PRUNING AND SAWING EASTERN WHITE PINE

Extrait en Français

W. W. Calvert and L. G. Brace
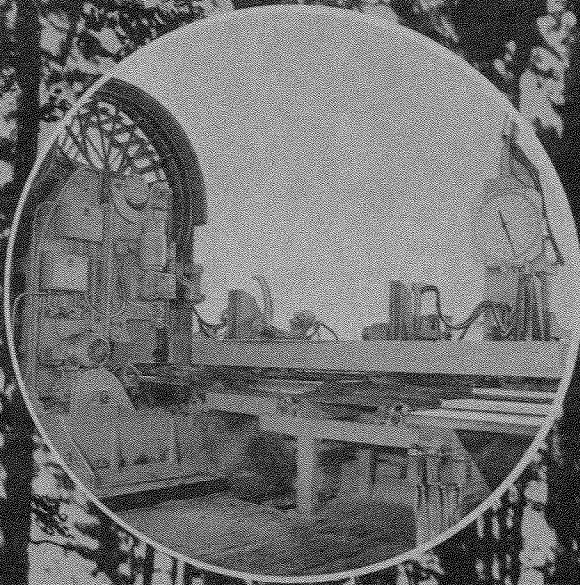
A case history from stand treatment to utilization

ABSTRACT

A natural stand of eastern white pine was thinned and partially pruned at the Petawawa Forest Experiment Station in 1939. In 1965, when the stand was harvested, a study was initiated to determine the effect of these silvicultural practices on the volume and quality of the lumber recovered. In addition, the effect of taper-sawing pruned logs was studied. Results showed that pruning, in combination with thinning, afforded a substantial economic return on the investment made in 1939 and compounded for 27 years. However, taper sawing had no effect on the quality (value) of recovered lumber. At the same time, this practice resulted in lower productivity in the sawmill and lower volume recovery from the log. A number of factors, notably the frequency of branch-stub wounds and the irregularity of the "clear" shell developed since pruning, could account for the absence of improvements due to taper sawing. The investigations led to a number of conclusions concerning pruning, thinning, and sawing practice.

EXTRAIT

En 1939 une futaie de Pins blancs (*Pinus strobus*) fut éclaircie et partiellement élaguée à la Station d'expériences forestières de Petawawa. Puis en 1965, lors de la récolte, les auteurs ont observé l'effet de ces traitements sylvicoles sur le volume et la qualité du bois d'oeuvre obtenus. Ils étudièrent aussi le rendement que procura le débit sur défilement des grumes ci-devant élaguées. L'élagage et l'éclaircie s'avérèrent ensemble très profitables (profit calculé de l'investissement de 1939 plus l'intérêt composé pour 27 ans). Par contre le débit sur défilement n'améliora pas la qualité (valeur monétaire) des sciages, et pis que cela, il entraîna une diminution de productivité dans la scierie et un bas rendement en volume. Cet échec peut avoir pour causes notamment la fréquence des blessures à chicots et l'épaisseur irrégulière du bois "clair" accru depuis l'élagage. Les auteurs donnent leurs conclusions à propos de l'élagage, des éclaircies et des méthodes de sciage.

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PRUNING AND SAWING EASTERN WHITE PINE:
A CASE HISTORY FROM STAND TREATMENT TO UTILIZATION

by

W.W. Calvert and L.G. Brace[1]

INTRODUCTION

A natural stand of eastern white pine (*Pinus strobus* L.) was thinned and pruned as part of an experimental improvement cut at the Petawawa Forest Experiment Station in 1939. In 1965, a sample of trees from this stand was felled and a complete record from pruning and thinning through to utilization was compiled, with the following objectives:

(1) To define the stand treatments;

(2) To compare the value of lumber from trees pruned and held for 27 years with that of unpruned controls;

(3) To compare the efficiency of two sawing methods - full taper sawing and conventional-grade sawing;

(4) To evaluate the silvicultural operations in terms of utilization.

This study is considered primarily a case history.

STAND DESCRIPTION AND TREATMENT HISTORY

STAND DESCRIPTION

The stand originated after a wildfire that occurred in 1875. It covers an area of about 10 acres on a ridge of fine wind blown sand varying in depth from 1 to 5 feet and overlying dumped glacial till. The site quality is above average, falling between Site Groups I and II of Horton and Bedell (1960) and within Site Class I of Plonski (1960).

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[1] Department of Fisheries and Forestry, Canadian Forestry Service, respectively Forest Products Laboratory, Ottawa, Ontario, and Petawawa Forest Experiment Station, Chalk River, Ontario.

At the time of treatment the stand was composed mainly of even-aged 60-year-old white pine. The general quality of the stand in 1965 was high for Ontario, as shown by a comparison of the lumber values[2] in the following tabulation:

Site	Age (years)	Value ($/M fbm)
Current study stand (untreated controls)	85	157*
Petawawa area	80	135
Haliburton	85	144
Algonquin Park	85	131
Algoma	over 200	127
Timagami	160	121

*Adjusted downward by $10 per M to allow for inclusion of upper logs, which will reduce average value.

1939 STAND TREATMENT

Thinning

The stand was marked before treatment by experienced personnel. Vigorous, well-formed white pine, mainly codominants, were favored in the thinning by removing competitors of sawlog size and girdling the others. An average of 1,260 fbm of sawlogs per acre was so removed and 5.3 cords[3] per acre were girdled. Cutting and girdling averaged 660 cubic feet per acre, approximately 20 percent of the standing volume. The stand was reduced from 600 to 300 stems per acre.

Pruning

After thinning, selected crop trees were pruned to a height of 18 feet with California-type saws. All branches were dead at the time of pruning. Pruning time records were inadequate, and some supplementary data were required to complete the study.

[2]From records of unpublished studies made by the Forest Products Laboratory and the Ontario Department of Lands and Forests.

[3]1 cord = 85 merchantable cubic feet; 1 merchantable cubic foot = 6 board feet.

