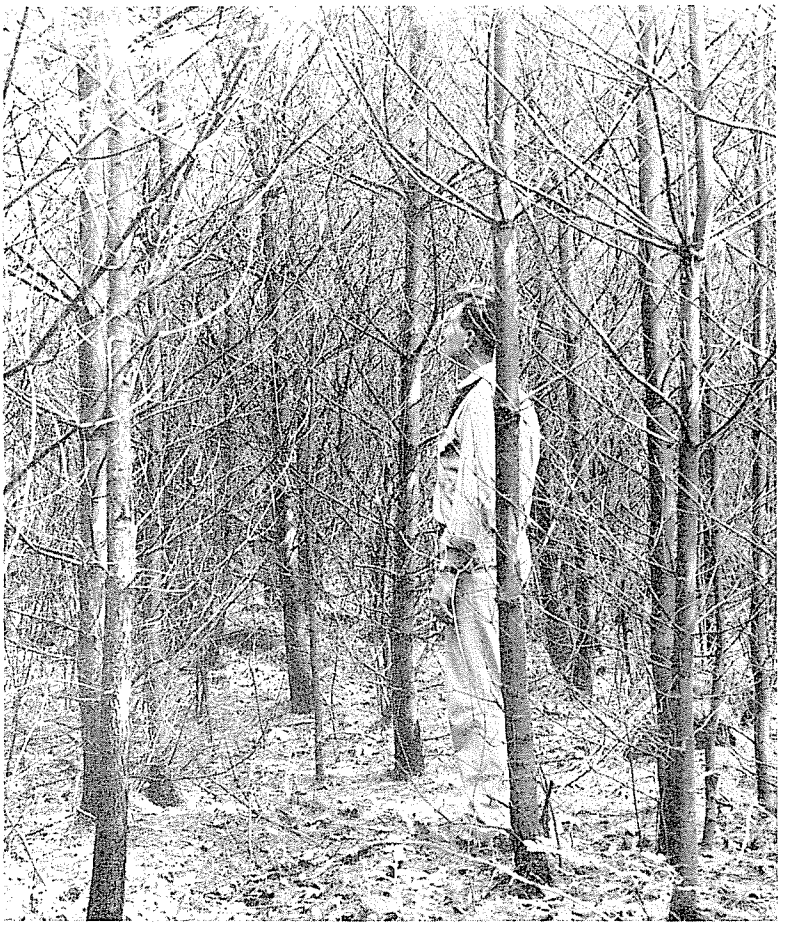


FIG. 58. JUNE, 1946. THE INTERIOR OF A WHITE PINE GROUP

The high density of stocking common to natural groupwise reproduction forces the pine to grow straight despite white pine weevil attack.

A fairly heavy ground cover was present everywhere except under the pine groups. The abundance of blueberry and wintergreen among the ground plants is an indication of the poor site and low stocking of the stand. The soil, also, failed to show the favorable change which invariably accompanies the conversion of old field pine to hardwoods on the best soils.

There still remains a thick layer of partially decomposed organic matter averaging 2 inches in depth, with little evidence of earthworm activity.

Discussion

This is a case where, largely because of the dryness of the site, partial cuttings resembling shelterwood brought relatively satisfactory results in pine reproduction. However, two or three weedings, instead of one, would have preserved a larger proportion of white pine, which, it now

FIG. 59. JUNE, 1946. A HARDWOOD GROUP

Red and white oak, and red maple are the leading species in the overstory. The density of stocking was too low from the start to permit developing high quality timber.

appears, would have been desirable in view of the poor condition of the hardwood areas.

In addition to considerations of lower growth rate and poorer stocking, frost-susceptible sites such as this are not favorable to the development of hardwoods of sprout origin under full exposure. Better results might have been obtained by increasing the number of shelterwood cuttings, thereby lengthening the regeneration period, bringing the hardwood reproduction along under a partial canopy until it became more resistant to frost injury.

A longer regeneration period also would have provided more reproduction, of both pine and hardwoods. The interval between the first and final cuttings was not long enough to establish reproduction in numbers sufficient to withstand losses from logging, slash burning, pales weevil attack, and exposure, and still leave a satisfactory stocking for a new stand.

Although this case is not a true illustration of the application of the shelterwood method, the results obtained indicate that such a method might be advantageously used in the conversion of even-aged white pine stands growing on the poorer sites. On such sites, a method is needed which will assure adequate reproduction before the final harvest, particularly of hardwoods. With even-aged stands, some form of the shelterwood method is the only means of such assurance. Group shelterwood appears to be especially adaptable for establishing a mixed composition of white pine and hardwoods. Dense reproduction usually occurs in groups, and hardwood advance growth of good density likewise tends to be groupwise. By taking advantage of these tendencies, the removal of the overstory can be so regulated that the groups are gradually increased in density of stocking, thus avoiding the formation of a heavy ground cover, minimizing frost damage, and affording needed protection of the site. The final cutting is delayed until the groups coalesce.

CASE NO. 11

Pine and Hardwoods Following the Clear-cutting of Old Field Pine and the Supplementary Planting of White Pine

Block: Tom Swamp — History to February, 1939
Compartment: IV
Stand: P-Hd-2, 4.5 acres

This case is included as an illustration of the relative ease with which a plantation of white pine may be established on a medium quality site, as contrasted with the extreme difficulty experienced on the heavy soils, and also because it is the scene of the first systematic attempt to reduce white pine weevil attack through the shading and suppressive action of a light cover of hardwoods.

While it had been observed for many years that partial suppression of white pines, by overtopping trees, reduced the probability of attack by the

white pine weevil, the temptation to cut overtopping hardwoods usually proved too strong, and the pines were given almost complete freedom in earlier weeding treatments. In this case, a large portion of the cutting area was planted, because of inadequate volunteer stocking, with the result that the large-sized planted groups created conditions similar to those in a pure white pine plantation. Because of the very severe damage from weeviling in widely spaced plantations on open land, an unusually close spacing was used in an open place where lumber and cordwood had been piled; but in the other planted portions of the area, the hardwoods present were to be used both as a substitute for closer planting and for their suppressive action.

Site and Land History

The area is located on a gentle westerly slope at an elevation of about 900 feet. The soil is a Gloucester stony fine sandy loam composed of shallow till material. Drainage is well established both internally and on the surface, and the site considered favorable for growing a mixture of white pine and hardwoods.

This is "second division" land, which probably was cleared for pasture not long after it was granted in 1738. Its abandonment as farm land took place around 1850, and the open fields seeded in densely to white pine and a scattering of hardwoods.

Thinning—Winter, 1911-12

At the time of this first treatment, the area supported a 55- to 60-year-old stand of old field white pine with more than the usual amount of hardwoods, principally red oak, red maple, white ash and paper birch. The stocking was extremely dense, and many of the pines were tall and spindling, with narrow crowns. No hardwood advance growth had appeared as yet and the ground was bare of herbaceous cover.

The records state that because of the dense stocking many pines were becoming infected with red rot. Thus the thinning was made to utilize such trees while they were still merchantable, as well as to improve the growth rate of the residual stand. All seriously defective and overtopped pines of merchantable size were cut for lumber, and some of the hardwoods for fuel. The thinning was light, removing about one-seventh of the total average volume of 35,000 board feet per acre. The operation was coincident with a heavy pine seed crop and it was expected that good reproduction would result.

Clear-cutting—Winter, 1923-24

Thirteen growing seasons had elapsed since the thinning operation

and the stand was now about 70 years of age. Hardwood advance growth occurred in patches. No appreciable amount of pine reproduction was present at this time, although temporary catches occurred the season immediately following the thinning, and after subsequent seed years. The opening of the canopy in the thinning had not reduced the thickness of the organic layer appreciably, so that pine seedlings were highly susceptible to the effects of dryness, and large numbers undoubtedly had died from this cause before they were able to develop roots in the mineral soil.

The advance growth hardwood was mowed just before logging, and the main stand clear-cut in the usual manner, by felling in windrows. Lumber and cordwood were piled on the area, along the compartment

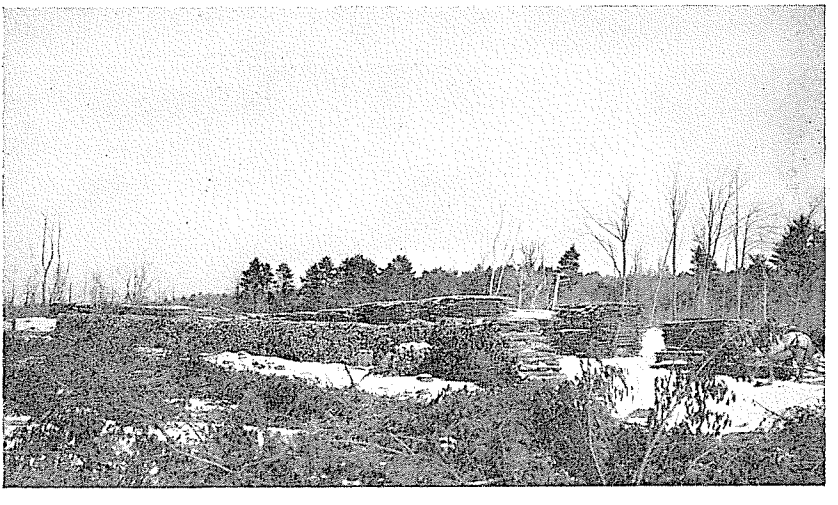


FIG. 60. THE CUTTING AREA AFTER LOGGING

The piles of lumber and cordwood killed the advance growth stools, thus reducing the amount of volunteer stocking. The slash lies in windrows ready for burning in the spring.

road. The red oaks produced some good quality butt logs, suitable for furniture lumber, but the bulk of the hardwood, chiefly red maple, went for fuel wood. The pine was mainly good "box" grade. In the following spring the slash was burned, thus completing the clean-up of the cutting area.

Planting—April, 1926

Since it had become evident by 1926 that the area would not be restocked fully by natural means, it was decided to plant the areas of unquestionably low stocking. Portions of the area sufficiently well stocked with volunteer hardwoods were carefully segregated by encircling with

string, and only the intervening "openings" planted—a method first used the preceding year (Case No. 6). Approximately 3,900 4-year white pine transplants were used, at a spacing of 6′ x 6′ in places where scattered hardwoods were present, and as close as 4′ x 4′ in bare openings. The planted groups were of relatively large size and, in the aggregate, occupied nearly two-thirds of the entire area. Had it not been for the use of part of the area for piling lumber and cordwood, thus causing the loss of advance growth stems, considerably less planting stock would have been required.

FIG. 61. NOVEMBER, 1926. THE FIRST WEEDING

Coarse stump sprouts like those in the center foreground, of red maple, were cut back with machetes to free the planted white pine.

