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THE YIELD OF VOLUNTEER SECOND GROWTH AS AFFECTED BY IMPROVEMENT CUTTING AND EARLY WEEDING

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The life history of the natural or volunteer reproduction which follows the usual portable mill operation of Central New England involves an enormous waste of potential lumber. This waste consists primarily in the elimination of the more valuable species of trees by the worthless or inferior. Such reproduction originates in part from seed falling at or near the time of felling; in part from stump sprouts, and in part from seedling and sapling advance growth, which was present in the previous stand. Coming after a clear cutting (which, for convenience in logging, includes most of the undergrowth, as well as the merchantable trees), the new crop is substantially even-aged. In composition, however, it exhibits such great variety as to make a classification into even secondary types extremely difficult. Nevertheless, there is a substantial percentage of young growth, amounting for the region under discussion to at least 20 per cent of the areas cut over, which, at the outset, contains the elements of a fully stocked forest of mixed pine and hardwoods.

The natural progress of such crops to maturity is well indicated by the accompanying photograph (fig. 1). This represents a stand which has followed a clean cutting of forty years ago. The original stand consisted of mixed pine and hardwoods over a hundred years old. The cutting was made in a seed year and was followed by a heavy reproduction of white pine. The balance of the new growth was furnished in part by hardwood sprouts and small advance growth and in part by seedlings of gray birch, pin cherry, and large-toothed poplar. The result of forty years of competition among the trees in mixture has been that practically none of the pine survived beyond the small sapling stage. The bulk of the valuable hardwoods, too, are in varying stages of suppression, and the dominant stand consists almost entirely of inferior trees, such as gray birch and poplar or poorly formed specimens of the better species.

This kind of deterioration is so wide-spread in second-growth forests and represents such an apparently preventable loss that it deserves analysis as an important problem of forest management. The purpose of this paper is to present the results of certain experiments, computations, and silvicultural experiences bearing on the practical possibility of increasing the final value of such forests by early weedings or improvement cuttings. In order to make comparisons significant, the

FIG. 1.—*Even-aged stand mixed pine and hardwoods forty years old*
Over 1,500 sapling white pines per acre dead or suppressed under weed species or worthless sprouts

study was limited to the same general association of species, namely, such second-growth forest on cut-over lands as had originated with (potentially) enough both pine and desirable hardwood reproduction to be fairly called a mixed pine and hardwood type. The data and material presented were all gathered on or near the Harvard Forest, in northern Worcester County, Massachusetts. This locality, though situated in the main white-pine belt of the State, is characterized also by a considerable number of hardwood species, due in part to a somewhat heavy soil and in part to being in a transition zone between northern and central forest types. The topography is, in general, a rolling upland or peneplain, ranging from 700 to 1,000 feet above sea-level, and featured mainly by shallow north and south trending valleys. The silvicultural conditions thus represent probably the keenest competition between white pine and hardwoods that occurs in New England.

In order to follow the life history of a typical stand of mixed pine and hardwoods, plots were located in four age-classes of this type, namely, at five, twenty, forty, and fifty years. It is, of course, possible in volunteer stands to find different areas with exactly the same composition, but the samples chosen are near enough alike for purposes of comparison and represent conditions very prevalent in the region.

TABLE 1.—*Summary of Reproduction*

Plot I. Area, 1/16 acre. Age, 5 years.

Species	Seedlings	Seedling sprouts. No. of clumps	Stump sprouts. No. of clumps
Red oak	38	21	1
Black cherry	180	5	..
Chestnut	19	8	9
White ash	68	54	4
Hard maple	33	9	..
Red maple	25	4	2
Gray birch	50	10	2
Large-toothed poplar	55	17[1]	..
White pine	62	...	..
Totals	530	128	18

[1] Root suckers.

The first plot examined (Table 1) shows what may fairly be expected as a volunteer forest following clear cutting. This table gives an enumeration of all trees, still growing and thrifty, five years after the previous stand was cut off. The cutting took place immediately following a heavy fall of pine seed, and differed from the ordinary commercial operation only in that the slash was burned after the logging and before the first growing season. The composition here shown is very nearly the same as that of the stand shown in the illustration (fig. 1). Although the white pine and many of the valuable hardwoods in this sample plot were still thrifty, they were already overtopped and plainly soon to be suppressed entirely.

