

PRUNING for PROFIT

AS APPLIED TO EASTERN WHITE PINE

by

A. C. CLINE and E. D. FLETCHER

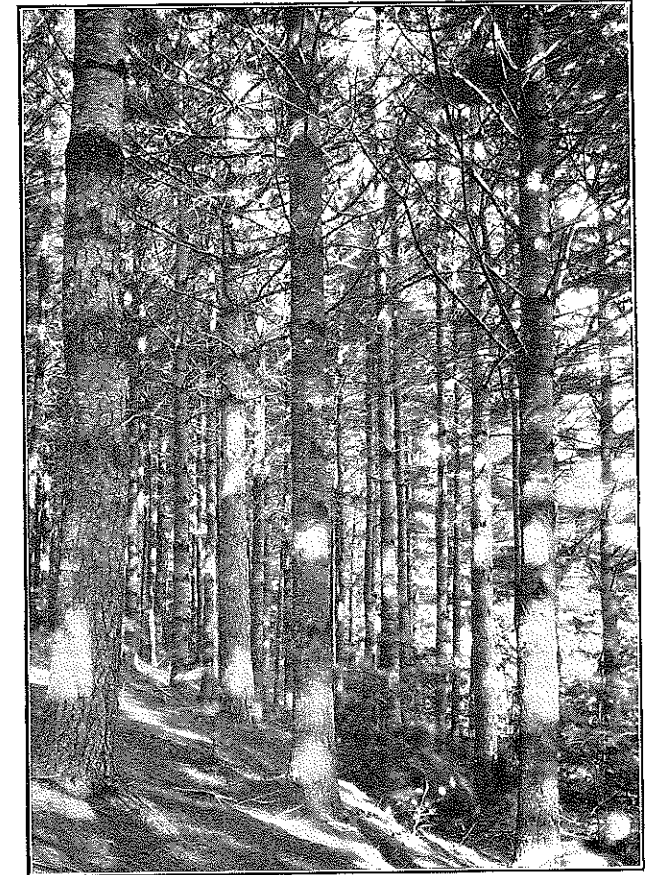


Photo. by A. C. Cline

FIGURE 1.

Fig. 1. A pruned white pine stand 52 years of age and nearly ready to cut. First six feet pruned 35 years ago; next six feet, 20 years ago. (See Fig. 6.) Stand owned by O. M. Pratt, Holderness, N. H.

A JOINT STUDY

by

THE HARVARD FOREST, Petersham, Mass.

and the

MASSACHUSETTS FORESTRY ASSOCIATION

4 Joy Street, Boston, Mass.

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PRUNING FOR PROFIT¹

Introduction

THE pruning of forest trees as a silvicultural measure has been carried on intermittently for two or more centuries in some of the older countries where forestry has long been practised. It was engaged in extensively in central Europe during the eighteenth century and again in the latter part of the following century. When applied to certain species and under favorable conditions, pruning has been looked upon with more or less favor; but when carried on indiscriminately, a reaction has invariably set in against it. The objects of pruning in the past have been based quite as much on the silvicultural needs of the stand, particularly the need for light, as on the production of high quality lumber. Schlich in his *Manual of Forestry* gives the following chief objects of pruning as practised in Europe: "(1) increase in value of the pruned trees; (2) freedom of younger growth from the too great cover caused by overhanging trees; (3) to stimulate the expansion of the crown in the upper part of the tree."

For the first time in this country the subject of pruning is now receiving considerable attention, especially in the Northeast. In this case interest centers around the possibility of improving the quality of lumber produced in white pine stands, plantations in particular, for the extensive planting of pure pine on open land has resulted in conditions unfavorable to the production of high quality lumber. Pine plantations are now well known among foresters for their poor quality, due chiefly to excessive weeviling and to persistent branches. Many owners are alarmed by the prospect of a final yield of low grade lumber, mostly "box boards." Numerous cases of pruning already exist throughout the Northeast. Generally they show a striking disregard for cost and a complete lack of knowledge of the fundamental principles of tree growth. In many instances every tree in the stand is pruned, regardless of opportunity for growth, limb size, or bole size, the total cost reaching as high as \$40.00 to \$50.00 per acre or more. In addition, the pruned branches oftentimes are carefully gathered up and burned. To be sure, there are places where pruning has been undertaken purely for aesthetic purposes, to enhance the appearance of the stand, to make it attractive as a pine grove. In such cases the pruning of every tree and the disposal of the

¹The authors wish to express their thanks to the several woodland owners, particularly to Mr. O. M. Pratt of Holderness, N. H., and to the foresters in this region who have so generously given their time and knowledge to facilitate the carrying on of this study.

Foreword

Pure stands of white pine, both the plantations which have been so extensively established and the natural second growth which is still developing on abandoned lands, produce only low grade lumber. In recent years not only has the demand for this sort of lumber fallen off, but the market for medium and upper grades of native softwood has been largely taken over by fir and pine from the West and South. Thus, much of the expectable profit from pine stands depends on the quality of the product. In well stocked mixed stands, natural pruning produces a substantial amount of better than average lumber, which is always salable at a fair price, but in pure pine stands clear lumber can be secured only by the removal of side branches when the trees are small. This report is a preliminary study of pruning as a means of increasing profit. It summarizes the results -- in improved grade, costs and returns -- of actual cases, and defines the conditions and methods under which pruning may be expected to pay.

The subject matter of this bulletin is presented by the Harvard Forest and the Massachusetts Forestry Association, to owners and prospective owners of white pine in the hope that it may lead to more intensive management of this type of woodlands, with a corresponding increase in profits.

R. T. FISHER, *Director,*

Harvard Forest.

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slash may be justified. But the fact remains that most pruned stands furnish examples of *what not to do*, and offer no encouragement to owners who desire to prune *for profit*. Furthermore, the ill-advised pruning of large limbs, oftentimes with an axe or a club, has resulted in such serious defects in the pruned lumber which has already come on the market that lumbermen are apt to look upon pruned trees with some doubt as to their worth. In contrast to these unfavorable results is the comparatively good showing made in the few cases where pruning has been undertaken solely as a commercial venture, and with noticeable regard for the factors which underlie the growth and development of pine stands.