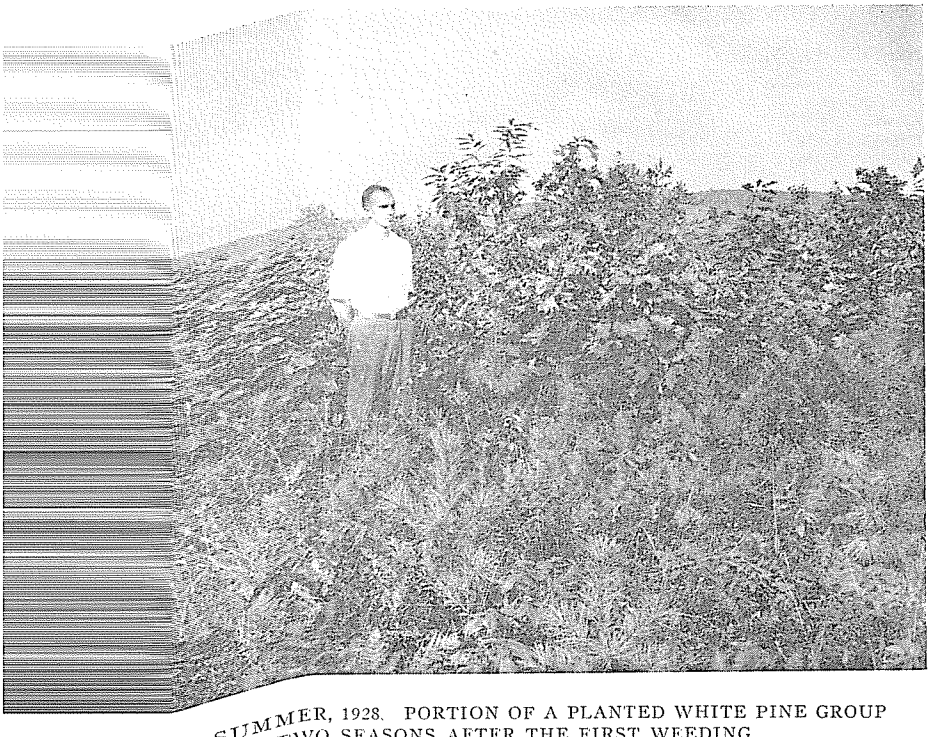
Weeding (First)—November, 1926

This treatment was applied in the fall following the planting and was confined to cutting overtopping hardwoods in the white pine groups. Rank-growing red maple stump sprouts were the most aggressive weeds. No attempt was made to develop a protective hardwood overstory for the pine, since it was known that the young plants would be free from white pine weevil attack for two or three years.

Weeding (Second)—May, 1929

The planted white pine had made good growth during the past three years and very few trees had as yet been attacked by the weevil. The

hardwood groups had steadily improved, and at one point birch had seeded in to justify the extension of one of the groups to include it. Rank-growing hardwood sprout clumps were left in pine groups, but nearly all of the more slowly growing trees were left for the purpose of reducing weevil damage and fertility. In the hardwood groups, all rank-growing sprout clumps were likewise cut back, to favor well-formed individuals of sprouts. All subordinate stems were left as future trainers.



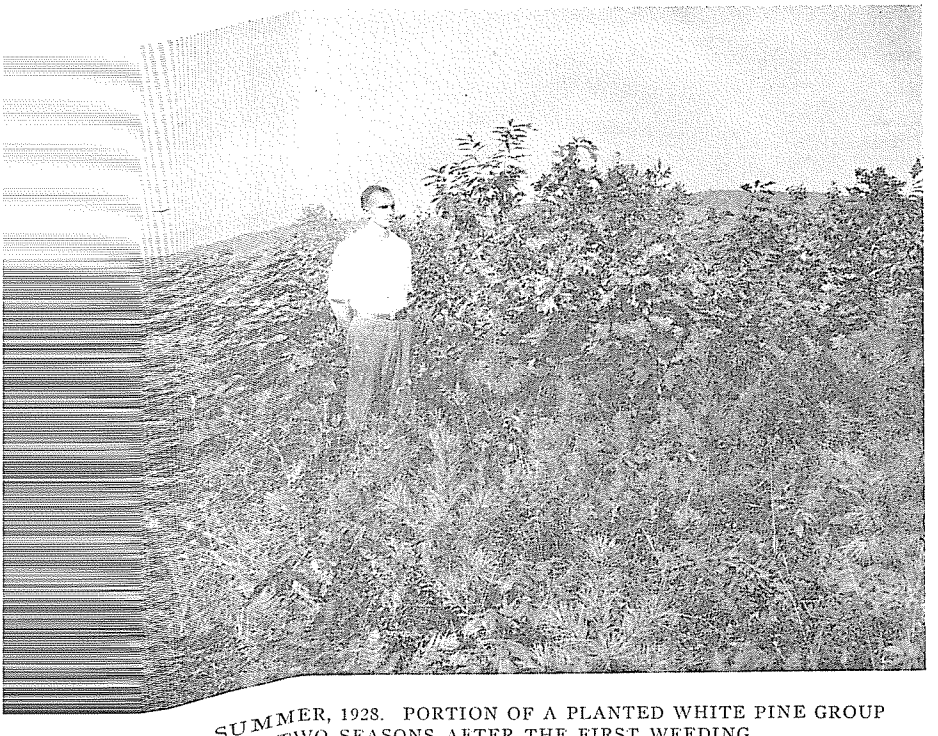
SUMMER, 1928. PORTION OF A PLANTED WHITE PINE GROUP TWO SEASONS AFTER THE FIRST WEEDING

Sprout red oaks from advance growth stools predominate in the adjoining hardwood background.

(Third)—May, 1933

Many of the pines had been attacked by the white pine weevil, making it possible to favor more overtopping hardwoods within the pine groups as a means of additional protection. Thus, overtopping undesirable hardwoods were trimmed, rather than cut, giving freedom for growth of the leaders but retaining full pressure of the hardwood filler on the sides of the pine crowns; in this way, trees which lost their leaders would be

hardwood groups had steadily improved, and at one point birch had seeded in to justify the extension of one of the ps to include it. Rank-growing hardwood sprout clumps pine groups, but nearly all of the more slowly growing s were left for the purpose of reducing weevil damage and fertility. In the hardwood groups, all rank-growing sprout likewise cut back, to favor well-formed individuals of es. All subordinate stems were left as future trainers.



2. SUMMER, 1928. PORTION OF A PLANTED WHITE PINE GROUP TWO SEASONS AFTER THE FIRST WEEDING

sprout red oaks from advance growth stools predominate in the adjoining hardwood background.

(*Third*)—*May, 1933*

of the pines had been attacked by the white pine weevil, making ble to favor more overtopping hardwoods within the pine groups ans of additional protection. Thus, overtopping undesirable hard- were trimmed, rather than cut, giving freedom for growth of the aders but retaining full pressure of the hardwood filler on the sides pine crowns; in this way, trees which lost their leaders would be

stocking of the hardwood groups had steadily improved, and at one point enough paper birch had seeded in to justify the extension of one of the hardwood groups to include it. Rank-growing hardwood sprout clumps were cut in the pine groups, but nearly all of the more slowly growing hardwood stems were left for the purpose of reducing weevil damage and improving soil fertility. In the hardwood groups, all rank-growing sprout clumps were likewise cut back, to favor well-formed individuals of desirable species. All subordinate stems were left as future trainers.

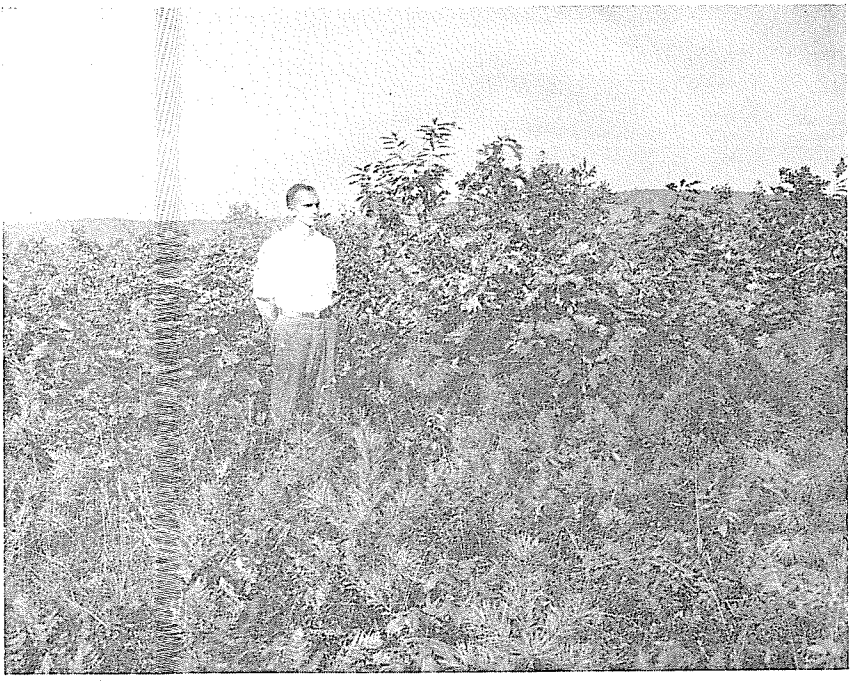


FIG. 62. SUMMER, 1928. PORTION OF A PLANTED WHITE PINE GROUP TWO SEASONS AFTER THE FIRST WEEDING

Seedling sprouts red oaks from advance growth stools predominate in the adjoining hardwood group in the background.

Weeding (Third)—May, 1933

Some of the pines had been attacked by the white pine weevil, making it desirable to favor more overtopping hardwoods within the pine groups as a means of additional protection. Thus, overtopping undesirable hardwoods were trimmed, rather than cut, giving freedom for growth of the pine leaders but retaining full pressure of the hardwood filler on the sides of the pine crowns; in this way, trees which lost their leaders would be

forced to straighten. And scattered hardwoods of good species and form, taller than the pines, were retained in order that their light suppressive action on the pines might lessen the incidence of weevil attack.

In the hardwood groups, dominant trees of inferior species or form were cut wherever better trees were available.

Weeding (Fourth)—April, 1938

This weeding was similar to that of 1933. In the white pine groups, some coarse sprout clumps which had again become dominant were trimmed with machetes just enough to give the pines head room; the other hardwoods, of good species and form, left in overtopping positions in the previous weeding, were retained for continued partial suppression. Side pressure from the hardwood filler was also maintained as before.

In the hardwood groups, individuals of poor form and quality were removed where they interfered with the development of better trees. All subordinate trees were retained as filler and trainer material.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Planting	4/1926	3.0	2	81.0	27.0
Weeding	11/1926	4.5	3	9.0	2.0
Weeding	5/1929	4.5	5	29.8	6.6
Weeding	5/1933	4.5	9	16.5	3.7
Weeding	4/1938	4.5	14	22.2	5.0
Total				158.5	

Condition of the Stand—February, 1939

The stand is about 15 years of age and composed of irregular groups of white pine and hardwoods. Better hardwoods, such as red oak, white ash, and paper birch, of both advance growth and post-cutting origin and taller than the pines, form a light overstory in the pine groups. Also, since the later weedings took the form of topping trees that were directly obstructing the height growth of the pines, there are hardwoods between the pines, acting as fillers to prevent bushiness.