It is in the older plots that the effect of the competition in height growth on the progress of wood production is chiefly to be looked for. By the time a stand is passing into the large sapling stage the relative position and condition of the crowns is a true index of the rate of growth and power of survival of the different trees. In analyzing these older sample plots the aim was, first, to show graphically the silvical condition of the stand, and, second, to get a basis for calculating the

TABLE 2.—*Basis for Calculation of Final Yield after Improvement Cutting*

Plot II. Area, ¼ acre. Age, 20 years.

Height (feet).	White Pine.			Red Oak.			Red Maple.			Chestnut.			Black Cherry.			Gray Birch.			Poplar.			White Oak.		
	Species by tree classes: A, clearly dominant; B, overtopped, but still thrifty; C, suppressed or dead.																							
	Stand before cutting (by heights)																							
	A	B	C	A	B		A	B	C	A	B	C	A	B	C	A			A	B	C	A	B	C
5	..	40	116	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10	..	65	62	..	..	2	..	1	4	..	..	1	..	..	..	..	..	..	..	..	..	..	..	3
15	1	77	6	1	1	11	..	13	13	..	..	3	..	1	2	..	4	1	..	..	1	..	7	16
20	3	13	3	4	1	1	2	13	3	..	8	1	..	..	..	6	18	1	2	2	3	2	13	..
25	3	3	...	7	8	2	2	9	..	2	5	..	1	2	..	34	10	..	4	9	5	6	3	..
30	1	...	...	4	6	..	4	1	..	7	1	..	..	..	..	35	1	..	25	4	1	1	..	..
35	..	...	...	9	3	..	1	..	..	2	..	..	..	..	..	15	2	..	15	..	1	..	..	..
40	2[1]	...	...	2	1	..	..	..	..	1	..	..	..	..	..	..	..	..	4	..	..	..	..	..
Totals	10	198	187	27	20	16	9	37	20	12	14	5	1	3	2	90	35	2	50	15	11	9	23	19
D. B H. (inches).	Tally of trees cut (by diameters)																							
1	..	...	...	1	3	..	1	3	..	1	..	..	..	2	..	8	19	..	1	3	..	1	1	..
2	..	...	...	2	6	..	6	3	..	1	8	..	1	..	..	52	15	..	10	2	..	4	1	..
3	..	...	...	4	..	..	1	..	..	5	2	..	..	..	..	24	..	..	22	7	..	3	2	..
4	..	...	...	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	11	..	..	1	..	..
5	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
6	..	...	...	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Totals	..	...	...	7	9	..	8	6	..	14	10	..	1	2	..	84	34	..	45	12	..	9	4	..

D. B. H. (inches).	Tally of trees left for final stand (by diameters)																						
1	..	84	...	..	6	..	1	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..
2	..	28	...	1	1	..	1	1	..	..	1	..	..	..	..	..	..	..	1	..	..	3	..	..
3	7	1	...	7	1	..	2	1	..	1	..	..	..	..	..	..	..	..	8	..	..	2	1	..
4	..	1	...	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	..	1	..	..
5	..	...	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6	1[1]	...	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	1[2]	...	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Totals	9	114	...	11	8	..	4	14	..	1	1	..	..	..	..	..	..	..	13	..	..	6	7	..

[1] Advance growth.

[2] 56 trees eliminated as certain to be crowded out in 10 years.

final yield upon two assumptions—one that the stand should remain untouched until maturity and the other that it should immediately be treated for the release and stimulus of the valuable trees through an improvement cutting.

Table 2 is a specimen of the form of record used for this purpose. It represents a quarter acre sample plot in a stand twenty years old. The upper section of the table shows all the trees on the area by species, by height, and according to whether they were (A) dominant, (B) overtopped but still capable of recovery, or (C) completely suppressed or dead. In the two succeeding sections of the table the same trees are listed by diameter breast high and separated into two classes—one for those to be taken out in the improvement cutting and the other for those which would remain to form the final stand. The section listed by height gives a significant representation of relative height growth. The two other sections of the table furnish the basis for the computation of final yield.