Though some foresters consider pruning dangerous and objectionable, owing to defects caused in the healing of the wounds and to excessive cost, others claim that it can be done both safely and profitably. In spite of differing opinions, all will agree that further study of pruning when applied specifically to eastern white pine is needed to settle the question. Undoubtedly pruning is the only possible means of producing clear lumber on a short rotation, and no one will deny that one of the chief reasons for the decline of the lumber business in New England is the lack of high grades.

FACTORS OF GROWTH, FORM, AND QUALITY IN WHITE PINE WHICH INFLUENCE THE PRACTICE OF PRUNING

Any factors which influence the growth of pine, especially the form of bole, the size of limbs, the process of natural pruning, and the rate at which wounds are healed, have a bearing on the practice of pruning, and must be considered of fundamental importance.

COMPOSITION OF THE STAND. Eastern white pine occurs both in pure stands and in mixtures. It has been shown¹ that when grown in pure stands it is a poorer tree than when grown in proper mixtures, for the following reasons: (1) In pure stands the branches, though dead, persist throughout the rotation regardless of the density of stocking, thus preventing the production of any clear lumber; whereas, in mixed stands, particularly pine-hardwood and pine-hemlock², pruning of the pine is carried on as a natural process by the associated species. (2) Pine when grown in suitable mixtures has smaller limbs than when in pure stands.

¹Harvard Forest Bulletins 5, 7 and 8.

²Harvard Forest Bulletins 7 and 8.

Harvard Forest Bulletin 7 shows that pine twenty to thirty years old in a pure, even-aged stand has knot sizes averaging .55 inches (for the first 12 ft. log); in a pine-hardwood mixture, .41 inches; in a pine-hemlock mixture, .30 inches. (3) In pure stands the weevil damage is commonly so severe¹ that the trees are forked and crooked, while in pine-hardwood mixtures weeviling is greatly reduced and the trees are comparatively straight and well formed. (4) It has been observed² in pure pine stands that a gradual impoverishment of the soil takes place with resulting slowing down in growth, while in pine-hardwood mixtures a much more favorable soil condition is present and growth correspondingly better.

DENSITY OF STOCKING. The density of stocking, usually expressed as number of trees per acre, is the most important factor in determining limb size, and hence in affecting the cost of pruning. The following table, taken from Harvard Forest Bulletin 7, shows the relation between the number of trees per acre and knot size for the butt log, pure white pine, age twenty to thirty years, site II (medium soil).

TABLE NO. 1

Relation between Number of Trees per Acre and Knot Size	
Number of Trees per Acre	Average Size of Knots
3000	.33 in.
2500	.37
2000	.43
1500	.53
1000	.65
500	.79

Density of stocking is also the principal factor influencing dead length (the length of the bole from the ground to the bottom of the green crown). The longer the dead length, the fewer the green branches to be pruned, and the less the effect upon the growth of the tree.

On account of heavy weevil attacks in *pure* stands, density of stocking furthermore very largely determines the straightness of bole. In densely stocked stands forking of the boles is reduced, inasmuch as there is a strong tendency for the weeviled trees to keep erect and to overcome crooks. With lower densities (wider spacings) the boles become increasingly more forked and crooked.

¹Harvard Forest Bulletin 5.

²Fisher, R. T. Soil Changes and Silviculture on the Harvard Forest. Ecology, Vol. IX., No. 1, p. 6.



Photo. by A. C. Cline

FIGURE 2. Density of stocking is the most important factor influencing limb size, straightness of bole, and dead length in pure pine stands. The photograph shows a densely stocked pine stand of natural origin ideally suited to pruning. Note the small limbs, straight boles, and marked differentiation into crown classes. Compare with Figure 4 which shows a stand of the same age, but poorly stocked.

SOIL QUALITY. Soil quality influences pruning, since both limb size and height growth vary directly with the fertility of the soil, that is, the richer the soil, the longer the "joints" (internodes), and the larger the limb size. The longer the joints, the fewer the limbs per linear foot of bole, and the lower the cost of pruning. On the other hand, the larger the limbs, the greater the cost of pruning, and the more serious the resulting defects.

FORM OF THE STAND. The term "form" refers to the relative heights or ages of trees composing a stand. For example, most plantations are even-aged in form, while natural stands are oftentimes uneven-aged. Likewise, stands with an overstory of large trees and an understory of smaller ones are spoken of as two-storied or double-decked in form. Stands with a complete representation of ages from seedlings to mature trees have a "selection" form. The form of the stand is closely related to differentiation into crown classes, namely,

"dominant," "co-dominant," "intermediate," and "suppressed," and hence influences the choice of trees to prune in any given stand. Obviously, it is money wasted to prune suppressed trees which will be overtopped and killed before they reach a merchantable size. Differentiation into crown classes is influenced by soil quality as well as by differences in age. It proceeds most rapidly on the rich soils and with the slightly uneven-aged form; least rapidly on the poor soils and with the strictly even-aged form. Pine plantations are exactly even-aged in form; pine resulting from the seeding-in of abandoned fields and pastures is oftentimes slightly uneven-aged, while pine growing naturally on light, sandy soils is characteristically uneven-aged.

AGE OF THE STAND. Age is plainly a factor which influences pruning. The older the stand, the larger the bole, the larger the limbs (until they die), and the longer the dead length of bole.

The extent to which the several factors outlined above and others of less importance are recognized, understood, and made use of, will determine almost wholly the outcome of pruning.

EFFECT OF PRUNING ON GROWTH

The removal of live limbs undoubtedly has an effect upon the growth of a tree, though usually not more than a temporary one. In the present study no trees were examined which had been pruned higher than one-half their total height. With this degree of severity, and under conditions which happened to favor the early death of the lower branches, no effect upon growth was observable. However, in the case of a drastic pruning in which the bulk of the living crown is removed, it is beyond doubt that diminished growth will result, and, in extreme cases, the tree may die.