1965 STUDY METHODS

SAMPLING

A total of 58 pruned and 58 unpruned trees covering similar ranges of diameter at breast height outside bark (dbhob) were chosen at random throughout the treated stand. All trees were straight, single-stemmed, and apparently healthy. Unpruned trees were of prunable quality, assumed to have been similar to the trees pruned 27 years previously. Since only a small proportion of the prunable trees were originally pruned, the stand afforded a good comparative sample.

The sample was then divided into four groups of 29 trees representing the four pruning treatment/sawing method combinations, as follows: taper-sawn, pruned (TP); taper-sawn, unpruned (TU); conventionally sawn, pruned (CP); conventionally sawn, unpruned (CU).

Before felling, crown widths were measured and increment cores taken at breast height. After felling, stem and live-crown lengths were measured and a disk was cut from the small end of each butt log for growth and age determination.

LOG CONVERSION

All logs were then sawn into 1-inch lumber with a band headsaw. Each log was either taper-sawn or sawn according to conventional practice as designated by the previous groupings.

In taper sawing, each of the four log faces was sawn parallel to the bark, in numerical sequence, by setting out the taper knees on the carriage. Turning was determined when the minimum sawn-face quality was exposed - in this study CLA grade No. 3 (Anon. 1966). Taper was removed by retracting the knees, in line, and sawing 1-inch boards to the required cant size. Because of the nature of this method, no square-edged, wedge-shaped boards were produced.

The conventional method simply followed good commercial-grade sawing practice, which involved turning the log frequently to minimize the effect of defects. For example, by the judicious turning of a cant, rot may often be confined to a single board rather than allowed to occur in small amounts through a series of boards. It should be noted that in any sawing method in which the log is placed against the knees of the carriage, sawing must be parallel to the bark on the opposite face.

All lumber was identified by log of origin and, after seasoning and dressing, was tallied and graded by an inspector of the Canadian Lumbermen's Association.

SAWING TIME

Two groups of 58 trees with size distributions similar to those previously discussed were taken from the stand to obtain 16-foot butt logs for use in an independent time study of the two sawing methods.

The logs were then sawn to the same specifications as the main sample, the sawing times being recorded by stopwatch. The dimensions of each piece of lumber were tallied to obtain lumber-recovery data, but the lumber was not graded.

PRUNING TIME

A 60-year-old stand of white pine resembling the 1939 condition was found. One hundred and twenty trees (20 in each of six 1-inch-diameter classes from 6 to 12 inches) were marked for pruning. Branch diameters, numbers of branches, and dbhob were recorded for the butt logs of each tree to be pruned. The trees were then pruned to a height of 18 feet, and pruning, movement, and rest times were obtained by stopwatch. The operation was done by an experienced crew using California-type saws similar to those employed in the original stand treatment and still in common use today.

LOG-SECTIONING PROCEDURES

Thirteen pruned butt logs were sectioned longitudinally in the sawmill, and 1-inch cuts *parallel to the pith* were used so that the center cut would bisect the pith (Figure 1). The purpose was to reveal in detail the effect of the taper sawing of pruned logs on lumber grade and value relative to conventional sawing. Boards were examined individually, and collectively as reconstructed logs.
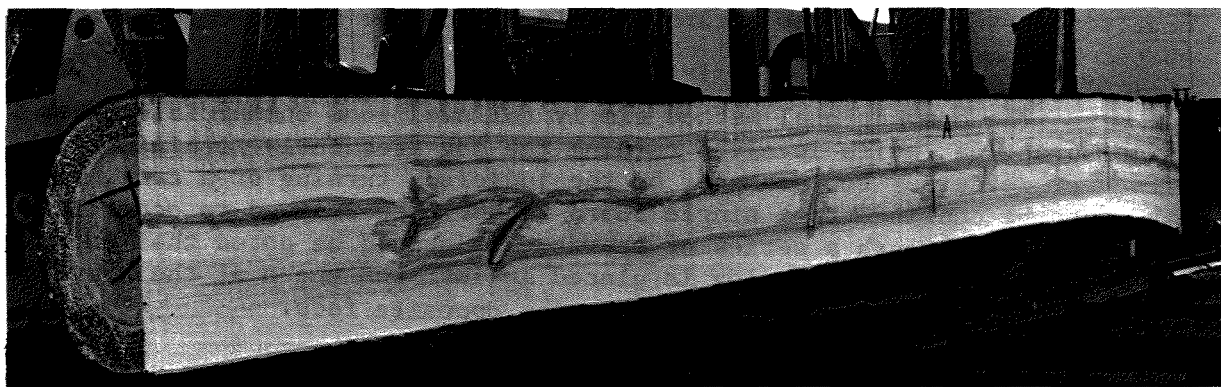

Figure 1. A white pine butt log cut along the pith showing pruned branch stubs.

All pruned-branch stubs that were sawn longitudinally during sectioning were measured to determine:

(1) The radial growth rate above the stub;

(2) The total growth at that point from the pruning to the felling date;

(3) The stub protrusion after pruning;

(4) The pruned-branch diameter;

(5) The number of years needed to heal over the pruned stub;

(6) The actual radial extension of the pruning scar (scar width).

ANALYSIS AND RESULTS

GENERAL

Comparative stem-analysis statistics for sample trees and logs are shown in Appendix 1.

On the assumption that pruning affected only the butt logs and that upper logs would exhibit similar volume and quality, the analysis was confined to the butt-log part of the tree. Stem-analysis data supported this assumption and, in general, verified the sampling procedure.

Butt-log statistics were as follows:

Group	Small-end diameter inside bark (inches)	Mean radial growth at small end after pruning (inches)
TP	11.2	2.1
TU	11.6	2.0
CP	11.7	2.5
CU	11.7	2.1

GROWTH AFTER TREATMENT

The statistical significance of the difference between means for radial growth after treatment, RGI[4] (a measure of shell taper), and shell-

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[4]RGI = relative growth index = $\dfrac{\text{radial growth inside bark since pruning at small end of butt log}}{\text{radial growth inside bark since pruning at breast height}}$

to-core ratio[5] was investigated by "t" tests (P = 0.05).