An examination of a representative sample of pines showed 81 percent to have been weeviled at least once, but only 15 percent badly deformed; the remainder had straightened sufficiently as a result of the side pressure by hardwoods to be considered as acceptable crop trees. It was noted that

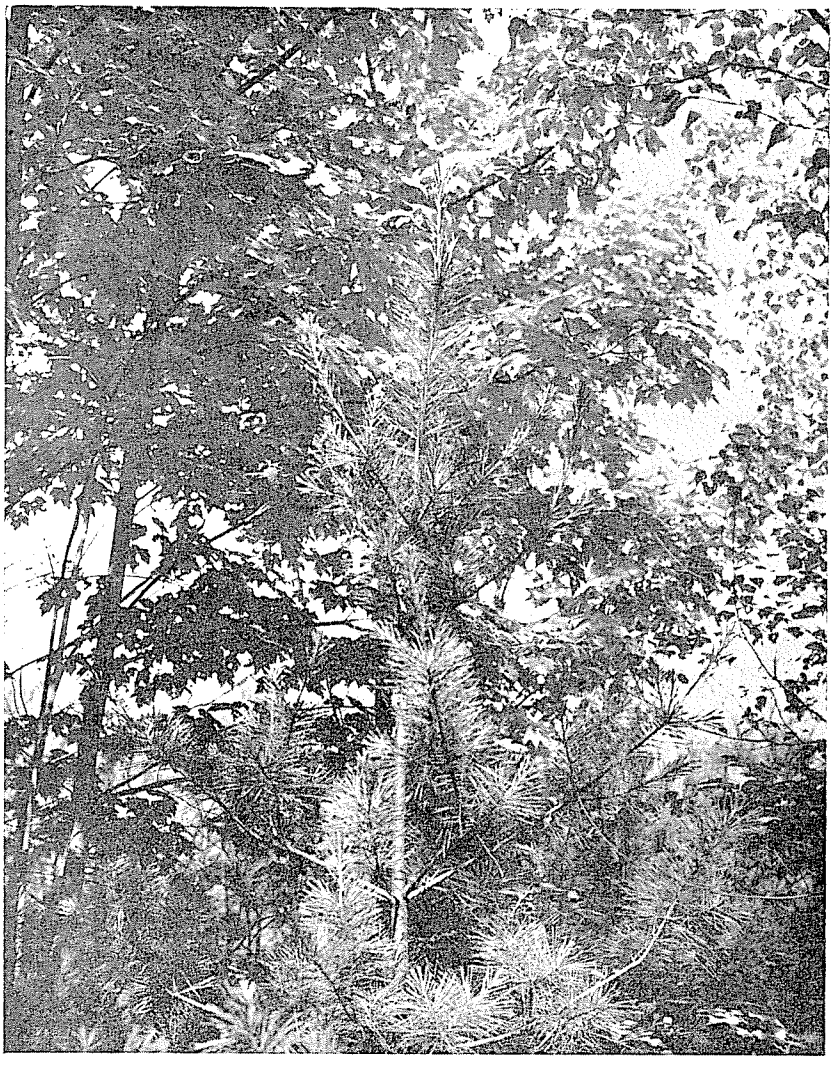


FIG. 63. WHITE PINE PARTIALLY SUPPRESSED BENEATH HARDWOODS

"Shade grown" white pine is comparatively free from attack by the white pine weevil and has smaller branches and a slimmer stem than trees grown in the open.

scrubbiness resulting from weeviling was directly associated with the absence of side pressure. Only 19 percent of the pines had escaped weeviling, and these generally were in subordinate positions.

The hardwood groups, which were rather poor in the beginning, have improved greatly in density and quality. They are dominated chiefly by red oak, which oftentimes is of poor form; but other valuable species, such as white ash, yellow and paper birch, and hard maple, are present in sufficient quantities to insure a good quality sawtimber crop. The average height of the dominant hardwoods is 25 feet, while that of the pines is 18 to 20 feet. It is evident that portions of the pine groups will be taken over by extensions of hardwood groups, a change which need not be resisted, since the hardwoods are quite desirable.

Discussion

The practice of very careful examination of the area just before planting, and encircling with string all adequately stocked groups of natural reproduction, is superior to the indiscriminate uniform plantings used in some of the earlier treatments; not only is the groupwise distribution less wasteful of planting stock, but it also simplifies weeding and facilitates later handling of the stand, the two markedly different elements—pine and hardwoods—being distinctly separated.

The cost of the treatments in this case would, of course, have been considerably less if no planting whatever had been done; and despite the care taken in choosing the areas for planting, it may be said that here again, at the start, the contribution of volunteer stocking was underestimated. However, the initial stocking was so light in places that, if relied upon solely, a second-rate crop would have been produced. Also, on the driest portions of the area, the planting of white pine probably will show more final profit than the volunteer hardwoods which were available for a crop.

Where planting is done so soon after clear-cutting, it is generally impossible to avoid some early weeviling of white pine. The hardwood cover is not sufficiently developed to afford protection for several years. Later, as the hardwoods succeed in forming a canopy over the pines, the degree of suppression can be so regulated as to minimize future attacks. In this case, it appears that better results would have been obtained from a more conservative first weeding and a considerable extension of the area of the hardwood groups, permitted by added volunteer stocking. However, the favoring of a certain number of hardwoods in overtopping positions within the pine groups proved to be helpful in protection against white pine weevil attack; this, together with greater

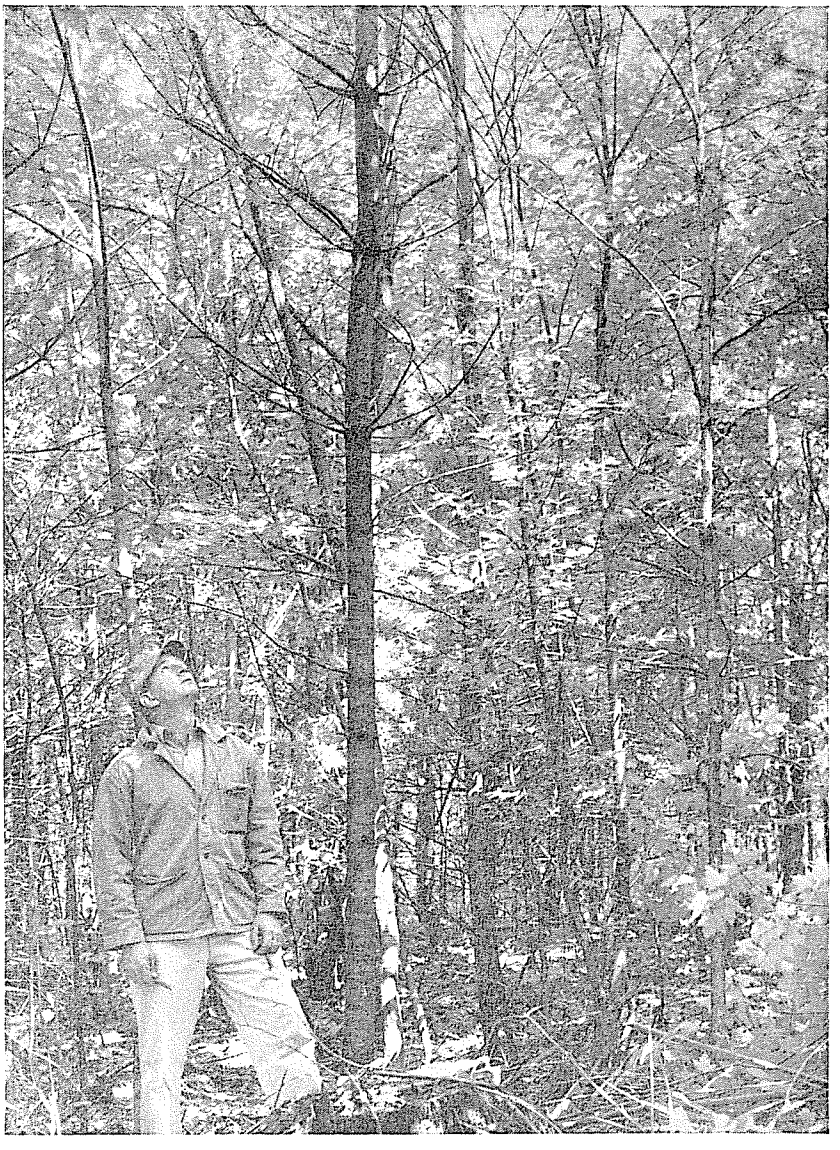


FIG. 64. JUNE, 1946. A PLANTED WHITE PINE GROWN UNDER HARDWOOD PROTECTION AND SIDE PRESSURE

The unusually straight, cylindrical stem with small branches forms the basis of a high quality saw log.

care in maintaining the fullest possible pressure on the sides of the crowns, marked an advance in the technique of growing high quality white pine sawtimber. Much more experience will be required before the best results are obtained. It is now considered impracticable to carry the treatment beyond the time required to produce a high quality butt log, and considerable care must be taken in the choice of hardwoods. Red oak is especially undesirable for the overstory, because of its space-demanding characteristics and its attractiveness to the gypsy moth. While the caterpillars ordinarily do not kill the oak, they may, in the later instars, attack and kill the pine.

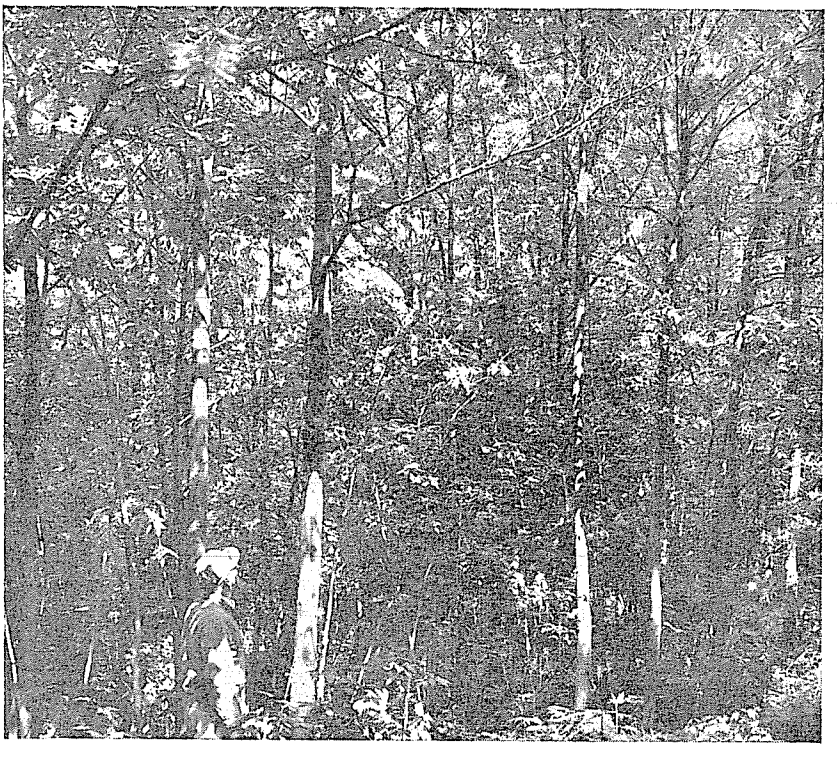


FIG. 65. JUNE, 1946. A HARDWOOD GROUP AT TWENTY-THREE YEARS OF AGE

This is growing on one of the original group areas chosen because of adequate natural stocking and segregated from the planting area by encircling with string.

GROUP SELECTION CUTTING IN OLD FIELD WHITE PINE ON A LIGHT SOIL

CASE NO. 12

Pine and Hardwoods Following a Group Selection Cutting in Uneven-aged Old Field Pine

Block: Tom Swamp
Compartment: IX
Stand: P-2, 10.5 acres

History to September, 1938

Ideally, the group selection form of stand is characterized by an even distribution of groups of trees, even-aged within themselves, but collectively ranging in age, in uniform steps, from young to old. The oldest groups are clear-cut when ready for harvesting, and the openings thus made are restocked by natural reproduction. Thus there is a continuous production, with cutting at short intervals; the soil is afforded partial protection at all times, and logging is facilitated by the removal of entire groups at one time. Such a stand form is never found in old field white pine stands on the heavier soils, but a crude likeness is quite common in pine stands on the lightest soils.