Pruning normally has a beneficial effect upon bole form (amount of taper). As Schlich¹ says, "pruning may exercise an additional advantage in causing the bole to grow more cylindrical instead of approaching the shape of a cone." This effect, sometimes referred to as "throwing the growth up the bole," is in harmony with well-known theories pertaining to bole form as determined by mechanical stresses. As an example of improved bole form, a pruning of Scotch pine in the forest of Boda² showed a marked decrease in diameter growth after pruning up to about 50% of the total height of the tree, a neutral point with unchanged growth at 57%, and from there to the top a markedly in-

¹Schlich's Manual of Forestry. Silviculture, p. 284.

²Meddelanden från Statens Skogsförsöksanstalt, 1924, p. 49.

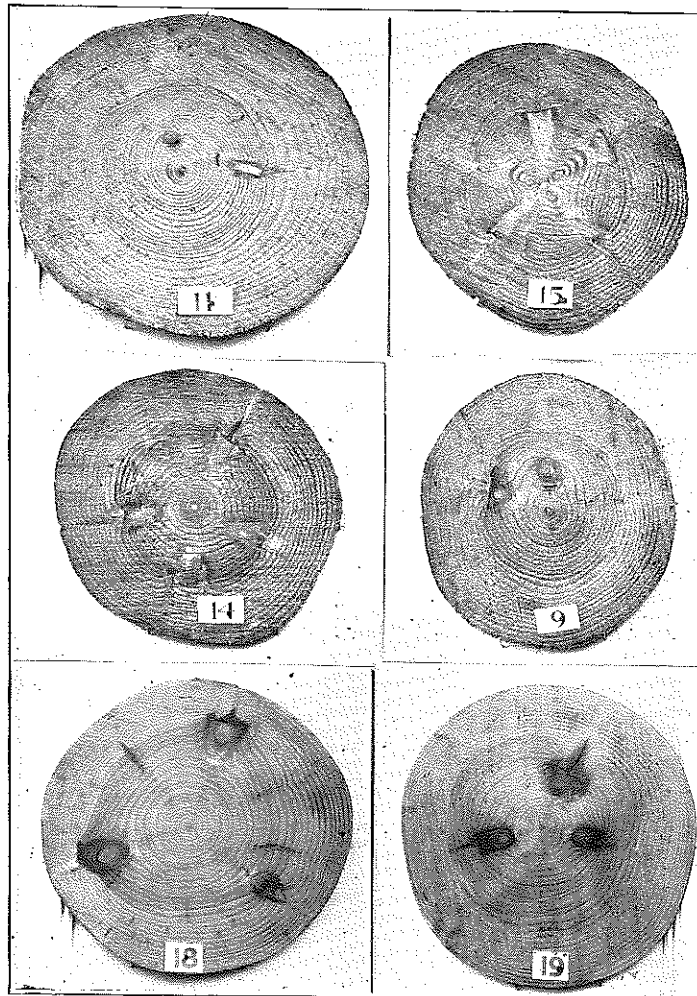


Photo. by A. C. Gline

FIGURE 3. CROSS SECTIONS OF PRUNED LOGS.

11. Slight defect caused by breaking off small dead branch near base of tree.
15. Pruned limbs healed over with almost no defect. The two uppermost knots measure 1" in diameter.
14. One small bark pocket caused by pruning a limb 1 1/4" in diameter. (This section was taken from a tree which was not a "dominant." With a better opportunity for growth the defect would have been less.)
9. Almost perfect healing over of a pruned limb 1 1/4" in diameter.
18. A case where pruning was delayed too long. Uppermost knot with small bark pocket measures 1 1/2" in diameter. Pruning done with an axe.
19. Large bark pocket caused by pruning with an axe. Although the branch measures only 3/4", the defective area is 1 1/2" wide. It shows plainly that the workman cut into the bole of the tree.

creased diameter growth. With respect to height growth the few results recorded furnish conflicting evidence. In the pruning just referred to, increased height growth resulted, while according to Schmuziger¹ height growth is diminished by green pruning. Another example² seems to be more in keeping with what will undoubtedly take place where a few green limbs are pruned. In this case from one-third to one-half of the green crown of twelve-year old spruces was removed. At first height growth was diminished, but after a few years it increased to normal. Hawley³ cites an example of drastic pruning in an eight-year-old pine plantation where "the branches clear to the base of the tree were still alive. All but the last three and in a few cases the last two whorls of live branches were removed. . . ." Even with this degree of severity height growth was reduced (temporarily) only about one-third. It is safe to say that when practised under proper conditions and if not carried to a point higher than one-half the total height of the tree, pruning will have but slight and temporary influence upon height growth. As concerns growth in volume, the pruning of the lower ten to sixteen feet of bole can have no lasting or serious influence, when considered in terms of final yields. Pine growing under conditions sufficiently favorable to warrant pruning will have a dead length of at least twelve to fourteen feet by the time the stand has reached an age of twenty-five to thirty years. Thereafter, the dead length having exceeded the length of the pruned butt, volume growth will proceed essentially the same as in an unpruned stand.

EFFECT OF PRUNING ON QUALITY OF LUMBER

DEFECTS CAUSED BY PRUNING LIVE LIMBS. The following observations are based on 25 cross-sections of pruned logs obtained by the authors from the forest of O. M. Pratt, Holderness, N. H. and the Plymouth (Massachusetts) Town Forest⁴, and from 30 boards sawed from pruned logs at Pratt's.

Where live limbs *not larger than one inch* in diameter are cut off cleanly without wounding the bole, the resulting defects are, (1) a thin layer of hardened pitch between the cut surface of the limb and the

¹Aufastungen. Schweizerische Zeitschrift für Forstwesen, May 1910, pp. 155-164.

²Untersuchungen über die Aufastung der Waldbaume. Centralblatt f. d. g. Forstwesen. Oct. 1909, pp. 413-427.

³R. C. Hawley, The Practice of Silviculture, p. 200.