Pruned groups combined differed significantly from unpruned groups combined in mean growth since treatment; and pruned groups differed significantly from one another in mean growth since treatment and mean shell-to-core ratio. Mean RGI (shell taper) was not significantly different between pruned groups.

The differences between pruned and unpruned groups are attributable mainly to the CP group. Trees in this group were smaller at treatment and grew more rapidly after treatment than did other groups. In this regard, similarity at felling was not a good index of similarity 27 years previously. There were no significant mean growth differences between groups in the decade before treatment.

The foregoing differences proved later to be of no practical importance.

Pruned trees were apparently released somewhat more by thinning than were unpruned trees (Appendix 1).

EFFECT OF PRUNING SCARS ON LOG QUALITY

After pruning, scars developed as new wood grew over the branch stubs. Examination of sectioned logs showed that many pruned branch stubs extended well beyond the bark after pruning, and, depending on their length in relation to growth rate, were capable of precluding the formation of sawable clear shell for many years.

Figures 2 and 3 show graphically the factors affecting the width of pruning scars and the healing time for the range of variables encountered.

Branch diameter and stub protrusion were the most important factors determining scar width; stub protrusion and rate of growth were most important in determining the time for stubs to heal. The increase in scar width with increase in growth rate appears less important than the corresponding decrease in healing time with increase in growth rate.

The results indicate that trees to be pruned should have straight logs and small branches. Branches should be pruned as close as practicable to the stem and trees released. This will result in minimum scar width, minimum healing time, maximum growth, and the maximum yield of clear sawable wood.

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[5]Shell-to-core ratio = $\dfrac{\text{radial growth inside bark since pruning at small end of butt log}}{\text{radius inside bark at small end of butt log at time of pruning}}$
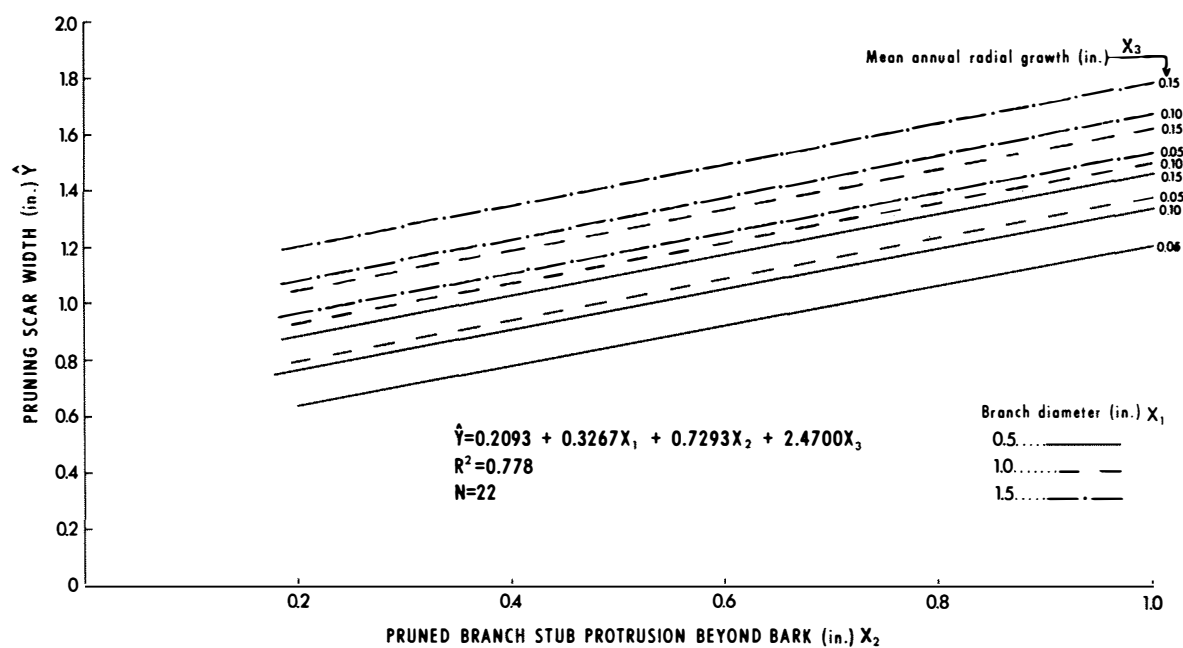
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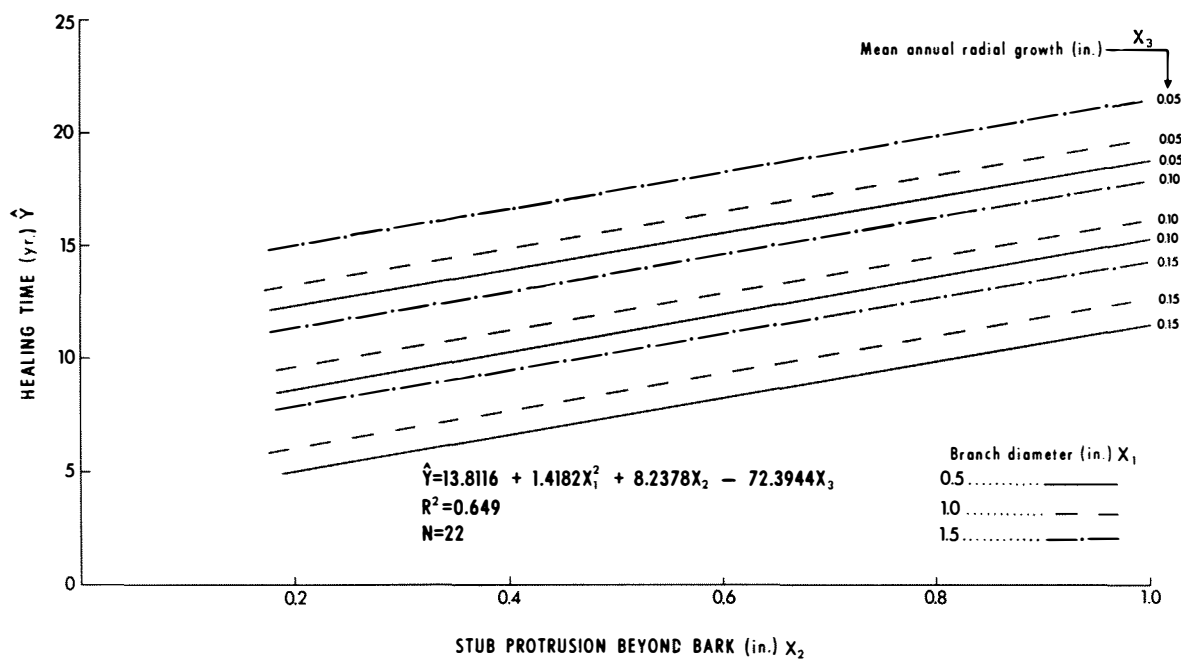Figure 2. *Pruning-scar width as a function of stub protrusion beyond bark.*