This single case of group selection in white pine in the Harvard Forest occurs on an area of abandoned farm land, an old pasture, on a light glacial outwash soil. Because of the groupwise tendency by age classes, caused by variable ground cover conditions which prevented uniform and simultaneous seeding in of the pine, a decision was made to try to obtain natural reproduction by means of a modified group selection cutting.

Site and Land History

The stand is located on a terrace near a valley bottom, at an elevation of about 850 feet. The soil is a Hinkley loamy sand developed from water-laid materials. The coarse material in the substrata insures perfect underdrainage, being made up of an assortment of sand and gravel of well-defined stratification. The soil is well adapted to conifers, its light texture and susceptibility to drought excluding the more exacting hardwoods.

The land was at one time used for pasturage and then abandoned, probably around 1860. The open ground seeded in slowly to white pine with a scattering of hemlock and hardwoods, chiefly white oak. A few "scrub" pine trees used for shade in the old pasture provided an abundant

source of seed. However, restocking was very irregular, as regards both time and spacing. Some places still remain open, while others support well-stocked pine groups or scattered trees of various ages. Despite an obviously abundant seed source since pasture abandonment, the quick-drying soil and heavy ground cover greatly retarded tree reproduction.

Group Selection Cutting—Winter, 1924-25

The stand at this time had a range in size class from small pine seedlings up to large "scrubs" 30 inches or more in d.b.h. and 70 to 80 feet in height. Except for the old pasture trees, the average age of the oldest pines was between 50 and 60 years. To a large extent the distribution was groupwise, with well-defined clumps of sapling- and pole-sized trees interspersed with a more scattered growth. In some places, open areas of lichen beds supported nothing more than an occasional feeble pine seedling. Many of the younger groups of pine owed their start to the protection of clumps of gray birch nurse trees.

On the whole, the quality of the trees in the young- and middle-age classes was better than under similar conditions of stocking on heavier soils, due largely to decreased susceptibility to damage by the white pine weevil. This difference in the severity of weeviling as related to vigor of tree growth and fertility of soil has been commonly observed (MacAloney, 1930, p. 45).

Observations in pine cuttings made on light soils in the neighboring town of Winchendon had shown that a heavy ericaceous mat invariably followed clear-cutting, and that this greatly hindered the establishment of white pine reproduction. Even pine plantations set out in these blueberry covers grew extremely slowly and could not be considered as a satisfactory means of restocking. The Forest staff, therefore, adopted the policy of applying a partial cutting system which it was believed would not only discourage the formation of such a heavy ground cover, but would also conserve soil moisture and improve seedbed conditions through the partial shading of the ground. Furthermore, the all-aged form appeared to be the natural one for white pine on light, sandy soils, and therefore the one most easily and cheaply maintained.

Within a cutting area of 10.5 acres, 11 groups of merchantable pine were cut; the group areas varied in size chiefly from 50 to 150 feet across, but were irregular in shape in conformance with the occurrence of the oldest groups. Felling was done with a view to easy extraction of the logs, rather than to leaving the slash in any particular manner with respect to reproduction. In some cases the slash was laid around the edges of the opening; in others, especially the larger group cuttings, it was left in piles throughout the opening.

FIG. 66. MAY, 1925. A PORTION OF THE STAND AFTER COMPLETION OF THE GROUP SELECTION CUTTING

The group opening in the foreground was made by cutting a few large, coarse white pines: the aim was to establish natural reproduction in the open places.

Over the remainder of the area scattered merchantable trees which were open grown and coarse-limbed were cut, except for the very largest scrubs. The latter were so crooked and limby as to be useless for lumber, but they made good seed trees.

After logging, the residual stand occupied approximately 45 percent of the total area; the openings made by the cutting took up 40 percent, and the natural openings the remaining 15 percent.

The residual white pine stand varied greatly from place to place, in both age and density of stocking. Generally it was made up of middle-aged trees from 4 to 60 feet high occurring in low to medium densities.

FIG. 67. JANUARY, 1925. OPEN-GROWN SCRUBBY WHITE PINE CUT TO FREE A YOUNG GROUP

The scattered old trees go back to the time the area was used as a pasture. Some of the extremely coarse trees, like the one in the right background, were left as a continuing source of seed.

In a few cases the stands surrounding the group openings were considerably younger, with trees only 10 to 30 feet high. Beneath the oldest residual groups was an understory of hardwoods, chiefly white and red oak and red maple; these occurred in lower densities than is common to understories beneath old field white pine on the heavier soils.

The selection cuttings yielded about 5,000 board feet per acre.

Weeding (First)—April, 1925

Gray birch clumps that had served as nurse trees for white pine repro-

duction had outlived their usefulness and were causing damage by abrasion. These were cut, giving the pine complete freedom. In some cases where the pine only recently had become established the birch clumps were left for further protection.

Weeding (Second)—May, 1929

This treatment was similar to the first except that it was limited to a narrow strip along the western edge of the cutting area. Pine seedlings firmly established under the protection of gray birch clumps were freed.

Weeding (Third)—June, 1937

As in the previous weedings, the purpose of the third treatment was the removal of gray birches overtopping white pines.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Man-hours*	
			Total	*Per Acre*
Weeding	4/1925	10.5	21.0	2.0
Weeding	5/1929	1.0	2.5	2.5
Weeding	6/1937	10.5	21.0	2.0
Total			44.5	

White Pine Reproduction—September, 1931

A report on white pine reproduction, by Cline and Borg, brought out the following relations between ground cover and the establishment of pine seedlings. Reproduction was most abundant on beds of *Hypnum* and *Polytrichum* moss. No reproduction was present in beds of blueberry or reindeer lichen. Where reproduction occurred on beds of mixed moss and lichen, or moss and blueberry, it was confined to spots where the moss predominated. On *Polytrichum* moss, it appeared that the abundance of reproduction varied directly with the thickness of the bed, there being relatively little on the thin beds found in the driest places.

The advance growth hardwoods, which consisted chiefly of red and white oak with lesser amounts of chestnut, red maple, black birch, and black cherry, now averaged 6 to 7 feet in height. Much of this had been cut back during logging, resulting in the sprout form. Hardwood seedlings which started after logging included pin cherry, red maple, gray birch, and some oak. Over the bulk of the area, the hardwood advance growth was of sufficiently good composition and density to warrant its

use as part of the new stocking, even though it was relatively slow growing and poorly formed due to the lightness of the soil.

Reproduction Observations (Cline and Steed, 1932-33)[13]

A later study of the effects of ground cover on white pine reproduction disclosed that all of the openings made in the cutting of 1924-25, no matter how small, had been invaded by ground plants. Among them the most common were bluebeerry, wintergreen, reindeer lichen, *Polytrichum* and *Hypnum* moss, *Lycopodium,* prostrate blackberry, and grass.

FIG. 68. SPRING, 1933. A THICK MAT OF BLUEBERRY IN ONE OF THE OPENINGS MADE IN THE GROUP SELECTION CUTTING OF 1924-25

White pine seedlings will not start in such a ground cover. To avoid its development, the group openings must be small.

Blueberry was found to be the most inhibitive type of cover for white pine reproduction, as well as one of the most common. It occupied a quarter of the total area of the open ground and predominated in the openings made by cutting, as contrasted with natural openings. The organic layer evidently favored the rapid spread of blueberry. In the few

[13]A detailed map showing the location of the various ground cover types in relation to the residual pine groups is in the Harvard Forest records.

places where pine reproduction had made a start in blueberry beds its growth was very slow.

The *Polytrichum* moss type was found to be very favorable for pine reproduction, especially where the beds were dense and shaded, as on the sheltered side of openings made in cutting. In such places the moss often occurred in mixture with wintergreen, while in natural openings it was found with reindeer lichen.

FIG. 69. SPRING, 1933. WHITE PINE REPRODUCTION ESTABLISHED ON POLYTRICHUM MOSS GROUND COVER IN A SMALL OPENING MADE IN THE GROUP SELECTION CUTTING OF 1924-25

This was found to be one of the most favorable conditions for white pine reproduction.

Hypnum moss proved to be the very best ground cover for the start of pine seedlings. Observations showed, however, that it was comparatively uncommon, and its occurrence almost invariably limited to small areas of well-rotted slash in the moister and more sheltered parts of openings made by cutting. The presence of *Polytrichum* moss in mixture with *Hypnum* did not influence the amount of reproduction, but, when wintergreen or blueberry formed a part of the cover, the amount of reproduction was lowered.

Stand Conditions—September, 1938

The openings made by the group cuttings of 1924-25 vary greatly in the amount of pine reproduction, the density depending upon the kind and abundance of ground cover. Those areas with a cover of *Polytrichum* and *Hypnum* moss support pine reproduction ranging from 15,000 to 18,000 stems per acre, while those covered with blueberry have practically no reproduction. Intermediate amounts of pine reproduction are found in the mixed ground cover types. Any association which contained partridgeberry, *Lycopodium*, grass, and wintergreen in mixture with other ground plants was fairly favorable.

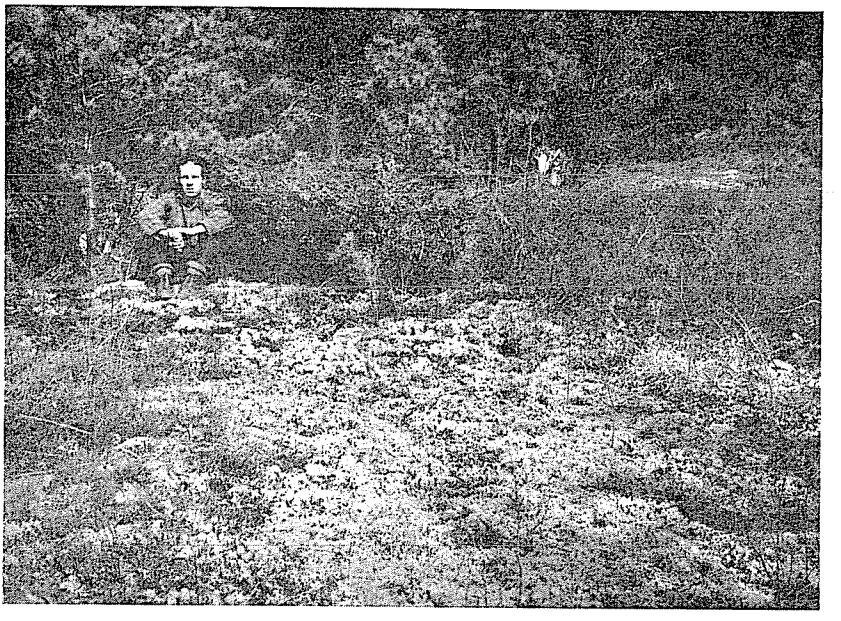


FIG. 70. SPRING, 1933. A GROUND COVER OF REINDEER LICHEN IN A NATURAL OPENING

Once this kind of ground cover becomes established, the area will remain unstocked with trees for many years. Reindeer lichen does not come in on an organic layer, and thus did not invade the openings made by cutting.

The former natural openings, some of which still remain, can be distinguished readily from the openings made by cutting by the presence in them of a *Polytrichum* moss—reindeer lichen association, as well as by the absence of stumps. Where the *Polytrichum* is dominant, reproduction is generally satisfactory; but in cases where the lichen is dominant, reproduction is sparse or absent.