⁴The pruning on what is now the Plymouth Town Forest was done by the late Nathaniel Morton, who was probably the pioneer in pruning white pine in New England.

new wood; (2) a discoloration (not rot) of the wood around the point of occlusion¹. When sawing the inner boards, if the saw passes through a pruned limb (knot) longitudinally, these defects appear as a dark line running with the grain of the wood, with usually slight discoloration on either side. In sawing the outer boards, if the saw just clears the end of the pruned limb, only the discoloration shows. When the next board is taken off, the saw will cut through the knot crosswise, and both the knot and the discoloration will be visible. In the case of small limbs the discoloration is too slight to be objectionable. (See Fig. 3).

Where live limbs *larger than one inch* (one to two inches) are pruned, there is likely to be, in addition to the defects noted above, a defect known as a bark pocket or pitch pocket. This is caused by the recurving of the bark over the wound made in cutting off the branch. It begins at the cut surface of the limb and extends outwardly toward the bark for an inch or more, depending upon the size of the limb and the rate of healing. This defect combines the disadvantages of discoloration, weakness, and the presence of bark or pitch, or both.

DEFECTS CAUSED BY PRUNING DEAD LIMBS. In cases where dead limbs are cut off cleanly without wounding the bole, the defects are the same as with green limbs, except that the pitch is absent and there is less likely to be a discoloration of the layers of new wood formed over the cut surface.

DEFECTS CAUSED IN THE USE OF AN AXE. The use of an axe in pruning usually results in wounding the bole or in breaking out a part of the limb inside the bark. Large and serious defects, such as pitch pockets, large areas of discoloration, and rotten spots, are almost sure to follow.

DEFECTS CAUSED BY WOOD-DESTROYING FUNGI. A serious defect, not observed by the authors in any pruned lumber studied, but well-known in Europe (though chiefly in species other than white pine) is that caused by the entrance of wood-destroying fungi where wounds are made in pruning. Spruce and fir in particular in Europe were considered unsuited to pruning owing to their susceptibility to fungal attack. Such hardwoods as the birches, poplars, and willows were likewise considered. Although complete information regarding the probability of fungi (especially *Trametes pini*, which causes red rot) gaining entrance through pruned white pine limbs is unavailable, the evidence at hand indicates that there is no danger of serious attacks.

¹The point where new wood is formed over the wound caused by pruning.

R. Hartig¹ states that "the younger class of trees enjoy immunity from infection because in their case wounds are quickly protected by an exudation of turpentine"; but "from the time when the heart wood (in the branch) becomes comparatively dry, turpentine ceases to exude from the central part of the branch wound, and this consequently becomes liable to attack from the spores of the fungus. This accounts for the disease (*Trametes pini*) not usually appearing upon trees younger than fifty years." In writing about the same fungus Duggar² says that "young conifers are in part protected from infection by the resinous exudations which form over the wounds." Numerous other authors have expressed a similar opinion. While it seems certain that the pruning of *small* green branches on young trees offers no chance for the entrance of red rot, there is less certainty in the case of branches which have just died. However, according to Abbott³ "When the branch dies, the free exudation of pitch causes that part which lies adjacent to the cambium (the growing tissue just inside the bark), as well as that inside the tree to become hardened and impenetrable . . . It will be noticed (from his Fig. 1) that the fungus growth is present in the vicinity, but does not penetrate this resinous wood of the old branch." Thus, one may conclude that the greatest danger is in the case of pruning large, green branches in which the heart wood is comparatively dry; but that in the case of small branches on young trees, whether green or dead, there is little danger of infection. As Spaulding⁴ says, "Pruning small pine limbs is not likely to lead to any serious attacks by *Trametes pini*."

From the foregoing evidence there is little doubt but that the objections to pruning on account of resulting defects apply chiefly to the pruning of large limbs, improper methods of pruning (with an axe or a club) and to species other than white pine. In this study the defects caused in pruning small limbs (one inch or less) have been found too slight to constitute an important objection.

COSTS AND RETURNS

COST OF PRUNING. The most important factor influencing the rate at which trees may be pruned is the size of limb. The following table gives the time required in pruning limbs of various sizes.

¹R. Hartig. *Diseases of Trees*. Eng. Trans. p. 191.

²B. M. Duggar. *Fungus Diseases of Plants*, p. 469.

³F. H. Abbott. *The Red Rot of Conifers*. Vermont Agricultural Experiment Station Bulletin 191, p. 9.

⁴Dr. Perley Spaulding in a letter to one of the authors.

TABLE NO. 2

Relation of Limb Size to Rate of Pruning*

Size of Limb	Time Required
1/4 inch	1 second
3/8	1 1/4
1/2	1 1/2
5/8	2
3/4	2 1/2
7/8	3
1	3 1/4
1 1/4	4 1/4
1 1/2	5 1/4
2	8
2 1/2	12

*Based on pruning 78 green limbs, using straight, 8-point, hand pruning saw.

Table 3 shows more significantly the relation between limb size and rate of pruning, since it is based on pruning several feet of bole.

TABLE NO. 3

Relation of Limb Size to Rate of Pruning the First 7.0 Feet of Bole*

Average Size of Limb	Time Required for Pruning
1/4 inch	1 min. 24 sec.
3/8	1 50
1/2	2 20
5/8	2 54
3/4	3 24
7/8	4 00
1	4 36
1 1/4	5 48

*Based on 48 trees pruned by three different workmen using both straight and curved hand pruning saws; both live and dead limbs; 5 to 8 whorls of branches removed.

The above table indicates that even with knot sizes within the range of those commonly found in stands suitable for pruning, the rate of pruning varies by as much as 300%.

Other factors which influence the cost of pruning are the time required in selecting the proper trees to prune, the accessibility of the trees selected, and the efficiency of the workmen. To complete the pruning of a tree two or more treatments, a few years apart, are usually necessary. Costs will vary somewhat from the first to the last treatment.



Photo. by A. C. Cline

FIGURE 4. WHAT NOT TO DO

A badly weeviled white pine plantation with a stocking of 960 trees per acre, showing crooks and excessive taper due to weeviling and low density. This stand was pruned at a per man-hour rate of 50 linear feet, equivalent to about \$55.00 per acre, and the expense represents almost a total loss.