Figure 3. *Healing time of a pruning scar as a function of stub protrusion beyond bark.*

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Left plot legend:
TP _____
TU _.._.._
CP _ _ _ _
CU _.._.._

$$\hat{Y}_{TP} = 0.1734 + 0.8961X \quad 29 \quad 0.971$$
$$\hat{Y}_{TU} = 0.3144 + 0.8774X \quad 29 \quad 0.967$$
$$\hat{Y}_{CP} = 0.7790 + 0.8528X \quad 29 \quad 0.974$$
$$\hat{Y}_{CU} = 0.3937 + 0.8759X \quad 29 \quad 0.972$$

(with columns headed N and R^2)

Right plot:

Pruned $\hat{Y} = 0.4759 + 0.8740X \quad 58 \quad 0.972$
Unpruned $\hat{Y} = 0.3544 + 0.8766X \quad 58 \quad 0.970$

(with columns headed N and R^2)
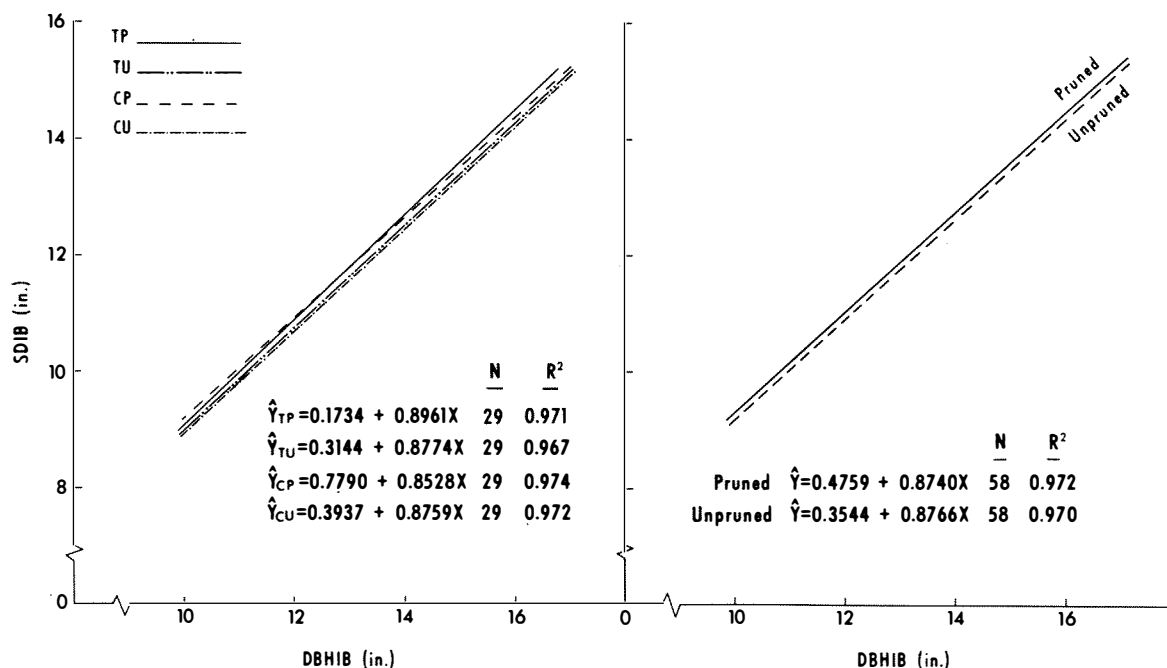
Figure 4. Log taper.

SIZE, TAPER, AND QUALITY AT FELLING

Mean dbhob, mean small-end diameter inside bark (sdib), and taper did not differ significantly between groups at the time of felling ("t" tests, P = 0.05).

The similarity in log taper for all groups is shown in Figure 4.

In general, sample groups were comparable in size, taper, and apparent quality at the time of felling.

SAWING

Lumber Grade, Value, and Volume

Table 1 lists percent grade recoveries by treatment group. A good criterion for comparative purposes is the yield of clears (D and better). It is shown that pruned logs yielded more than twice as much lumber in this category as unpruned logs. It is also apparent that taper sawing had little or no effect on the yield of clear lumber.

A more important consideration, however, is the effect of pruning and the sawing method on unit values. Unit value per log was determined by applying wholesale lumber prices by grade (Appendix 2) to each piece of

TABLE 1.   PERCENT GRADE RECOVERY

Grade	Taper-sawn, pruned	Taper-sawn, unpruned	Conventionally sawn, pruned	Conventionally sawn, unpruned
C Select	6.7	1.6	7.3	2.1
D Select	13.8	9.0	15.5	7.4
1 and 2 cuts	2.8	0.8	2.6	0.7
D and better[a]	23.3	11.4	25.4	10.2
No. 1	37.4	39.1	34.1	44.3
No. 2	22.0	25.1	18.4	25.6
No. 1, 2	59.4	64.2	52.5	69.9
No. 3	12.6	19.1	15.1	17.3
No. 4	3.8	4.5	6.1	1.9
No. 5	0.9	0.8	0.9	0.7
No. 3, 4, 5	17.3	24.4	22.1	19.9
Total	100.0	100.0	100.0	100.0

[a]Includes cuts.