First, as to silvical inferences which can be drawn from the table. The site was, of all the plots dealt with, the poorest, being a flat, rapidly drained area on the edge of a small sand-plain. As such it was distinctly less favorable for the better hardwoods than any of the other situations considered. Nevertheless, at twenty years old, the majority of the white pines were less than 15 feet high, and the main portion of the dominant stand, consisting almost wholly of hardwoods, was over 25 feet high. The amount of true sprout growth was relatively small and the main stand was made up of large-toothed poplar and gray birch. Of dominant trees, 30 feet or more in height, there were 128. Of these, 95 were poplar and gray birch and only three were pines, two of which were advance growth that had escaped the previous cutting. From the point of view of silvicultural treatment, the significant thing was that about half the white pines on the area (trees of class B) were still vigorous enough to make normal growth if released.

The last two sections of the table show how the stand would be reduced if this release were carried out. The separation into trees to be cut and trees to be left was made after the stand had actually been marked on the ground for the necessary cutting. The computation of growth from this classification necessarily contains an element of silvicultural judgment, but one which is justifiably based on the results of similar cuttings carried out on the forest during the past nine years. In the first place, it was a question of judgment which of the overtopped trees were to be considered capable of resuming their normal growth after being released. No trees were put into this class about which there was any reasonable doubt, and in calculating their growth for the balance of the rotation five years were allowed for recovery from the condition of partial suppression—a period found in practice to be conservative. A further element of silvicultural judgment was involved in arriving at the number of trees of each species to be expected in the final stand at sixty years. This reduction was made on the ground at the time the plot was measured. Naturally, considerably more trees would be left after the improvement cutting than could survive to maturity, even though all were individually capable of thrifty growth. In the present case the number of trees left standing was arbitrarily cut down in accordance, first, with the relative crown development of each group, and, second, with the number of stems to be expected in a fully stocked stand at sixty years, as determined from local yield tables. The irregularity of crowns, inevitable in a volunteer forest, of course prevents exact uniformity in the density of the stand. The figures here assumed are at least conservative for the growing stock actually on the ground. The rotation was taken as sixty years; height and diameter growth were derived from model curves, based on stem analyses of normal trees accumulated over several years of fieldwork on the forest. The volumes were obtained from mill tally volume tables applicable to local usage and tested with reference to actual sawmill output. The results of the computation of yield, first, for the plot if left to reach maturity without treatment, and, second, after having been given an improvement cutting, are shown in Table 3.

TABLE 3.—*Plot II—Summary of Final Yields at 60 Years*

Species	Final volume without improvement cutting			Final volume with improvement cutting		
	No. trees	Saw timber, bd. ft.	Firewood, cds.	No. trees	Saw timber, bd. ft.	Firewood, cds.
White pine..	9	2,689	....	60	7,165	....
Red oak ...	12	550	....	14	470	....
Red maple..	12	....	1.75	14	....	1.50
Poplar	33	....	1.75	9	445	.45
White oak..	8	....	.60	9	....	.30
Chestnut[1] ..	15	....	.....	...	....	....
	89	3,239	3.10	106	8,080	2.25

[1] Eliminated as certain to die of disease.

The improvement cutting thus raises the final volume of saw timber on the quarter acre from 3,239 board feet to 8,080 board feet. This increase is almost entirely in pine, since most of the dominant hardwoods would be cut to make way for it. In addition, by removing heavy crowned trees and effecting a better distribution of those which remain, the cutting makes possible a higher number of trees per unit of area, a more complete utilization of growing space, and consequently a better quality of tree. The net result of the operation is to convert a stand which was prospectively composed of inferior hardwoods into one which would at maturity consist largely of white pine.

To show the tabulated records for the remaining older plots would require an unreasonable amount of space. Therefore, since with the type in question it is the final percentage of white pine which really

FIG. 2.—*Even-aged reproduction mixed pine and hardwoods seven years old, immediately after second weeding*

Species: White ash, white pine, red oak, and paper birch

fixes the value of the crop, the condition of the stand in the remaining two plots, as well as in that just discussed, is shown by a tabulation with respect to white pine alone.