At the start pruning is comparatively easy, as the work is within reach of a hand saw, but, as soon as the bole is cleared up to head height, it is necessary to use either a pole saw or a ladder with a hand saw. Offsetting the comparative difficulty of sawing limbs above arm's reach is the facility with which trees already pruned once are again located, and the greater freedom of movement possible, due to the absence of lower branches.

Everything considered, chiefly the time spent in selecting the trees to prune and the time actually spent in pruning, the rate of pruning was found to vary from 50 to 200 linear feet of bole per man-hour¹. The

¹Based on time studies by the Harvard Forest in pruning a badly weeviled plantation and a densely stocked stand of natural origin; also on cost figures supplied by O. M. Pratt, F. B. Knapp, K. W. Woodward, L. R. Grose, A. F. Hawes, H. C. Belyea, E. D. Fletcher, and others. The rate of 100 linear feet of bole per man-hour given by O. M. Pratt is both fair and conservative when taken as an average for well formed trees two to six inches in diameter pruned to 16 ft. In one pruning test carried out under unusually favorable conditions, a rate of 250 linear feet was attained.

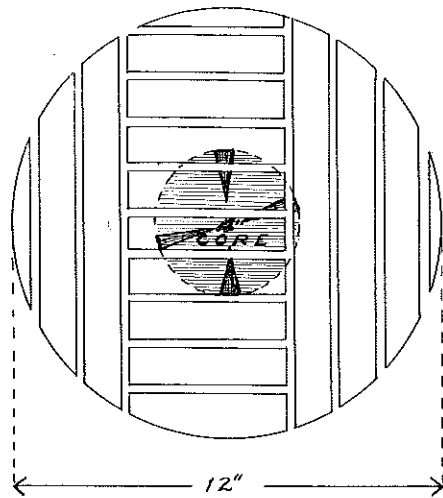


FIGURE 5. A diagram of a cross section of a pruned log showing how the amounts of clear and knotty lumber were determined. This diagram is for a log 12" in diameter at the small end with a 4" core; sawed into 1" boards; $\frac{1}{4}$ " saw kerf.

former rate applies to badly weeviled plantations; the latter to densely stocked stands of natural origin. With labor at 50c per hour, these rates are equivalent to \$1.00 and 25c per 100 linear feet of pruned bole, respectively. By knowing the number and size of pruned butt logs obtainable from 100 linear feet of bole at fifty to sixty years (the usual rotation) the cost of pruning per 1,000 bd. ft. may be determined. It is assumed that the pruned butt logs are 14 ft. long. The diameter at the small end (inside bark) is estimated to be 12", and the contents of each log 97 bd. ft. This gives 7.14 logs and 693 bd. ft. per 100 linear feet of bole. On the basis of 1,000 bd. ft. the rates of \$1.00 and 25c (per 693 bd. ft.) become \$1.44 and 36c, respectively. By compounding these initial costs to the end of the rotation (at 6% for an average of 35 years) final costs of pruning per 1,000 bd. ft. of \$11.04 and \$2.76 are obtained. With this added cost per 1,000 bd. ft. of pruned logs, is pruning profitable, and if so, how profitable?

RETURNS FROM PRUNING. In order to determine the increased value of pruned logs, diagrams were constructed to show the relative amounts of clear and knotty lumber produced by pruning trees of different diameters. Then these amounts of clear and knotty lumber were applied to given values per 1,000 bd. ft. of lumber, as shown in the following table.

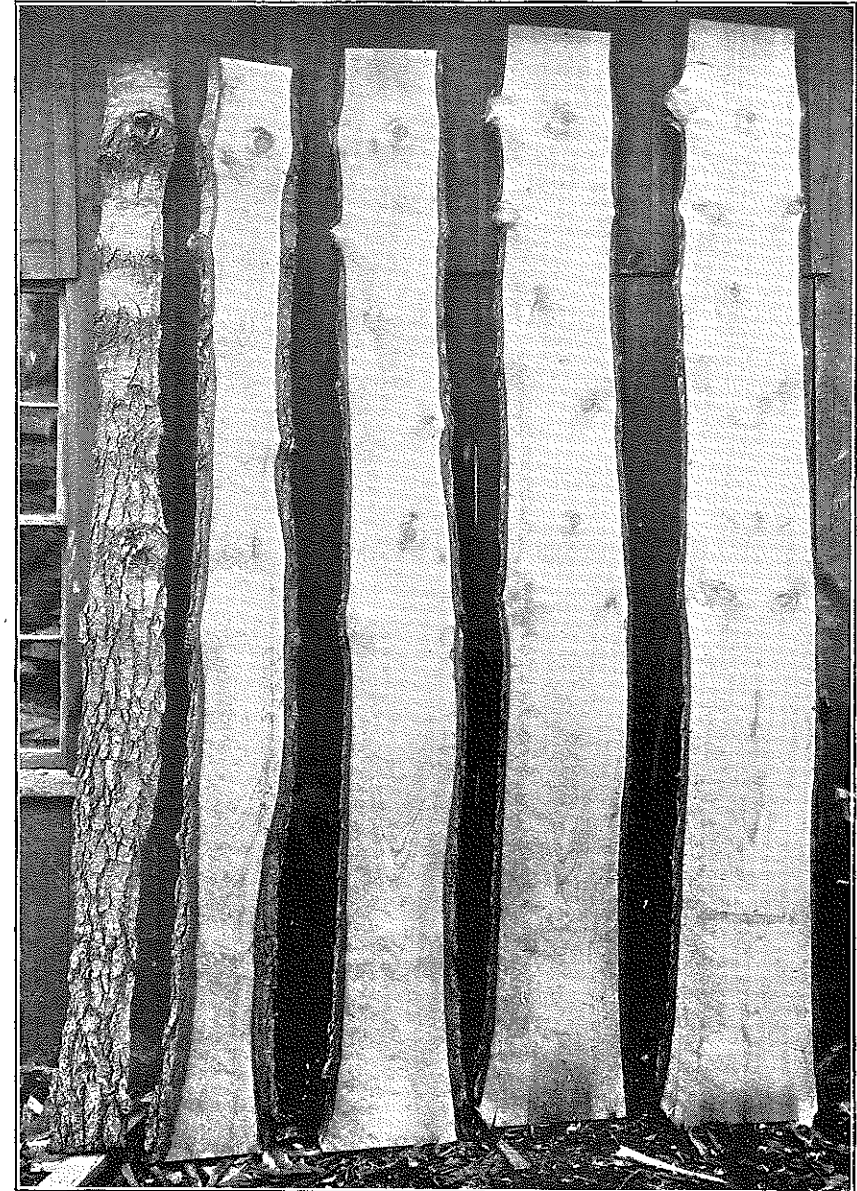


Photo. by U. S. D. A.