A much larger quantity of hardwoods, both of advance growth and post-logging origin, is present than was anticipated at the time of earlier observations. Chief among the young hardwoods in the openings made by cutting are white oak, red maple, and gray birch, with lesser amounts of chestnut, red oak, and black birch. Their average height is 12 feet. Hemlock has come in scatteringly in the smaller openings.

FIG. 71. 1946. GROUP OF WHITE PINE REPRODUCTION WHICH STARTED ON A MOSS BED

The hurricane destroyed the residual groups, completely freeing all reproduction.

Discussion

The application of a partial cutting system, rather than the usual procedure of cutting all merchantable trees and leaving the ground fully exposed, was not uniformly successful. Many of the openings were large enough to encourage the invasion of ground cover types which inhibited the establishment of white pine reproduction. It is now evident that care must be taken on such sites to keep the group openings small, probably not more than 50 to 75 feet across, in order to avoid a heavy mat of

blueberry. Once such an unfavorable ground cover becomes established, stocking by natural means is extremely slow; and the alternative method of artificial restocking is almost equally unsatisfactory, because of slow early growth.

The best ground cover type, *Hypnum* moss, occurred only on low-lying slash in the moister and more protected portions of the openings. It would appear that this desirable type could be encouraged by lopping and scattering the slash so as to bring it in close contact with the soil.

At the time of an earlier inspection it was recommended that the hardwoods be favored as part of the crop. While hardwoods are at a disadvantage when growing on such light, sandy soils, certain species are beneficial in improving soil fertility, as well as acting as nurse trees for the pine. Even a limited amount of oak may be encouraged, though its effect on soil fertility is at present considered much less favorable than that of the birches and red maple. The form and growth rate of the white pine may be expected to be improved by the presence of hardwoods in mixture.

STANDS FOLLOWING THE CUTTING OF OLD FIELD HARDWOODS

CASE NO. 13

Hardwoods Following the Clear-cutting of Old Field Hardwoods

Block: Tom Swamp History to February, 1939
Compartment: IV
Stand: Hd-2, 5.9 acres (Swale Portion, 2.0 acres)

This is one of the rare cases in the Forest where hardwoods, rather than white pine, took over the land immediately after its abandonment for agriculture. This unusual succession was due to the presence of a number of old open-grown hardwoods in the pasture at the time of abandonment and to the wetness of the site.

The hardwood stand so originating was over 60 years old at the time of the first cutting made by the Harvard Forest. In this cutting and for the first and only time in the Forest, standards[14] were left to go through a second rotation. In combination with a condition under which the hardwood advance growth had become established under a hardwood rather

[14]Trees reserved to go through two or more rotations to provide a certain proportion of large timber and to furnish seed for natural regeneration following the cutting of the single rotation crop.

than a white pine overstory, this departure from the usual cutting practices provided an opportunity for a new series of treatments and observations.

Site and Land History

The area is made up of two narrow benches which converge to form a "Y." The land between the forks is a ridge which rises to a height of 20 to 30 feet above the level of the benches. The slope is generally westerly, and the elevation about 900 feet. Such areas as this are commonly called "tilted depressions," and the water table is comparatively high, due to outseepage from underlying strata. The soil is a Sutton stony silt loam, which is highly productive for hardwoods.

There is evidence that the area was used for a good many years as a pasture. Presumably, because of the wetness of the site, it was not considered a good pasture, and therefore no effort was made to clear it entirely of trees. It was probably reserved as a shade place for cattle. The scattered trees were chiefly red maple, elm, red oak, and chestnut. Abandonment took place about 1850, and the ground became stocked with hardwood seedlings. The new stand was permitted to develop undisturbed until 1910.

Clear-cutting with Standards—Winter, 1910-11

With the exception of a few remaining old pasture trees, the stand at this time was even-aged, 60 to 70 years old. Chestnut, black cherry, red oak, basswood, white ash, and some white pine and poplar occupied most of the area, except in the wettest places, where red maple, elm, yellow birch, hemlock, and white ash were more abundant. The stocking of the main stand was fairly uniform, but its quality and growth rate had been reduced in places by the old overtopping residuals. Advance growth hardwoods in varying degrees of density were present throughout the area, including principally chestnut, black cherry, red oak, and white ash.

The stand was clear-cut, including the advance growth, except for a number of selected standards of white ash, black cherry, elm, and chestnut. All were well-formed specimens with symmetrical crowns. It was believed that allowing them to grow through a second rotation would prove profitable; also that their seed would help restock the cutting area. The cut amounted to about 11,500 board feet per acre, plus an additional 14 cords of fuelwood. A number of large-toothed poplars were allowed to stand to avoid root suckering. As the slash resulting from the cutting was not particularly heavy, it was disposed of by lopping and scattering.

Inspection—November, 1913

The cut-over area was covered with ferns, other herbaceous growth, and young hardwoods. According to a small sample taken in a represen-

tative portion of the stand three years after cutting, the composition was as follows:

	New Seedlings	*Advance Growth Seedlings and Seedling Sprouts* (*Number of stems per acre*)	*Stump Sprouts* (*Clumps*)	*Total*
Black Cherry	96	848		944
White Ash	16	800		816
Yellow Birch		560		560
Chestnut		272	32	304
Red Maple		112	112	224
Red Oak	16	96		112
White Pine	80	32		112
Basswood		96		96
Poplar	32	64		96
Hard Maple		32	32	64
Total	240	2,912	176	3,328

Only 7 percent of the stocking was of post-logging seed origin. Five percent was made up of sprouts from large stumps. The remaining 88 percent owed its origin to advance growth present at the time of cutting. The most abundant species in the stand as a whole were black cherry, white ash, and yellow birch, these three species combined comprising about 70 percent of the total stocking.

Weeding (First)—August, 1914

This treatment was carried out during the fourth growing season after logging. The cordwood cut in the operation of 1910-11 was not removed from the area until the summer of 1912, and considerable damage was done to the young hardwoods at the time of extraction. Blackberry, hay-scented fern, and sedge had come in since logging, but this ground cover was confined to small patches and did not hinder the young hardwoods. In the fall of 1911 a good pine seed crop was produced, and it is likely that seed from an adjoining pine stand fell in the cutting area. However, only a few pine seedlings were found in 1914, and these were in exposed spots along the edge of the stand. The red maple and chestnut sprouts were 15 feet high. Other young hardwoods ranged upward from 6 feet in height. The stocking was fairly dense, and enough well-formed trees were present to produce a good quality stand. The treatment consisted of cutting or breaking back trees of inferior form or species that were interfering with more promising individuals.

Weeding (Second) and Girdling—November, 1920

Six years had elapsed since the first weeding, and many of the better stems were again overtopped by rank-growing sprouts, chiefly red maple and chestnut. Many of the standards left in the cutting of 1910-11 had sprouted epicormically, while others had been windthrown, thus causing some breakage in the young stand. At first it appeared as though a mistake had been made in allowing such a long time between weedings, but,

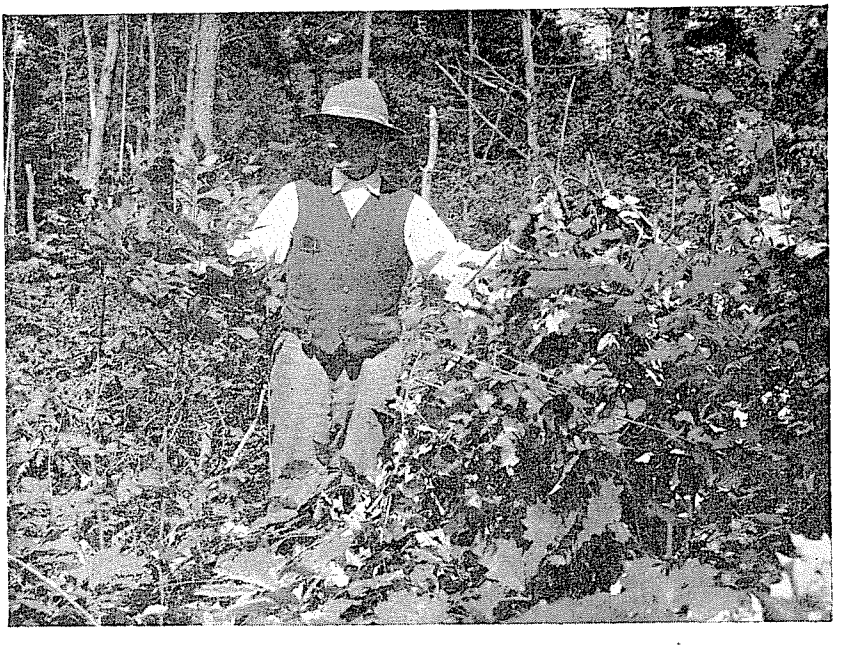


FIG. 72. SEPTEMBER, 1914. THE YOUNG STAND IN ITS FOURTH GROWING SEASON, IMMEDIATELY AFTER THE FIRST WEEDING

Good stems of white ash and red oak were here freed from overtopping stump sprouts of red maple.

actually, enough good stems remained in thrifty condition to insure a fully stocked stand.

The rank-growing sprouts were removed where they interfered with selected crop trees, and many of the remaining standards were girdled. The poor condition of the standards was ample proof that much greater care was required in the choice and development of trees to be retained for a second rotation.

Weeding (Third)—Spring, 1925

A number of red maple sprout clumps, cut back in the earlier weed-

ings, had again overtaken some of the selected crop trees, and these clumps were removed (the chestnut sprouts had been killed by the blight). In some cases, one or two stems in a clump were saved, when leaving them caused no interference with favored crop trees, in the hope that the sprouting vigor of the stumps might be reduced. This hope proved false, as an inspection a year later showed that the reserved stems had grown at a greatly increased rate.

FIG. 73. APRIL, 1929. THE STAND AT EIGHTEEN YEARS OF AGE, AFTER THREE WEEDINGS

White ash is the most abundant species on such moist sites, but the red oak, where it occurs, is faster growing.

Improvement Cutting and Thinning (First)—February, 1933

The stand at this time was 22 years old and composed of a good mixture of promising hardwoods; among the most abundant were white ash, red oak, and yellow birch. Other species occurring less frequently were hard maple, black birch, red maple, basswood, and elm. White ash was the leading species in point of numbers, but red oak the largest in size. Many of the oaks were coarse-crowned and becoming wolf trees.

A small area was staked out to be reserved as a control, and the rest of the stand marked for improvement cutting and thinning. Trees of inferior species or form overtopping promising crop trees were cut, and places of

very high density were thinned. This latter treatment was applied especially to dense white ash groups in which the trees had developed spindling forms.

Approximately 185 trees per acre 2 inches and over in d.b.h. and containing nearly 2 cords were cut. In volume, red oak constituted nearly 30 percent; white ash, black and yellow birch, and red maple, 15 percent each; and paper birch, hard maple, and white oak, the remaining 10 percent.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	8/1914	2.0	4	12.0	6.0
Weeding and Girdling	11/1920	2.0	10	19.6	9.8
Weeding	4/1925	2.0	14	2.0	1.0
Improvement Cutting and Thinning	2/1933	2.0	22	5.0	2.5
Total				38.6	19.3

These treatments have been effective in bringing about the desired results in regard to composition and distribution. From now on, intermediate treatments can be expected to yield material of more than sufficient value to offset the cost.