TABLE 4.—*Total Number White Pines in the Several Tree Classes for all Plots, Showing Progress of Suppression as Related to Age and Site*

Plot	Age	A trees	B trees	C trees	Quality	Area
II	20	10	198	187	III	¼ acre
III	40	14	39	413	I	¼ acre
IV	50	24	24	141	II	¼ acre

In Table 4 are summarized the numbers of white pines on each of the three plots, according to the crown classification used above. There is also noted for each plot the quality of the site. Even making liberal discount for original differences in the number of trees per acre, this crown classification, taken in connection with the character of the sites, brings out some useful facts. The number of dominant, or A, trees is hardly significant, since it is largely a matter of accident how many individuals have been free from suppression from the start. The sudden drop in the number of B trees (overtopped, but still thrifty) between the twenty and the forty year age seems to indicate that any attempt at a profitable improvement cutting must be made before the twentieth year. In fact, considering conditions on Plot III, the cutting would probably have to be made even earlier. This plot represents soil of quality I—a site distinctly more favorable for hardwoods than for pines. The figures show that suppression proceeded here much more rapidly than on the lighter, sandier soil of Plot II. The 413 trees in class C were all dead, for the most part about twenty years old and between 10 and 15 feet in height. These were almost exactly the general dimensions of the B trees in Plot II, which, nevertheless, though completely overtopped, would most of them have survived from five to ten years longer on the poorer soil. It seems fair to conclude, then, that if a young mixed stand is to yield a substantial percentage of white pine it must be treated for release and improvement not later than the twentieth year, and still earlier on good soils.

Similar but less well-marked conclusions can be drawn with respect to some of the more valuable hardwoods in such mixed stands, but, being more difficult of decisive statement and less important in determining the final value of the stand, they are not here considered. Again, it should be noted that the several plots are not sufficiently uniform, either as to site or stocking, to make absolute comparisons possible. The results, however, are sufficiently large to be, in spite of this, conclusive.

TABLE 5.—*Summary of Computations for all Plots on Basis of Yield per Acre at 60 Years*

Plot	Age	Final volume without improvement cutting: No. trees	Saw timber, bd. ft.	Firewood, cds.
II	20	356	12,956 (pine, 60 per cent)	12.40
III	40	284	13,880 (pine, 60 per cent)	22.68
IV	50	320	12,820 (pine, 55 per cent)	8.50

Plot	Age	Final volume with improvement cutting: No. trees	Saw timber, bd. ft.	Firewood, cds.	Intermediate yield: Firewood, cds.
II	20	424	32,320 (pine, 85 per cent)	9.00	11.40
III	40	368	17,356 (pine, 75 per cent)	17.00	6.28
IV	50	332	16,064 (pine, 60 per cent)	2.50	7.12

In Table 5 are stated the final yields for each of the three plots on an acre basis, including the volume of mixed wood in cords derived from the improvement cutting, which, under average market conditions, would more than pay for the operation. For simplicity all species yielding saw timber were thrown together, but the per cent of the total represented by white pine is shown in each case in parenthesis. The figures show that the final yield of saw timber, at least on sandy soil, can be nearly tripled by a release cutting made about the twentieth year, and that thereafter the possibility of improving the final yield grows rapidly less. The figures do not indicate, however, what may be expected from proper cuttings made before the twentieth year, although

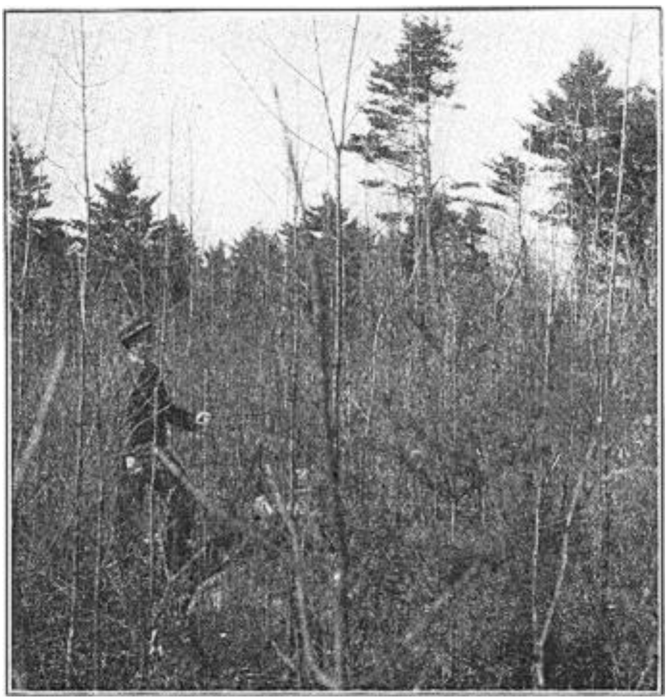

FIG. 3.—*Even-aged sapling stand two years after second weeding*
Species mainly white ash, red oak, and white pine. Forest weeds finally eliminated.

the obvious presumption is that an earlier cutting would produce a still better result, especially on the better soils. In stands less than twenty years old, where the effect of competition in height growth has not so completely declared itself, it is very difficult to make a crown classification on which a specific calculation of yield can safely be based. Nevertheless, it is possible to get a definite idea of the possibilities of earlier forest weeding by reference to operations and experiments carried out in young growth less than ten years old.