FIGURE 6. Boards sawed from tree at O. M. Pratt's showing two different pruning operations 15 years apart. At the time of the first pruning, 35 years ago, the tree was so small that almost solid clear lumber resulted. The second pruning, 20 years ago, was delayed too long so that only a narrow rim of clear wood has been formed. The upper two feet were unpruned.

TABLE NO. 4

Amount and Value of Clear and Knotty Lumber
from 1,000 Bd. Ft. of Pruned Logs with
Cores of Different Sizes*

Size of Knotty Core	Kind of Lumber	Bd. Ft.	Rate per M	Value	Total Value
2 inch	clear	969	\$50.00	\$48.45	
	knotty	31	25.00	.78	\$49.23
3 inch	clear	959	50.00	47.95	
	knotty	41	25.00	1.03	48.98
4 inch	clear	835	50.00	41.75	
	knotty	165	25.00	4.13	45.88
5 inch	clear	750	50.00	37.50	
	knotty	250	25.00	6.25	43.75
6 inch	clear	661	50.00	33.05	
	knotty	339	25.00	8.48	41.53
7 inch	clear	593	50.00	29.65	
	knotty	407	25.00	10.18	39.83
unpruned	clear	none			
	knotty	1000	30.00	30.00	30.00

*Amounts of clear and knotty taken from diagrams made for logs 12" in diameter at the small end, 14 ft. long, with small limbs at time of pruning, sawed into 1" "round-edge" (outer boards) and "square edge" (from heart) so as to obtain the maximum amount of clear; a few boards near the core clear one face only, and no boards less than 4½" wide. Price per M for clear lumber based upon present market.

With the highest final cost of pruning, \$11.04¹, and the largest (7") core, it will be seen that the net loss per M bd. ft. is \$1.21. With the lowest final cost of pruning, \$2.76, and the smallest (2") core, a net profit of \$16.47 per M bd. ft. is realized². Using higher values per M bd. ft., such as \$60.00 or \$70.00³, pruning can be shown to be even more profitable. As it is impossible to foresee what the value of lumber will be thirty or forty years hence, one may assume almost any value he chooses. Clear lumber from pruned trees grown on a short rotation, although its technical properties are inferior to those of clear lumber from old growth, will undoubtedly find a ready sale for finish, cutting up stock, pattern stock, etc.

It is plain that pruning badly weeviled stands (See Fig. 4), at the rate of 50 linear feet is an unprofitable undertaking on account of both

¹This amount is excessive, as it is based on pruning stands so badly weeviled that from the standpoint of defects alone pruning could not be justified.

²This is in addition to 6% compound interest on the investment.

³O. M. Pratt has obtained \$65.00 per M for lumber from pruned butts about 16" in diameter, sawed through and through into cutting up plank, and \$25.00 from the same kind of logs unpruned.

cost and resulting defects. On the other hand, the pruning of well-formed, small-limbed trees at the rate of 200 linear feet will show a handsome profit. Although it is impossible to state definitely just how much one can afford to spend in pruning, the indications are that *no stand should be pruned unless it can be done at a per-man-hour rate of 75 linear feet or better.*

RECOMMENDED PRACTICE IN PRUNING

KINDS OF STANDS BEST ADAPTED TO PRUNING. Pruning when undertaken on a commercial basis should be confined to selected stems in young stands composed of well-formed, small-limbed trees capable of making rapid growth. The conditions under which white pine of suitable form and limb size is commonly found growing in central New England are as follows:

1. Densely stocked pure pine or mixed softwood plantations with a spacing of not more than five feet¹.
2. Densely stocked pure pine stands originating through the natural seeding-in of abandoned fields and pastures.
3. Pure pine stands on light, sandy soils, usually forming a permanent forest type, and characteristically uneven-aged in form.
4. Mixed stands of pine-hardwood, pine-hemlock (occasionally other mixtures as well) of natural origin.

TIME TO COMMENCE PRUNING. Because of the obvious advantage of a very small core of knots, it has been suggested that pruning be commenced when the tree is only a few feet high, or even smaller. From the standpoint of the proportion of clear lumber produced, such a suggestion is thoroughly sound; but, unfortunately, it cannot be safely carried out under ordinary conditions. In the first place it is unwise to prune a tree which is only a few feet high if later it is weeviled from one to three or four times before it reaches a height equal to the length of a butt log. Furthermore, since pruning, to be profitable, must be limited essentially to the dominant trees in each stand, it is necessary to delay until differentiation into crown classes has taken place; otherwise it is impossible to pick out the trees (dominants) which will form the final stand. In most plantations the dominant trees cannot be determined with any certainty until the stand has reached an age of

¹Dense stocking is necessary on account of the severity of weevil damage in more open stands. It should be understood that in cases where weevil damage is slight or absent it is unnecessary to limit pruning to closely spaced stands. Were it not for the crooks and large limbs caused by weeviling, plantations spaced at six, seven or even eight feet might in many cases be suitable for pruning.

twelve years or more. Therefore, it is recommended that in pine plantations, *except in cases of dense stocking and unusually early differentiation into crown classes, or in sections where weevil damage is known to be slight, pruning be delayed until the dominant trees have reached a height equal to the length of the pruned butt log desired (10 to 16 feet.)*¹

In slightly uneven-aged "old field" pine of natural origin, it is oftentimes possible to select the dominant trees earlier than in plantations. For this reason pruning may be begun somewhat sooner than in plantations, providing weevil damage promises to be slight.