NOTE: Total yield from 116 logs = 10,250 fbm.

lumber sawn, making a summation, and dividing by total log recovery. Analysis of variance indicated that pruning had a highly significant effect on unit value, while the sawing method had none at all. Mean unit lumber values for the four groups are as follows:

Group	Value ($/M fbm)
TP	177
TU	165
CP	176
CU	169

Percent recovery expresses the amount of lumber recovered from a log in terms of the solid volume of the log and is, to some extent, a measure of sawing efficiency (Calvert 1963). Analysis of variance indicated a highly significant (P = 0.01) advantage for the conventional sawing method in terms of percent recovery. The analysis also indicated, at a relatively low level of significance (P = 0.10), that proportionally more lumber was recovered from pruned trees. In this regard, Figure 4 shows that pruned trees had slightly less taper than unpruned trees. Other things being equal, logs with lower taper will yield more lumber per unit of solid volume than logs with higher taper (Calvert 1963). The slightly lower taper for butt logs from pruned trees cannot be attributed to pruning, since no live crown was removed.

Mean percent recovery values[6] for the four groups are as follows:

Group	Percentage
TP	50.9
TU	49.8
CP	56.9
CU	53.9

Sawing Time

The measure of this operation was sawing time per M fbm. Figure 5 shows the relationship between sawing time, log size, and sawing method. The decreasing trend of unit production time with increasing log size is well known. However, the remarkable and highly significant difference in sawing times, in favor of the conventional method, is revealing and is indeed substantially greater than expected.

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[6]It should be remarked that all percent recovery values are relatively low, by commercial standards, because all lumber is sawed to a 1-inch thickness.
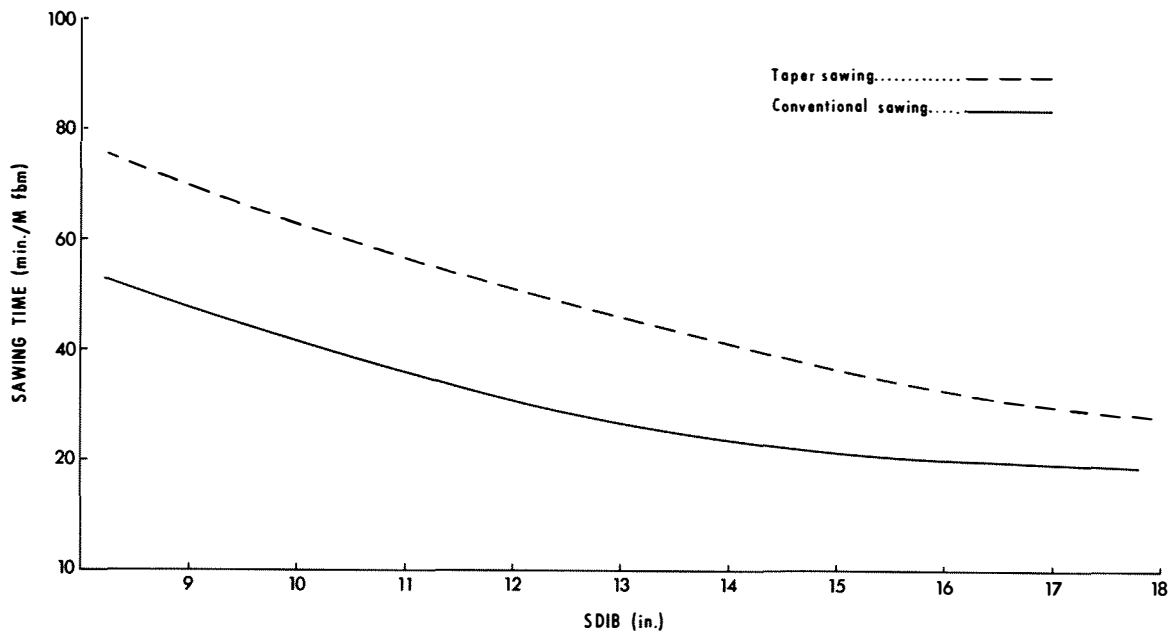
Figure 5. Sawing time per M fbm by log diameter class.

Currey and Endersby (1965), Horton (1966), and Telford (1951) have suggested that taper sawing may have general merit. It has been recommended specifically for pruned logs so that maximum advantage can be taken of the clear shell. The literature on taper sawing, however, is very limited, and comments on this method are in many cases based on opinion and theory rather than on experience.

WHY TAPER SAWING SHOWED NO ADVANTAGE

In this study, there was no apparent advantage due to taper sawing. To investigate the possibility that peculiarities of sampling might be the reason for these results, 20 matched[7] pairs of butt logs were evaluated. Table 2 shows that unit value was erratic in relation to growth and diameter and not clearly affected by sawing method, as reported for the total sample. Therefore, the original comparisons (tabulated data at top of page 10), which showed similar unit values for both sawing methods, appear valid for the range of relevant variables found in the stand.

'The effect (or lack of effect) of taper sawing on lumber value may be rationalized as follows. Lumber value is a function of both the grade and the dimensions of the piece. For like dimensions, value increases with grade; for like grades, value generally increases with increases in thickness, width, and length (Appendix 2). Since all lumber in this study was sawn into

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[7]Pairs of logs were closely matched by sdib, radial growth, and RGI.