The destructive competition that takes place in a young mixed stand is not solely a matter of worthless species against desirable species or of rapid-growing against slow-growing trees. It is a matter of faulty physical arrangement of the whole crop. Enormous variations in height growth are exhibited by the same species, according to whether the individual stem is a seedling which originated under forest cover, or a sprout from such a seedling, or a sprout from a stump. Furthermore, the size and situation of the stump or stool itself involve still further fluctuations in height growth. Again, a vigorous and symmetrical sapling, such as would be abundant in the advanced growth under the previous stand, may by five feet of extra height at the start develop into a destructive wolf tree, even though itself of a valuable species. In other words, it is not possible to reduce the rates of growth and behavior in a stand of different species to the basis of an exact statement. Each individual tree has peculiarities of its own, and only the judgment of a person of experience can analyze a stand according to its prospective development.

The ideal silvical condition for timber production is a well stocked and evenly distributed stand of trees in which all are of valuable species and of such uniform height growth that the general crown canopy will develop evenly. An early weeding, therefore, should have for its object the best distribution of the best available trees and a uniformity of height and height growth such that there will be an early closing of the crown cover and the certainty that the desirable species will at least keep pace with any inferior trees that may have to be left.

TABLE 6.—*Average Heights up to Six Years Old of White Pine and the Sprouts of Six Associated Species*

	Average heights in feet							
Age, years	Red maple	Gray birch	Poplar	Red oak	White ash	Chestnut	Sugar maple	White pine
1	3	4	2½	2	2	3	2	...
2	5	7	4	4	4	6	4	.4
3	7	9	6	6	6	9	6	.8
4	9	10	8	7	7	11	8	1.5
5	12	11	11	10	10	13	11	3.0
6	14	12	16	13	13	15	13	4.0

Based on approximately 800 measurements. Quality, I.

Reference to Table 6 will show the difficulty of achieving this result. Speaking in general, the dominant new growth on a cut-over area will be between 12 and 15 feet in height (at the end of six years), when white pine of the same age and not retarded by overhead shade will have reached the height of only four feet. Furthermore, owing to dense and bushy development, the sprouts of desirable species like white ash may be quite as worthless in prospect as those of red maple. Between the two extremes of height growth, as represented by the hardwood stump sprouts at one end and the white-pine seedlings at the other, there will be a large amount of other seedling and sapling reproduction, as shown in Table 1, much of the best of which will be nearer the normal rate of white pine than the excessive rankness of the sprouts.

If the best results in the form of final value are to be achieved, it is plain that the first weeding must be applied earlier than the sixth year, since by that time suppression of the more valuable elements in the crop is already well under way. On the other hand, if the first weeding is made too early, the smallness of many of the seedlings and the rankness of herbaceous growth may render impossible a proper recognition of the true composition and promise of the crop. In addition to the most favorable date for the first weeding, it is also highly important for the forest manager to know how often and how many times the operation will have to be repeated. The proper date for the first weeding should coincide with the time when the reproduction is large enough to be fully recognizable in detail (*i. e.*, as to species and condition) and before any of the more valuable trees have begun to be seriously suppressed. Experience on the Harvard Forest indicates that this time is during the third or fourth year. The frequency with which the crop will have to be treated depends both on its composition—that is, how vigorous and numerous the desirable trees are in comparison with the undesirable—and, second, on the quality of the locality. The better the site the more rapid and persistent will be the growth of the hardwoods that must be eliminated. The general object should be to maintain the largest possible proportion of valuable trees in favorable growing condition until they have reached a size and rate of height growth that will enable them to keep even with or ahead of the weed element in the stand.