With uneven-aged pine growing on light, sandy soils, weeviling is usually less, the trees straighter, and knot sizes smaller than in the case of pine on the heavy soils. Pruning may therefore be started earlier, and perhaps with greater assurance of success, than in the foregoing cases; but extreme care must be taken to select trees which are free to grow, or are soon to be released by the cutting of overtopping, mature trees.

The pruning of pine when growing in mixed stands has been touched upon only superficially in the present study, and no recommendations concerning it will be made, other than to warn against pruning trees which are not free to grow and which, because of more rapidly growing associates, will continue to be overtopped unless special preventative measures are taken.

The above recommendations may be summed up as follows: *Do not commence pruning until there is sufficient differentiation of the stand into crown classes to permit the easy selection of dominant trees, and in addition make sure that at least the butt log will be straight.*

NUMBER AND KIND OF TREES TO PRUNE. Pruning in even-aged pine stands should be limited to those trees which will form the final stand, from 150 to 300 trees per acre, depending upon the size of tree desired for the final crop. Care should be taken to select well-formed, dominant (most free to grow) trees, spaced about 12 to 17 feet apart (equivalent to 300 to 150 trees per acre respectively). The pruning of more than enough trees to form the final crop cannot be justified except under very favorable market conditions. It costs nearly as much to prune an overtopped tree as it does a dominant, and the pruning of any trees in the subordinate crown classes is a total loss.²

¹Dominant trees 10 to 16 ft. high under favorable conditions in even-aged pine stands will range from ten to fifteen years of age and from two to four inches D. B. H. (diameter at breast height). Knot size will vary from $\frac{1}{8}$ to $1\frac{1}{4}$ inches, the average falling well below one inch, and dead length from 1 to 7 feet.

²Overtopped trees either grow very slowly or are killed out before they reach merchantable size.



Photo. by A. C. Cline

FIGURE 7. Pruning should be limited to from 150 to 300 dominant trees per acre. This photograph shows a dominant tree in a densely stocked pine stand of natural origin well adapted to pruning. Owing to the high density of stocking, the lower branches were dead to a height of 7 ft. thereby making it safe to carry the first pruning to a height of 10 ft. or more. The total height of the tree was 24 ft.

TIME OF YEAR TO PRUNE. Most foresters recommend that pruning be done during the dormant season, preferably in the fall. After twenty-five years' experience in pruning pine, O. M. Pratt expresses a decided preference for the fall season. Opinions to the contrary, such as one noted in the case of Zederbauer's¹ experiments, apply chiefly to deciduous trees or to conifers other than white pine. Observations made in the present study indicate that season of the year is unimportant in the case of pruning small (one inch or less) limbs. Bleeding which results from cutting live limbs does not form pitch pockets when *small* limbs are properly pruned, and is considered beneficial in sealing the wound against the entrance of fungus spores. In the majority of cases pruning will be done when most convenient, usually in the fall or winter.

HOW TO MAKE THE FIRST PRUNING. The most important question at the time of the first pruning is, How much of the green crown should be removed? In view of the desirability of delaying pruning in most even-aged stands until the dominant trees are 10 to 16 feet high, there is a tendency in the first pruning to go as high as one can conveniently reach with a hand saw, from five to seven feet, or about one-half the total height of the tree. From the experience of O. M. Pratt² and observations made by the authors, pruning to one-half the total height in well-stocked stands is a safe practice. This degree of severity will have very little effect upon the growth of trees in well-stocked stands where the limbs are already dead for several feet up the bole, but an increasingly greater, though not a serious, effect with reduced density of stocking.

It is important that the limbs be cut off close to the bole³, as it is well established that healing of the wound is thereby hastened.

Since only a small percentage of the total trees in a stand should be pruned, there is no reason for disposing of the pruned branches. From the standpoint of soil condition their presence on the ground is probably beneficial.

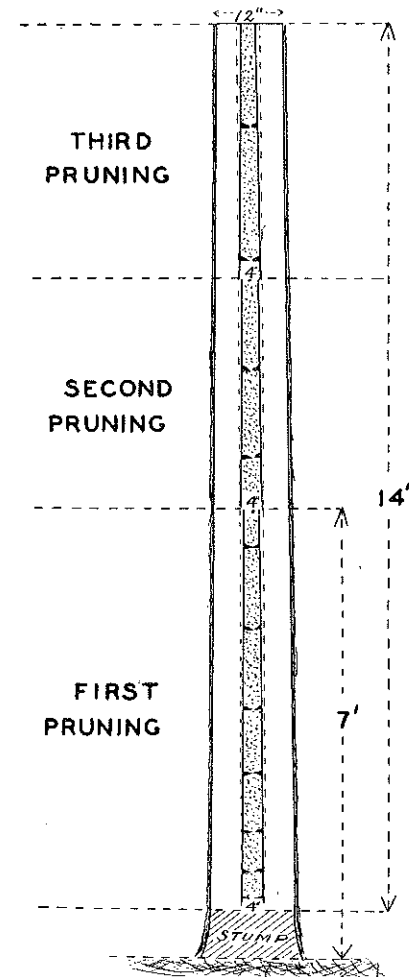
No coal tar or other preservative should be applied to the wound. Coal tar discolors the wood and may delay the process of healing.

¹Untersuchungen über die Aufastung der Walbaume. Centralblatt f. d. g. Forstwesen. Oct. 1909, pp. 413-427.

²Pratt has made it a rule never to prune higher than a point midway on the bole.

³Where there is an enlargement or "collar" at the base of the limb, the cut should be made close to the "collar" but not through it.

FIGURE 8. A diagrammatic sketch showing a longitudinal section of a pruned log 14 ft. long, 12 in. at the small end, with a core not exceeding 4 in. at any point. Special care should be taken to make the core in the upper part of the log about the same size as in the lower part. In many cases the second and third prunings are delayed too long. See Fig. 6.