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TABLE 2.   EFFECT OF SAWING METHOD ON UNIT VALUE FOR MATCHED PAIRS OF PRUNED LOGS

	Taper-sawn				Conventionally sawn					Difference (taper-conventional)		
Tree no.	sdib (inches)	Radial growth (inches)	RGI	Unit value ($)	Tree no.	sdib (inches)	Radial growth (inches)	RGI	Unit value ($)	sdib (inches)	Radial growth (inches)	Unit value ($)
35	8.81	1.35	0.98	202.61	55	8.81	1.56	1.00	192.12	–	-0.21	10.49
128	9.54	1.96	1.00	196.70	69	9.28	1.75	1.04	176.65	0.26	0.21	20.05
131	9.56	2.49	0.98	177.23	114	9.70	2.22	0.91	199.57	-0.14	0.27	-22.34
54	9.71	1.97	1.09	203.89	49	9.05	1.97	1.13	204.78	0.66	–	- 0.89
47	9.78	1.74	0.93	136.23	48	9.82	1.71	1.05	162.46	-0.04	0.03	-26.23
53	9.85	1.85	1.08	180.53	52	9.07	1.86	1.08	186.99	0.78	-0.01	- 6.46
112	10.01	1.90	0.91	174.59	77	10.37	1.94	1.00	172.19	-0.36	-0.04	2.40
123	10.29	1.93	1.26	167.52	97	10.95	1.99	1.14	163.12	-0.66	-0.06	4.40
3	10.52	2.37	1.01	185.34	63	10.90	2.32	1.17	188.31	-0.38	0.05	- 2.97
8	10.62	1.87	0.97	206.46	73	10.74	1.86	0.97	182.00	-0.12	0.01	24.46
45	10.92	2.43	1.03	163.17	126	10.58	2.47	0.95	225.49	0.34	-0.04	-62.32
13	11.12	1.65	0.97	193.52	4	10.51	1.71	0.83	196.22	0.61	-0.06	- 2.70
93	11.93	3.05	1.17	165.03	99	11.85	3.01	0.97	160.81	0.08	0.04	4.22
44	12.09	2.33	0.98	117.63	70	12.77	2.25	0.99	140.97	-0.68	0.08	-23.34
90	12.10	2.67	0.91	202.96	94	11.71	2.80	0.91	186.61	0.39	-0.13	16.35
95	12.20	2.19	0.88	184.56	101	12.12	2.17	1.04	141.41	0.08	0.02	43.15
5	12.80	1.94	0.77	209.80	10	12.53	1.86	0.94	190.79	0.27	0.08	18.29
98	12.91	2.48	0.95	181.52	107	12.42	2.84	0.83	152.97	0.49	-0.36	28.55
86	13.46	3.51	0.94	168.63	109	13.38	3.62	0.90	225.68	0.08	-0.11	-57.05
102	14.92	3.11	1.04	160.18	106	15.49	3.28	1.15	138.88	-0.57	-0.17	21.30
Mean	11.15	2.23	0.99	177.10		11.10	2.25	1.00	177.15	Mean diff. 0.05	-0.02	- 0.53

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1-inch thicknesses, only width and length need be considered. Average widths and lengths were computed for each sawing method, and the results are as follows:

Method	Average width (inches)	Average length (feet)
Taper sawing	5.7	12.5
Conventional sawing	6.2	13.2

Although small, the differences partially offset increases in value due to grade. This, however, does not fully explain the results. It is quite evident from Table 1 that the yield of "clears" is virtually the same for each of the two sawing methods. This statistic is independent of the dimension effect.

Log-sectioning

Log-sectioning revealed further details concerning the taper-sawing results.

Only four of the 13 sectioned logs were judged to have greater potential for grade recovery by taper sawing, and of these only two showed the tendency clearly. The principal reasons for the lack of grade increase due to taper sawing seem to be:

(1) Orientation of defects (including pruning scars);

(2) Sweep;

(3) The nature of the clear shell after pruning.

With regard to defect orientation, there is no advantage for taper sawing relative to conventional sawing, unless:

(a) No defects are present; or

(b) Major defects are located on one face; or

(c) Major defects are confined to two opposite faces.

In conventional sawing the poor face is sawn first so that the face opposite is automatically sawn parallel to the bark. Thus, where major defects occur on two adjacent faces, there is no potential for taper sawing. Where major defects are located on opposite faces only, the two remaining clear faces offer potential for taper sawing. Where major defects are confined to one face, the potential is the same as that just mentioned (keeping in mind that potential refers to the increase in the lumber value due to taper sawing over the lumber value resulting from conventional sawing). Where all faces are clear, the greatest potential exists for taper sawing.

In many of the sectioned logs, failure to obtain a value increase by taper sawing could be attributed to the difficulty of detecting major

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defects (pruning scars) just below the log surface. Because of these
defects, the logs could not be oriented to take advantage of taper sawing
in the manner just discussed.

Sweep affects taper-sawing potential. In a clear log (four faces)
sweep will virtually limit the potential to two opposite faces out of the
sweep plane. If, however, both sweep and major defects (knots) exist
(Figure 6), the potential is further reduced unless the defects occur on
those faces within the sweep plane. The chances that this will happen are
low. For example, although only one face may be affected by a major defect,
the probability that the defect will occur within the sweep plane is 0.5.
By itself, sweep is just a limiting factor; but when it is combined with
other defects, its adverse effect is considerably magnified.