Stand Conditions—February, 1939

The stand is 28 years of age and composed of a potentially valuable stocking of trees, well distributed and so differentiated that the selected crop trees are generally in a free-to-grow position. Most of the dominant trees have a clear length of at least 16 feet, and a few have clear lengths of nearly two logs. Most of the standards left at the time of girdling in 1920 were windthrown by the hurricane, and some damage by breakage was caused in the young stand. Most of the few standards remaining are elm, and their form is poor.

The composition of a representative portion of the stand is shown in the following table. The tally was made on a cut-and-leave basis, and the trees are grouped according to stand elements.

White ash is the leading species, making up about 75 percent of the 380 crop trees. Red oak is considerably behind in numbers but leads in size. Of the total stocking of 1,720 trees, only 130 were tallied for cutting, most of them poorly formed red oaks.

Diameter (Inches)	LEAVE Crop Trees				LEAVE Inferior Trees (Trainers, Weeds, etc.)								CUT Inferior			
	WA	RO	HM	BB	WA	RM	HM	RO	Bswd	BB	YB	Elm	RO	WA	Bswd	WO
	(Number of stems per acre)															
1					430	40	20	20	10							
2	80		10	10	310	40	40	50	50	10	40	10	10		10	
3	110	10	10		40	10	20				10		30	10		
4	50	10	10							20		10	10			10
5	20	10		10				10		10			30			
6	10									10			10			
7		30														
8													10			
Total	270	60	30	20	780	90	80	80	60	50	50	20	100	10	10	10

Total stems per acre, 1,720.
Average height of dominant trees, 55 ft.

When the above table is compared with that showing the composition in 1913, significant changes are evident. The leading valuable species in 1913 were black cherry, white ash, and yellow birch, of which only the white ash has succeeded in holding a leading position. Black cherry has disappeared from the stand; and yellow birch is so reduced in numbers and position that it will form only a minor part of the ultimate crop. Unlike upland hardwood sites, in which red oak almost invariably becomes more and more dominant as the stand develops, the moist sites favor the development of stands in which white ash predominates.

The wealth of desirable species, clean stems, and an average height of 55 feet for the dominant trees at 28 years of age give promise of a high quality timber crop.

Discussion

The retention of standards at the time of cutting in 1910-11 did not turn out in accordance with expectations. The chestnuts were killed by the blight, and the others were windthrown or sprouted epicormically. The result is not necessarily a reflection on the system itself, but rather on its application in this particular case. Stands which have reached 70 years of age without having been thinned do not contain the well-developed, strong-rooted individuals required to withstand the shock of sudden isolation.

The early treatment of hardwood stands growing on a moist site is less costly than that of stands on better-drained areas, because of the relatively small quantity of red oak. A young mixed stand in which the majority of the crop tree elements are growing at a comparatively uniform rate is

FIG. 74. JANUARY, 1942. A STANDARD KILLED BY GIRDLING

Other standards were windthrown or greatly reduced in quality by side-suckering; and the understory was weakened from competition with the old trees.

covering the larger part of the area, and a Sutton stony silt loam covering the remainder. The former is well drained, and the latter imperfectly drained, but, because of a high water table in this particular area, there is an abundance of soil moisture at all seasons. Conditions were typical of hardwood swales, generally considered very favorable for growing certain hardwoods.

The earliest records (map of 1830) show this area as timbered. Very probably it was a wooded pasture, never completely cleared of trees, although there is unmistakable evidence that most of the surrounding land was cleared for pasture. Perhaps this piece, traversed as it is by a small stream, was used as a watering place and a shade for cattle. In any event, a heavy cutting was made about 1850 which gave rise to a stand of stump sprouts.

Cordwood Cutting—Winter, 1916-17

At this time the stand was largely red maple coppice, with a little white ash and yellow birch, even-aged except for a few old residuals. The age ranged between 60 and 70 years, and the tallest trees reached a height of 80 feet. The quality of the trees was poor, particularly the red maple, which is invariably black-hearted when of stump sprout origin. The ash and birch would have produced some sawtimber, but the quantity of such material was so small and its marketing so uncertain that the entire cut was put into fuelwood.

The stand was clear-cut, and the wood put into 4-foot lengths and yarded to the nearby compartment road. The slash was burned in piles, leaving the area clear for the new stand. No advance growth of any account was present, but a natural seeding in of desirable hardwoods was expected from trees in adjoining stands.

Weeding (First)—March, 1925

Eight growing seasons had elapsed since the clear-cutting. Early expectations regarding the seeding in of valuable species had been realized. White ash, yellow birch, and some hard maple and elm had come in between the red maple sprout clumps. The sprouts were about 15 feet high and the seedlings from 8 to 12 feet. The overtopping sprouts were cut, with the hope that this one weeding would suffice to free permanently the more desirable stems, particularly since the red maple sprouts did not appear to be very vigorous.

Improvement Girdling—June, 1932

At this time the stand was in its sixteenth year, and had a sufficiently high density of good stems to assure the production of sawtimber. Many

of the crop trees were again overtopped by red maple stump sprouts and other weeds. Weed trees were girdled with a chain saw, rather than cut, in order to check the results against a similar girdling operation carried out in a nearby stand in 1929. The trees favored for the crop were the better formed white ash, yellow, black, and paper birch, hard maple, elm, and an occasional red oak.

Improvement Cutting and Thinning—April, 1933

An examination of the girdling done the previous season showed that most of the saw grooves had bridged over, so the girdled trees were cut. Since no bridging of wounds occurred in the nearby area, where the trees were girdled during the dormant season, the failure in this case was charged against the season in which the girdling was done, early June. In some places trees were cut to relieve crowding, the stand being composed chiefly of crown-sensitive species requiring thinning at a comparatively early age.

Labor Summary

Kind of Treatment	*Date*	*Area Covered Acres*	*Age of Stand Years*	*Man-hours*	
				Total	*Per Acre*
Weeding	3/1925	1.5	8	12.0	8.0
Improvement Girdling	6/1932	1.5	16	2.0	1.3
Improvement Cutting and Thinning	4/1933	1.5	16	5.5	3.7
Total				19.5	13.0

The man-hour expenditure for cultural treatments has been very small. This area required only one weeding, in contrast to the usual minimum of two, and occasionally as many as four, required in the volunteer hardwood stands following the cutting of old field pine. The principal reason for this saving was the weakness of the red maple sprouts from large stumps and the scarcity of red oak, a species not well adapted to wet sites.

Stand Conditions—January, 1939

At 22 years of age this stand is one of the best demonstrations of the conversion of the red maple swale type in the Forest. Whereas red maple comprised 80 percent of the old stand, the balance being made up of white ash and yellow birch, 88 percent of the new stand is composed of the more valuable species and only 12 percent of red maple. The treatment has thus accomplished somewhat more than a complete reversal in the relative

proportions of the more valuable species and the less desirable red maple.

The following table shows the composition of the stand:

Diameter (inches)	*Crop Trees*			*Inferior Trees*				
	WA	*YB*	*RO*	*Elm*	*YB*	*RO*	*WA*	*RM*
	(Number of stems per acre)							
1				20	40		10	
2	10			30	120	10	30	30
3	10	40			70	40	10	40
4	60	70	10	20			10	10
5	50	20	10					20
6	30	10						
Total	160	140	20	70	230	50	60	100

Of a total of 830 stems per acre, 320 are potential crop trees, which is more than enough for full stocking at maturity. The inferior trees are generally of good species, but poor in form or subordinate in position.

The crop trees range from 2 to 6 inches, d.b.h., with more than 80 percent in the 4 to 6 inch class. The tallest trees are 40 to 50 feet in height. Such heights at 22 years of age indicate a highly productive site.

Discussion

The present predominance of red maple in swales is due chiefly to past practices, especially the grazing of livestock and repeated clear-cutting for cordwood. Red maple is not as palatable to cattle as some of its common associates, such as white ash and yellow birch, and in cases of light grazing it is rarely fed upon (Day and Den Uyle, 1932, p. 16). Where grazing is heavy, it is eaten; but its ability to sprout vigorously still gives it an advantage over its associates. In the absence of weedings and improvement cuttings to regulate competition, the maple is able to suppress most of the other species at an early age.

In the case at hand, a typical stand of red maple coppice was clear-cut for fuelwood in accordance with the practice commonly followed by local farm woodland owners. An abundance of seed from adjoining stands provided a desirable new stocking of hardwoods. Two treatments during the first sixteen years served to check the undesirable stems, mostly red maple stump sprouts, and to bring out the best crop tree material.

The girdling operation of 1932 was not successful, apparently because it was done at the wrong season of the year; but there is abundant proof elsewhere of the usefulness of this method of eliminating undesirable

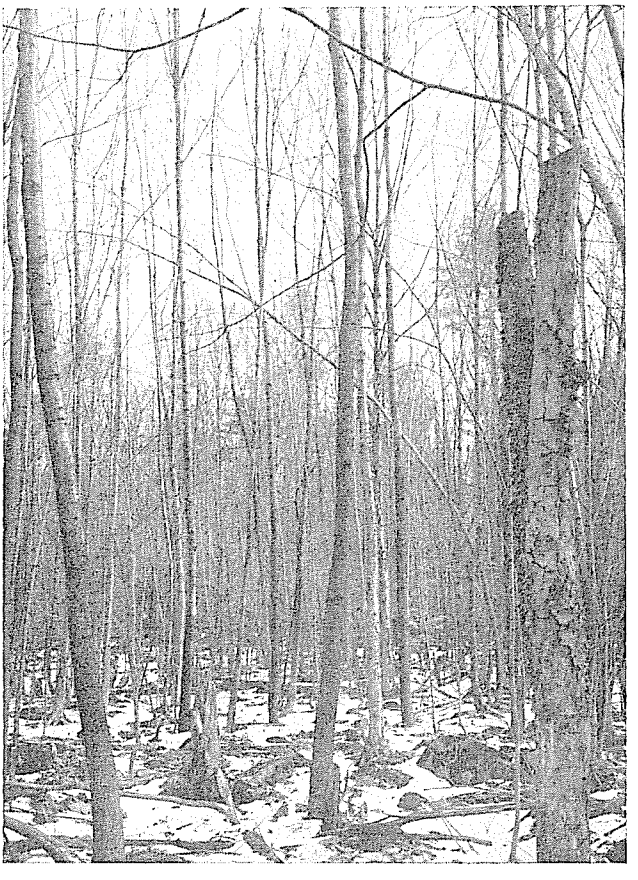


FIG. 76. JANUARY, 1942. THE STAND AT TWENTY-FIVE YEARS OF AGE

Beginning in 1916 with the clear-cutting of a stand of red maple coppice, the application of weeding and improvement cutting to the succeeding volunteer stand has resulted in improved composition and quality. The dead tree at the right was one of those killed by girdling with a chain saw.

trees which cannot be profitably utilized. Girdling is less expensive than cutting, and in cases of light density of stocking or where continued side pressure on neighboring crop trees is desired, it is now considered the preferred method.