HANDLING OF THE STAND AFTER THE FIRST PRUNING. In all prunings after the first one, two points should constantly be borne in mind: first, keeping the core of knots at the upper end of the log as small as at the bottom end; second, leaving sufficient green crown to insure normal, or nearly normal, growth of the tree. A safe rule to follow is not to prune higher than one-half the total height of the tree. This rule should not be followed blindly, however, as there are cases of densely stocked stands past twenty years old, but still well suited to pruning, where the dead length has passed the midway point, making it desirable to completely prune the butt log in a single operation. Un-

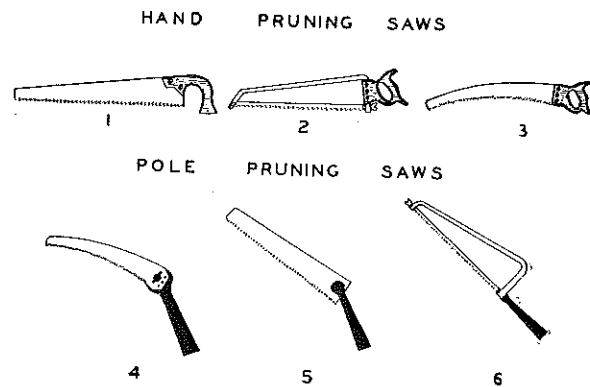


FIGURE 9. TYPES OF PRUNING SAWS

1. Hand pruning saw with pistol grip.
2. Frame type of pruning saw. Sharp blades may be inserted quickly in place of dull ones.
3. A curved saw with long, slender teeth cutting on both the thrust and draw strokes.
4. A saw similar to No. 3 affixed to an adjustable socket for use with a pole.
5. O. M. Pratt's pruning saw. It is 24" long, 4" to 2" taper, $3\frac{1}{2}$ point, $\frac{1}{16}$ " thick, cuts on draw stroke, teeth set at sharper angle than in ordinary cross-cut saw, cutting edge set at an angle of 30 degrees with pole.
6. Frame type of pole pruning saw which may prove very satisfactory for sawing small, live branches. It may be set to cut with either a thrust or draw stroke, and blades are easily changed.

der the usual circumstances two or more prunings *two or three years apart* will be required to clear a butt log.

Of equal importance with the proper method of pruning is the later handling of the stand with respect to thinnings. With pruned stands a special effort must be made to give the pruned trees sufficient room for rapid growth. In fact, in the great majority of cases *pruning, unless followed in due time by thinnings, will be wasted effort.* In unthinned stands wounds made in pruning heal slowly, diameter growth is greatly reduced, thereby lessening the production of clear wood formed after pruning, and red rot (caused by *Trametes pini*) is likely to make serious inroads into the final yield. In even-aged pine stands the first thinning will ordinarily be needed when the stand is about 25 years old, and the second one about ten years later, at the age of 35. The third and last thinning, at around 45 years of age, should be a very heavy one, giving the remaining trees, all of which have been pruned, an opportunity for extra rapid diameter growth. The final cutting would then be made at about the age of 55 years.

TOOLS USED IN PRUNING. In no case should an axe be used as a pruning tool. The practice of going into the woods and knocking off dead branches with an axe or club will undoubtedly result in serious defects. Even a skilled axeman will occasionally wound the bole, and there is always a danger of the limb breaking off inside the bark, leaving a cavity which will be filled with pitch or give entrance to fungus spores. The saw is undoubtedly the best all-around tool to use. For pruning within arm's reach a hand saw is commonly used. As there are at least thirty different models of hand pruning saws on the market, and since choice of model will vary with the individual workman, no one saw can be recommended in preference to all others. Other tools which have been used for pruning include pruning knives and shears, double action clippers, and pushing chisels. For pruning above head height either a pole saw or a ladder with hand saw may be used. The former will be found more efficient under the usual conditions. For pruning the lower branches a single edged saw which cuts on the thrust stroke will be found satisfactory, though some may prefer either a curved saw with long, slender teeth (cutting both ways), or a straight saw with "lightning" teeth. For the higher branches a saw which cuts on the draw stroke, such as Pratt's, appears best adapted. Other pole saws in common use include those with a crescent-shaped blade and long, slender teeth. Frame saws, in which a narrow blade is tightly stretched between the ends of a metal frame, are also available in both hand saw and pole saw models, and may prove fully as efficient as the other types. Double edged pruning saws are objectionable on account of the idle blade interfering with the bole of the tree and nearby branches. Sprinkling a little kerosene on the saw will be found greatly to facilitate the sawing of green branches.

PRUNING SPECIES OTHER THAN WHITE PINE. Pruning should not be applied to species grown for pulpwood, nor to those utilized chiefly for poles, posts, dimension lumber, etc. With the possible exception of red (Norway) pine, the authors believe pruning should be confined to white pine. From a biological standpoint there appears to be no reason why red pine is not equally well suited to pruning, but from a financial standpoint there is considerable doubt as to whether clear red pine lumber will ever be as valuable as that from white pine.

Conclusion

In this study it has been shown that pruning white pine when limited to stands composed of straight trees with small limbs (averaging under one inch in diameter), to selected trees of the "dominant" crown class which are to form the final crop, and to boles of small diameter at the time of pruning (preferably not over 3" to 4" D. B. H.) is a very profitable undertaking. The selection of suitable stands combined with timely treatments and skillful handling may result in a profit for pruning alone of from \$15.00 to \$35.00 or more per M bd. ft. (in addition to 6% compound interest on the investment), depending upon the future value of clear lumber.* On the other hand, when applied to stands composed of badly weeviled trees with large limbs, to every tree in the stand regardless of crown class and to boles 6", 7" and 8" or more in diameter, pruning will be found very unprofitable. Not only will the initial cost exclude all hope of profit, but, in addition, the resulting lumber will be so defective that it will probably bring a lower price than that from unpruned trees.

*With short rotations about 50% of the volume of the tree is in the butt log, and, since in a properly handled stand the pruned butts will contain from 60% to 80% of clear lumber, about 30% to 40% of the final yield per acre should be "clear."