The nature of the so-called clear shell since pruning and its
effect on taper sawing must be considered in terms of and in combination
with defect orientation and sweep. Clear shell, from the sawing point of
view, is directly proportional to radial growth since pruning and inversely
proportional to the width of pruning scars and the degree to which the shell
tapers and "wanders." On the sectioned logs, radial growth averaged 2.10
inches and ranged from 1.40 to 3.90 inches. Scar width averaged 0.95 inch
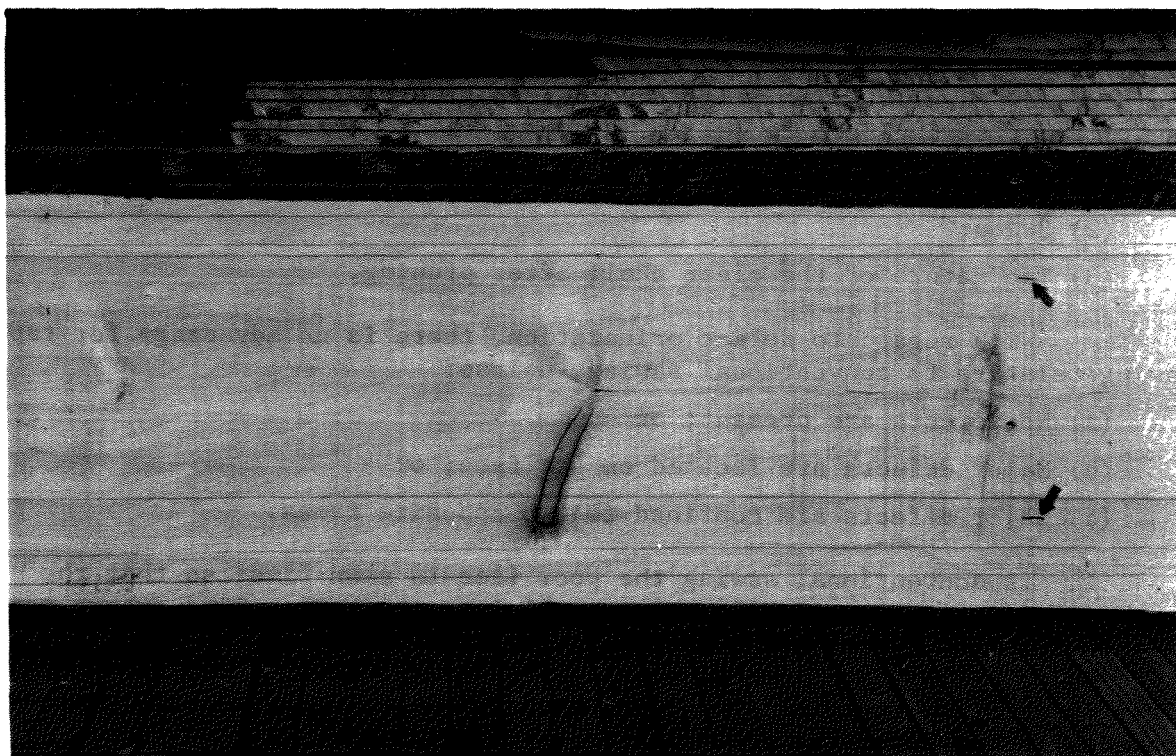

*Figure 6. A close-up view of a center-cut board showing a pruned branch.
The arrows indicate log diameter 27 years ago. The inner lines,
representing a projection of this diameter, cut across the knot
well inside the extremity because of a slight upward sweep in
the log.*

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and ranged from 0.65 inch to 1.50 inches. Clear shells were observed to
deviate in unexpected ways, and they tapered, generally becoming narrower
toward the small end of the log. Moderate growth rates, pruning scars,
and shell irregularity combined to preclude increased value recovery by
taper sawing on many of the logs. These factors can be controlled to some
extent by releasing trees adequately (and even fertilizing) after pruning
to increase growth rate, and by pruning branches close to the stem.

PRUNING QUALITY

        The quality of pruning (the length of pruned-branch stub left
protruding from the stem) was obviously a factor in the reduction of lumber
quality in the pruned sample, On the basis of current experience, the
quality of the pruning job in 1939 was average. Pruned-branch stub pro-
trusions of 0.5 inch are not uncommon for heights over 12 feet from the
ground. Table 3 shows the effect of scar width on clear shell for the
relevant range of variables.

PRUNING TIME AND RETURNS

        Figure 7 shows pruning times applicable to the mean-diameter tree
at pruning and covering the range of relevant variables in the sample.
Table 4 shows economic returns for the mean and range of pruning times and
costs. Returns on investment were calculated from the average and range
of pruning costs, the volume of the butt log of average size, and the
corresponding lumber-price difference between pruned and unpruned logs.
The indicated return of 14.2 percent is attractive even if lending costs
at current rates of interest are charged against it. An economic study, in
depth, would require consideration of alternative investment opportunities
to complete the picture.

        It is clear that pruning costs decreased with decreasing branch
size and number. Tree dbhob, within the range of 6 to 12 inches, had a
minor effect on pruning time: times decreased slightly with decreasing tree
size, presumably because, when work was done around a smaller tree, fewer
moves were necessary to cut branches flush with the bole.

        Branch size and number varied little over the dbh range of 6 to
12 inches, thus allowing some latitude in the selection of the diameter of
trees for pruning, without regard to these features.

        Time and costs saved by pruning smaller trees may well be offset
by the effect of compound interest charges over the longer waiting period
that must elapse before the smaller trees can be sawn (Horton 1966). Also,
smaller trees have smaller crowns (in even-aged pine stands) and hence have
less total growth potential over a given time after treatment. Even if
smaller trees grow as much in radius as larger trees in a given time and
produce a higher unit value (a tendency apparent in the sample stand), the

TABLE 3. REDUCTION OF CLEAR SHELL BY PRUNING SCARS

Branch diameter (inches)	0.50			0.85[a]	1.00			1.50		
Stub protrusion (inches)	0.20	0.50	1.00	0.40	0.20	0.50	1.00	0.20	0.50	1.00
Scar width (inches)[b]	0.74	0.96	1.32	1.00	0.90	1.12	1.49	1.07	1.29	1.65
Mean clear shell (inches)[c]	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Mean effective clear shell (inches)	1.58	1.36	1.00	1.32	1.42	1.21	0.83	1.25	1.03	0.67
Percent clear-shell reduction by scars	32.00	41.00	56.00	43.00	39.00	48.00	64.00	46.00	56.00	71.00

[a]Average condition for all pruned trees sawed in main sample.

[b]Used range of branch diameters and stub protrusions for main pruned sample and mean of annual growth rates for all pruned trees, and values computed from equation in Figure 2.