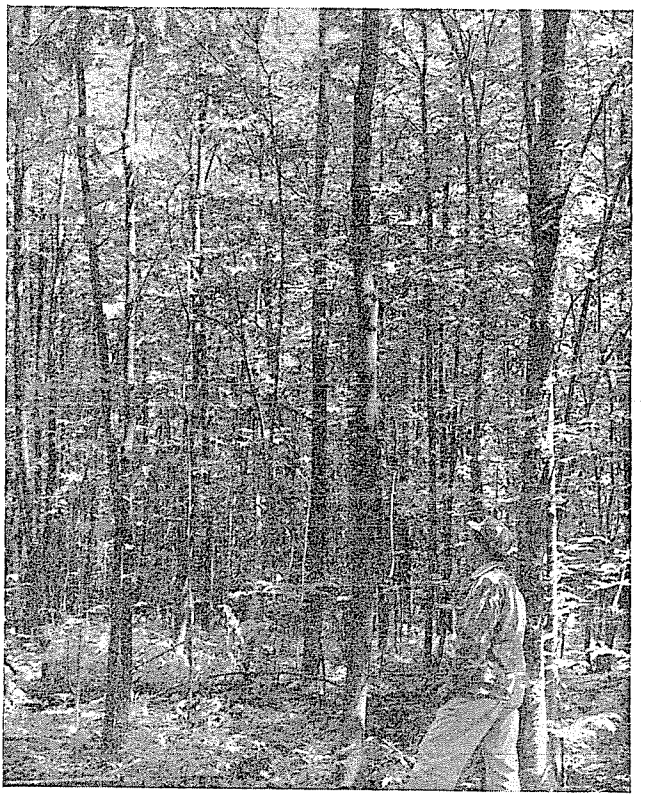


FIG. 77. JUNE, 1946. THE STAND AT THIRTY YEARS OF AGE

The leading crop trees are white ash and yellow birch. Form and growth rate are favorable for producing a sawtimber crop.

The results of treatment in this case strongly indicate that swales can, at little expense, be made to produce good sawtimber in place of red maple coppice, provided a seed source is available. Their limited size and good seed bed condition are favorable for natural restocking following clear-cutting.

SUMMARY AND CONCLUSIONS

The conversion of stands of old field origin has been illustrated by fourteen cases. These cases were chosen as being representative of the various reproduction methods tried out by the Harvard Forest staff, of the results obtained under differing site conditions, and of the varying cultural treatments applied to the new stands. The results are summed up in the following table.

THE RESULTS OF VARIOUS REPRODUCTION METHODS APPLIED TO OLD FIELD STANDS

	Case Number	*Reproduction Method*	*The Succeeding Stand*
		OLD FIELD WHITE PINE CASES	
HEAVY SOIL	1	Clear-cutting in a seed year	Hardwood
	2	Uniform shelterwood	Hardwood[15]
	3	Clear-cutting and supplementary planting of white pine and Norway spruce	Hardwood with one sizable group of white pine[17]
	4	Clear-cutting and supplementary planting of white and red pine	Hardwood[15]
	5	Clear-cutting and supplementary planting of red pine	Hardwood[15]
	6	Clear-cutting and supplementary planting of white, red and Scotch pine and Norway spruce	Hardwood with one sizable group of red pine[18]
	7	Clear-cutting	Hardwood
MEDIUM SOIL	8	Clear-cutting	Pine and hardwood[16]
	9	Strip shelterwood	Pine and hardwood[16]
	10	Shelterwood type cutting	Pine and hardwood[16]
	11	Clear-cutting and supplementary planting of white pine	Pine and hardwood[16]
LIGHT SOIL	12	Group selection	Pine and hardwood
		OLD FIELD HARDWOOD CASES	
	13	Clear-cutting with standards	Hardwood
	14	Clear-cutting	Hardwood

[15]Less than 10% white pine and other softwoods.
[16]In a groupwise distribution.
[17]Pine group on a portion of the area where the soil is comparatively poor.
[18]Pine group on a portion of the area where advance growth hardwoods were killed by lumber and cordwood piles.

It will be observed that in the case of old field stands on heavy soils, the results are practically the same regardless of the reproduction method applied. The strong tendency of hardwoods to follow old field pine was not successfully counteracted by any of the reproduction methods employed or by subsequent weedings to favor the pine. At best, the new stands contain only a minor portion of white pine, or other softwoods; and this portion is subject to still further shrinkage with time. On the medium soils, the proportion of white pine, or other softwoods, in the new stands is decidedly greater. Most of these stands may fairly be called mixed white pine and hardwood. On the light soils the proportion of white pine is still greater, though there are too few cases on light soils in the Harvard Forest to permit determining the measure of the increase.

The conclusion is inescapable that soil is the predominant factor in determining the outcome of reproduction methods and that attempts to encourage species not in the natural line of succession for a given site prove unsuccessful and costly beyond all hope of return commensurate with the outlay.

As to the results of the cultural treatments applied in the young stands following the cutting of the old field stands, they cannot now be fully appraised either in terms of dollars and cents profit or loss, or in terms of altered composition, form and quality of the final stand. Time alone can give the answer. But the treatments have, in numerous ways, changed the natural course of development of the young stands. During the formative period, trees of undesirable species, form or condition have been eliminated by cutting or girdling; congestion has been relieved by thinning; various softwood species, including exotics, have been introduced through supplementary planting; competition between softwoods and hardwoods has been reduced by segregating the two diverse elements into groups; white pine weevil attack has been lessened by using hardwoods as a protective cover; and the gypsy moth has been checked by reducing the proportion of favored food species. All of these treatments were aimed at improving the quality and yield of the final crop, and at showing a greater profit than would have resulted from no treatment or less treatment.

THE OLD FIELD WHITE PINE CASES HEAVY SOILS[19]

Reproduction Methods

The seven cases dealing with the reconversion of old field white pine

[19]Charlton stony loam, Charlton stony fine sandy loam, Charlton stony silt loam and certain types within the Gloucester series which have highly favorable moisture relationships. The term "heavy soils" is here equivalent to "best sites," where total height for the leading hardwood species at 50 years ranges from 65 to 70 feet.

stands on the best soils, well suited to hardwoods, are of special interest in that such meager results followed the expenditure of such large efforts. Clear-cutting in a pine seed year, the shelterwood method, the supplementary planting of white pine or other softwood species, early weedings in the new stand to favor the pine—all failed to make more than a minor impression on the strong natural forces at work in restoring a composition more like that of the original forest. Once the temporary old field type is out of the way, hardwoods voluntarily take over the ground. Space not preempted by individuals of advance growth origin is quickly seized by seedlings of light-seeded species which flourish under conditions of full light and exposure. Within a few years after the cutting of the old field stand, a dense thicket of hardwood stems has formed.

To be sure, better results would have been obtained if all the knowledge gained in thirty years had been available at the outset. However, it is unlikely that such reproduction methods as clear-cutting in a seed year and shelterwood would have worked out successfully even with the fullest possible knowledge of their application. Whether use is made of clear-cutting or partial cutting, cutting by groups or cutting by strips, hardwoods quickly and vigorously take advantage of any break made in the canopy of the old field pine stand, forcefully suppressing all pine reproduction no matter how abundant.

Clear-cutting followed by the planting of thrifty four- or five-year-old softwood transplants gave better results than the natural reproduction methods, especially where planting was confined to groups in places selected in advance as being least favorable for hardwoods. Such places were where the advance growth hardwoods had been killed by lumber piled on the cutting area, and spots, such as knolls, where the soil was comparatively dry.

As between white and red pine used in supplementary planting, the latter proved to be more easily brought through, largely because of its freedom from attack by the white pine weevil and the retention of a leading shoot.

Cultural Treatments

Here again, much better results would have been obtained in treating the new stands if more experience had been available at the start. Outstanding among the advancements made in handling mixtures of softwoods and hardwoods was the development of the groupwise arrangement, either through planting by groups in spots carefully selected as being least favorable for hardwoods, or through weeding out the hardwoods in spots where natural white pine reproduction was most abundant and

thrifty. If this arrangement had been favored in all cases on heavy soils, instead of a stemwise distribution, the outcome undoubtedly would have been more favorable both with respect to the proportion of softwoods in the new stand and the cost of treatment. But such a gain is generally not sufficiently great to warrant the heavy expenditures for planting and weeding on sites so well suited to hardwoods.

Another important discovery was the widely differing growth habits of red oak and white ash, the leading species on the best sites, and the need to assist the ash in competing with the much more aggressive and space-demanding oak. Earlier recognition of this need together with the corollary need of eliminating the rankest growing oaks early in life, especially in isolated positions, would have improved the composition and quality of the new stand, at the same time reducing the cost of cultural treatments. In the early years, those individual oaks which showed a strong tendency to forge ahead were apt to be favored in weedings. This policy might have proved wise had it not been for the loss of chestnut, the only common associate that grew fast enough to keep the red oak in check. With the chestnut gone, red oak became outstandingly aggressive; in the absence of cultural treatments to favor other desirable species, it will form upwards of 75 percent of the crown canopy in older stands. This outcome might not be too objectionable were it not for many extremely coarse and large-crowned individuals, and for the susceptibility of the stand to periodic stripping by the gypsy moth.

The number of weedings and other cultural treatments required during the formative period, approximately the first twenty-five years, ranged from three to six. With due allowance for the unnecessary and futile efforts to bring through softwoods in certain cases, it is believed that four treatments, properly timed, are sufficient, and all that can be justified under present economic conditions. The intervals between treatments in the seven cases of old field pine on heavy soil show an extreme range of from 1 to 14 years. On the basis of all experience to date, the following spacing of treatments appears to be most advantageous:

	Age of Stand Years
First weeding	5-7
Second weeding	8-10
Third weeding	12-14
First improvement cutting and thinning	17-20

One reason, patent to all silviculturists in New England, why young stands should, as a rule, be gone over every few years is that many unpredictable things can happen to set back the stand if not corrected in due time. There may be injurious animal, insect or disease attacks, frost, snow or ice damage, that can at least be partially overcome by timely cultural treatments and control measures.

The range in labor costs for weeding and the other cultural treatments was equally wide, but, with present knowledge and cultural techniques, costs should not exceed 15 to 20 man-hours per acre for the four treatments, not including supervision.

MEDIUM SOILS[20]

Reproduction Methods

The results of various reproduction methods applied to old field white pine on medium soils, as shown for four cases in the table above, are markedly different from those on heavy soils. In every case a substantial portion of the new stand is white pine. This is to be expected, since the less exacting soil requirements of the pine, as compared with those of hardwoods, increase its relative competitive ability. It is evident from experience in the Harvard Forest that the medium quality sites provide the most favorable conditions for growing mixtures of white pine and hardwoods, and that success is likely to attend the application of any one of a number of reproduction methods, including clear-cutting following a seed year, shelterwood, or clear-cutting and supplementary planting.

Of principal concern in developing a high grade, mixed timber crop on these soils is the hardwood element, rather than the pine. As brought out in the cases here included and in other studies made at the Harvard Forest, the hardwood stocking is less dense, the composition less varied, and growth less rapid than on the heavy soils. With a lowering in site quality, the proportion of oak (not only red oak, but less valuable species of oak as well) increases, while that of the more exacting hardwoods, such as white ash, hard maple and basswood, decreases. And, because of lower density of stocking, there is an increased tendency towards coarseness in tree form, particularly in the oaks, and a generally poorer quality crop. At least, the density of hardwood stocking could be increased before the old stand is completely removed, through the use of the shelterwood method, and experience thus far points to the desirability of employing such a reproduction method, rather than a method which, like clear-

[20]Gloucester stony fine sandy loam, Gloucester fine sandy loam, and Brookfield stony loam. The term "medium soils" is here equivalent to "medium sites," where total height for the hardwood species at 50 years is around 60 feet.

cutting and supplementary planting of pine, contributes nothing to the betterment of the hardwood element.