TABLE 7.—*Current Height Growth for last Two Years in Even-aged Sapling Stand Eight Years Old and Twice Weeded*

Species in mixture	Seedlings, height growth, feet		Seedling sprouts, height growth, feet		Stump sprouts, height growth, feet	
	1915	1916	1915	1916	1915	1916
White pine	1.2	1.4	...	...	...	...
White ash	.5	.3	.8	1.0	...	...
Red oak	...	...	1.1	1.7	...	...
Sugar maple	.6	.9	...	...	1.0	1.4
Red maple	.7	1.4	...	...	2.0	1.6
Black cherry	.9	.7	...	...	.8	1.0
Chestnut	1.5	1.0	...	...	1.3	1.6
Paper birch	...	...	1.6	2.1	...	...
Gray birch	...	...	1.5	1.1	...	...

Based on measurements of 245 trees. Average number per acre, 2,500. Average height, 6.4′; range of height, 4.2′ to 11′. Quality, I.

In the case described below this equality of height growth seems to be reached after the eighth growing season and in consequence of two weedings. The figures in Table 7 apply to the same cut-over area from which was taken the summary of reproduction in Plot I. They represent, however, not a single plot, but measurements taken at random. The young stand was first weeded at the end of the fourth growing season. Three years later the forest weeds had again reached a sufficient height and rate of growth to threaten the progress of the trees which had been released. A second weeding was therefore carried out. The measurements given in Table 7 were made two years after this second weeding, with the purpose of showing how near the current height growth of the trees selected for the final stand had come to equaling the height growth of the weed trees, already twice cut. Comparison of the rates shown in this table with those in Table 6 will show that, in general, the desirable trees were making height enough to keep them ahead of all but a very few of the weeds. It is reasonable, therefore, to conclude that two weeding operations applied before the seventh year will suffice to set free 70 to 80 per cent of the selected trees.

The cost of the weeding, described above, and of a number of others carried out during the same period is many times justified by the final return. On the basis of wages obtaining at the time (1912-1916), it cost from two to two and a half dollars per acre for each weeding. A person used to the work can easily accomplish from an acre to an acre and a half a day. Making proper allowance for necessary supervision, the costs to date for the two operations can be put at $7.50 per acre. Assuming that the crop was thereafter in condition to prosper without further treatment, this amounts to having secured a highly valuable reproduction for less than the average cost of planting an acre of pine. At present prices this cost would undoubtedly be increased by from two to three dollars; but, on the other hand, the prices of all kinds of timber yielded by wood lots have also risen sharply. Average white-pine box boards are now bringing at least $27 a thousand feet; second growth red oak, $30 and upward; even red maple, sound and straight, brings $20 at the factory. These prices all apply to timber between fifty and sixty-five years old and to qualities of lumber which are inferior to what might fairly be expected in the well-stocked stands resulting from early release cuttings. That superior straightness and uniformity can thus be brought about is plain to see in fig. 2, which illustrates the condition of the reproduction summarized in Plot I after nine years of growth and two weedings. On this particular area the unusual vigor and density of white ash made it desirable to favor that species at the expense of pine; hence the comparative scarcity of the latter species. Assuming, therefore, that two weeding operations carried out before the seventh year will produce in an equally abundant reproduction an even higher yield than that produced by improvement cutting at twenty years, as shown in Plot II, it is safe to count on 35,000 feet of saw timber to the acre at a rotation of sixty years. Giving this a value on the stump of $12 a thousand, the crop will be worth $420. If the quality of this timber is better than average as regards only 10 per cent of the volume, it would increase the total selling price in the present market by from $50 to $75, so that it is safe to put the final return from the crop at at least $500. Compare this figure with the final value of the stand considered in Plot III, which stood on the same quality of site and contained at the start very much the same representation of species in the reproduction. The final value of the stand on this plot, left without improvement, amounts in round figures to $175 per acre. Thus, by applying two weedings at a combined cost of approximately $10 per acre, the actual final return from an acre of mixed volunteer reproduction can be increased by $325.

Naturally, such results as these can only be expected in case of a well-stocked reproduction containing an abundant element of white pine. Nevertheless, it is the fact that from a fifth to a quarter of the areas cut over in central New England do reproduce fairly well to pine, and a much larger proportion are well stocked with valuable hardwoods, many of which are now almost as valuable as timber trees. When one considers that this region possesses unusually good local markets for practically every kind of lumber, and that these markets are constantly improving, it seems clear that no silvicultural process can more favorably affect both financial returns and forest production in general than early and systematic weeding.