Here, also, the segregation of softwoods and hardwoods in groups has proved to be much better than a stemwise mixture. Variations in soil fertility may be taken full advantage of, groups of hardwoods being favored in the lower and moister spots and softwoods in the higher and drier, such as on the knolls. Oftentimes, a natural groupwise arrangement develops in shelterwood reproduction prior to the final cutting; this may be perpetuated, with some improvements in the size and shape of the groups, in the course of weeding treatments.

Cultural Treatments

As on the heavy soils, cultural treatments in the new stand are needed to get rid of trees of inferior species, form or condition overtopping desirable crop trees. But on the medium soils where mixtures of pine and hardwood are being developed, there is the additional need of segregating the two elements into groups and of repeatedly adjusting the competition around the group margins, where the tendency is for the hardwoods to encroach upon the pine.

Despite less rapid growth rate and generally lower hardwood stocking than on the heavy soils, the presence of two elements growing at such greatly different rates in early life requires at least as many cultural treatments during the formative period, the first weeding coming sooner than in the case of pure hardwoods on heavy soil. Where four treatments are applied, their spacing will be approximately as follows:

	Age of Stand Years
First weeding	3-5
Second weeding	6-8
Third weeding	10-13
First improvement cutting and thinning	15-20

Labor costs will not differ substantially from those on heavy soils, that is, 15 to 20 man-hours per acre. Although more than four treatments may be needed to keep free the margins of the pine groups, such treatments are limited in extent and relatively cheap to carry out.

The pine groups should be small, preferably less than a fifth acre in size, and densely stocked, in order that the pine may benefit from the presence of the surrounding hardwoods and escape the injurious effects of white pine weevil attack. While the presence of hardwoods cannot

directly affect the quality of the pines, except those trees forming the margin of the group, the growth rate and vigor of the entire group should be improved by the addition of hardwood leaf litter and the more open crown canopy and greater exposure of the ground, which promotes decomposition of the litter and its incorporation with the mineral soil.

With respect to density of stocking, one great advantage of pine groups of natural origin over those which are planted is in their high density of stocking and freedom from the crooked and forked boles so common to wider spacings. Where the pine groups are established by planting, serious damage from white pine weevil attacks can be prevented by close spacing (not more than 4 feet) or by using volunteer hardwoods to form a partial cover over the pines (see Case No. 11).

The treatment of the hardwood groups differs from that of hardwood on the heavy soils in that the increased proportion of oak and the generally lower density of hardwood stocking require special efforts to favor other desirable species without resort to heavy cutting. This can best be accomplished by weeding out the coarsest oaks in early weedings—as soon as their inferior form can be recognized—where promising individuals of other species can take over the space. Not the least among the objections to a large percentage of oak is the probability of severe damage to the white pine groups by gypsy moth defoliation.

LIGHT SOILS[21]

Reproduction Methods

Although only one case of old field pine on light soil occurs in the Harvard Forest, the Forest records contain the results of treatments applied under supervision of the Forest staff to such stands occurring elsewhere in the region.

The light sandy and gravelly soils are the natural habitat of white pine and it is on such sites that the species can be grown in almost pure stands with comparatively little expense for treatments to control competing hardwoods. Since the stands usually are uneven-aged and more or less groupwise, some modification of the group selection method is ideally suited to the reproduction and perpetuation of this desirable form of stand.

In contrast to conditions on the heavy and medium soils, where ground cover presented scarcely any problem in connection with the establishment of reproduction, on the light soils ground cover assumes a place of first importance.

The greatest hazard in the employment of the group selection method on light soils—or any other reproduction method, for that matter—is the

[21]Hinkley loamy sand.

coming in of a thick mat of blueberry on the ground opened up by cutting, a mat which practically precludes the establishment of pine reproduction. Best protection against this objectionable ground cover lies in making the group openings small. Just how small is a question requiring further tests, but it is now believed that the group openings should not exceed 50 to 75 feet in width.

Experience gained thus far also shows that scattered low-lying slash in shaded openings encourages the establishment of beds of *Hypnum* moss, which in turn encourage the abundant establishment of white pine seedlings.

Where reproduction of white pine is successful, such as on moss beds and beneath clumps of gray birch nurse trees, its density is high and consequently there is little danger of serious injury from white pine weevil attack. Although the growth rate, and hence the yields, are lower than on the better sites, the form and quality of white pine grown on the light soils is frequently better than that of pine on medium and heavy soils.

The hardwood element on light soils, though less prominent, runs even more strongly to oaks than in the case of the composition of the new stands following cutting of old field pine on the heavier soils. However, on the light soils the hardwoods are obviously so much less desirable a crop than the pine that comparatively little attention is given the constitution of the hardwood element.

Cultural Treatments

Even on the lightest soils, hardwoods, of both advance growth and seedling origin, become established in fair abundance in the openings made by cutting. They include, besides several species of oak, chiefly red maple, gray, black and paper birch, shagbark and pignut hickory, and black and pin cherry. Although the present policy is to favor stands of softwood on these soils, all past experience teaches the exercise of caution in eliminating all hardwoods. Undoubtedly, the hardwoods have a beneficial influence on the soil, increasing its organic content and its water-holding capacity; and it is equally certain that there are many other benefits not yet fully understood.

Except where hardwoods are directly interfering with the growth of young softwoods, as, for example, scattered oaks growing in the midst of a dense white pine group, or clumps of gray birches which have outgrown their services as nurse trees and are whipping the pines beneath, it is advisable to retain a good number of the better hardwood stems, at least during the formative period. In some places softwood reproduction may be scanty or lacking; here hardwoods can be advantageously used to complete the stocking. Such species as the birches, hickories, and red maple

might well be favored in preference to the oaks, both because of their more crown-sensitive characteristics and the more rapid decomposition of their leaf litter.

Where the density of white pine reproduction is very high, as may be the case on *Hypnum* moss beds, thinning may be necessary at an early age to prevent serious damage from snow bending.

A single case provides insufficient experience in weedings on light soils to warrant a definite statement on timing and costs. It appears that as many as three weedings may be necessary to free the young pine from overtopping hardwoods. These will, however, be much less time-consuming than those required on the heavier soils, probably not exceeding 3 man-hours per acre per treatment.

THE OLD FIELD HARDWOOD CASES

The early custom among farmers of leaving a partial stand on wet, swaley areas, because they made poor pastures and served better as watering places and shade for cattle, was partly responsible for the coming in of hardwoods after farm abandonment. However, the swale type seems to be naturally one predominantly of hardwood; and the common occurrence of swales in the Harvard Forest, and in the region, prompted the inclusion of two case histories.

Swale soils[22] are wet and heavy, and imperfectly drained—an ideal habitat for such species as white ash, elm, and red maple. The general practice in recent years of clear-cutting swale stands for fuelwood has resulted in converting what originally doubtless was a good mixed hardwood composition to one dominated by red maple of stump sprout origin —a worthless crop for anything but fuelwood or a similar product.

Reproduction Methods

In both cases herein described, the Forest staff made heavy cuttings in the old field hardwood stands—one in which scattered standards were left to go through a second rotation, and the other a clear-cutting. In the first case, a hardwood advance growth of good composition was available to take over the ground after the cutting of the old stand; in the second case, where the old stand was red maple stump sprouts, a new stocking of desirable hardwoods depended principally on seed from the adjoining stand. In both cases the moist soil made a most favorable seed bed and no difficulty was experienced in obtaining adequate reproduction.

As a general rule, the even-aged stands of red maple coppice, now so

[22]Sutton stony silt loam and Whitman stony silt loam.

prevalent in swales in central New England, can probably best be converted to a mixture of good timber hardwoods by some partial cutting method, preferably some form of shelterwood, which takes full advantage of seed trees of desirable species. White ash, elm, and yellow birch together with red maple of seed origin and good form will supply the bulk of the crop tree material for the new stand.

Cultural Treatments

Weedings and similar cuttings in young stands differ very little from those applied to hardwood following the cutting of old field white pine on heavy soil. Four treatments during the formative period, spaced from 4 to 6 years apart, were required in Case No. 13; and this would seem to be about what is needed in most cases. The labor cost was 19.3 man-hours per acre, which falls within the range of from 15 to 20 man-hours given for the treatment of hardwood following old field pine. In Case No. 14, the timing of the treatments (three in number) was rather irregular and not considered as giving such favorable results as that used in the former case. There is no doubt that great improvement in the composition and quality of swale hardwoods can be accomplished by early treatments to check the red maple stump sprouts and bring out the better crop tree elements.

* * * * * *

Farm abandonment resulted in the temporary establishment of "old field" cover types markedly different from those which originally occupied the land. But the strong successional trend in stand composition toward that of the climax association becomes evident within a few decades after fields and pastures have seeded in to white pine. A thicket of hardwood develops beneath the old field pine. On the heavy soils, the cutting of the pine is followed by the establishment of hardwoods—a long step in the restoration of the original composition. On the medium and light soils, the transformation is in the same direction, though not so extreme; here pine enters into natural mixtures of pine and hardwood, the proportion of pine increasing as the soil becomes lighter.

In the application of reproduction methods in the conversion of old field pine stands, the degree of success varies directly with the degree to which the method operates in harmony with the natural successional trends. A similar relationship exists in the application of weedings to the new stands to alter their natural composition.

Since natural tendencies in composition can be counteracted only by an outlay of time and money commensurate with the extent of divergence therefrom, foresters must decide in each case how far to go in modifying

the natural composition. Judicious modifications are desirable in the interests of stand security, soil improvement, and a more varied final crop. The destructiveness of introduced insect pests and diseases, not a factor in the original forests, is one reason why departures from the natural composition are desirable.

Silvicultural treatments to improve the quality of the new stand by the removal of inferior individuals and the regulation of the density of stocking are on safer ground than strictly composition control treatments and undoubtedly serve effectively to increase the final value of a sawtimber crop.

The successful and economical conversion of the temporary old field pine type to more stable and valuable mixed stands depends very largely upon a working knowledge of local forest ecology and land use history.

APPENDIX

LIST OF TREE SPECIES MENTIONED

Scientific Name[23]	*Common Name*	*Abbreviation*
Acer rubrum L.	Red maple	RM
Acer saccharum Marshall	Hard maple	HM
Betula lenta L.	Black birch	BB
Betula lutea Michaux	Yellow birch	YB
Betula papyrifera Marshall	Paper birch	PB
Betula populifolia Marshall	Gray birch	GB
Castanea dentata (Marsh.) Borkhausen	Chestnut	Chest.
Fagus grandifolia Ehrhart	Beech	Be.
Fraxinus americana L.	White ash	WA
Hicoria spp.	Hickory	Hky.
Ostrya virginiana (Mill.) Koch	Hornbeam	Hnb.
Picea abies (L.) Karst.	Norway spruce	NS
Pinus resinosa Solander	Red pine	RP
Pinus strobus L.	White pine	WP
Populus spp.	Poplar	Pop.
Prunus pennsylvanica L.	Pin cherry	PC
Prunus serotina Ehrhart	Black cherry	BC
Quercus alba L.	White oak	WO
Quercus borealis Michaux	Red oak	RO
Quercus coccinea Muenchhausen	Scarlet oak	SO
Quercus velutina Lamarck.	Black oak	BO
Rhus spp.	Sumac	Su.
Salix spp.	Willow	Wil.
Tilia glabra Ventenat	Basswood	Bswd.
Tsuga canadensis (L.) Carrière	Hemlock	Hem.
Ulmus americana L.	American elm	Elm

[23]From *Check List of the Forest Trees of the United States: Their Names and Ranges*, by George B. Sudworth. U. S. Department of Agriculture, Miscellaneous Circular 92. 1927.

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