[c]Mean clear shell is average of shell thicknesses for all pruned trees in main sample, at small end.
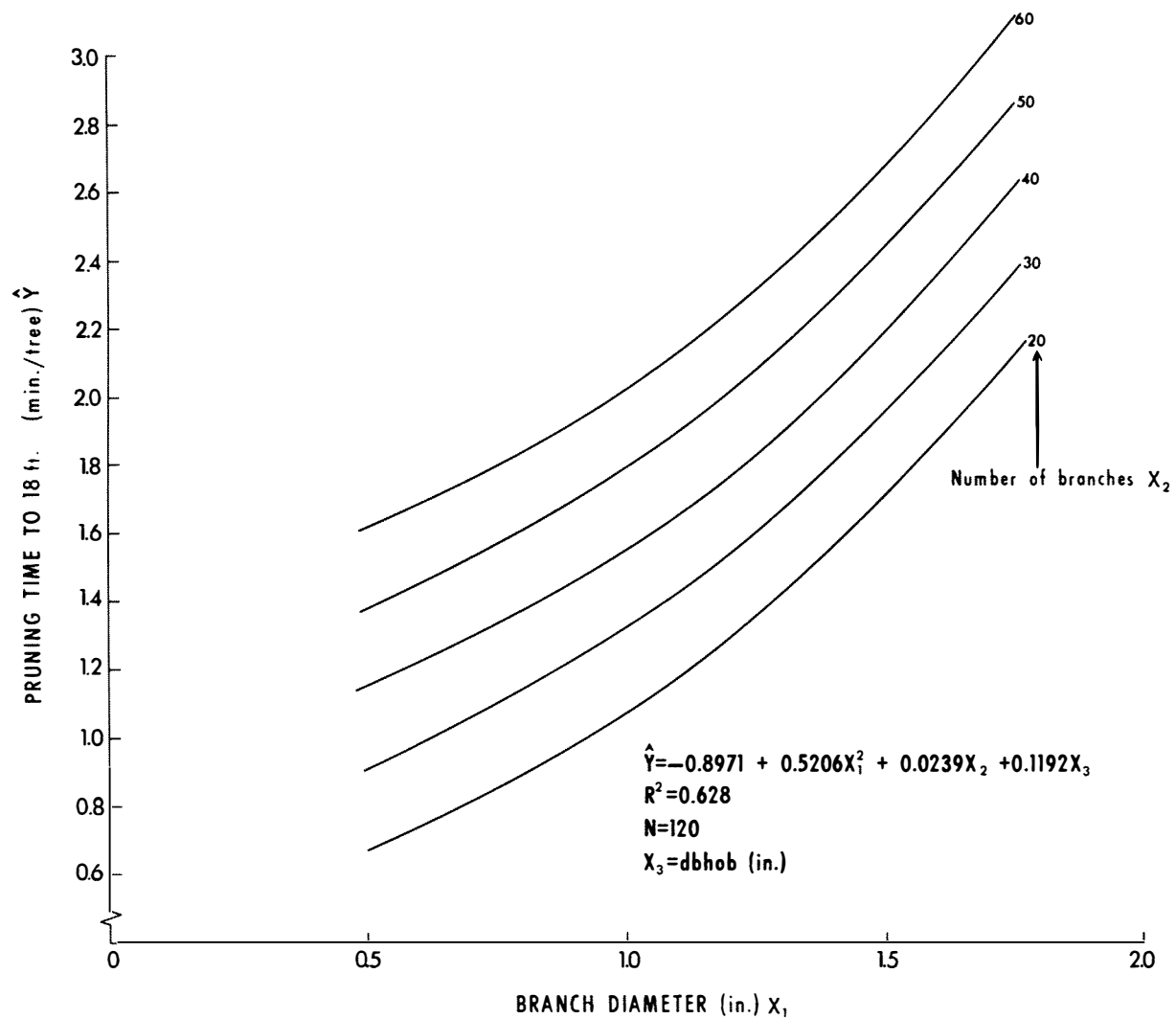
Figure 7. *Average pruning time per tree for various sizes and numbers of branches.*

actual amount of lumber produced is less. Therefore it appears that larger second-growth pine (8 to 10 inches dbh in this study) should be favored in pruning, within the limitations of branch size and number, to achieve maximum pruning returns.

The effects of greater growth, which might be achieved from more release and perhaps from fertilization, on value gain in a similar period are mere speculation but should be considered.

TABLE 4.   PRUNING TIME, COSTS AND RETURNS PER TREE FOR MEAN, AND RANGE OF MAIN VARIABLES

	Lower limit	Mean[a]	Upper limit
Branch diameter (inches)	0.50	0.85	1.00
Number of branches	20	50	70
Pruning time (minutes)[b]	0.79	1.69	2.25
Rest and movement (minutes)	1.22	1.22	1.22
Total time per tree (minutes)	2.01	2.91	3.47
Cost per tree (dollars)[c]	0.012	0.017	0.020
Cost per tree with allowance for supervision and tree mortality[d]	0.014	0.020	0.024
Compound interest on pruning investment (percent)[e]	15.5	14.2	13.5

[a] Computed for average tree in pruned sample; dbh = 8.0 inches at pruning.

[b] Pruning time computed from equation in Figure 7.

[c] Labor rate in 1939 = $0.35 an hour.

[d] Allow costs for pruning 20 percent more trees per unit of area (prorated on an individual-tree basis) to compensate for cost of supervision and losses due to mortality.

[e] Compound interest computed from $V_n = V_o (1 + i)^n$

V_n = average lumber-value difference between pruned and unpruned butt logs (page 10, top), which, on basis of average log volume of 77 fbm, is $0.73 a log.

V_o = cost of pruning average tree in 1939.

i = interest rate.

n = 27 years.

SUMMARY AND CONCLUSIONS

In an experimental improvement cut carried out in 1939 at the Petawawa Forest Experiment Station, a substantial value increase (average of $9.50 per M fbm) was realized by pruning white pine crop trees to 18 feet and sawing them after 27 years. The average compound interest earned on the pruning investment was 14.2 percent.

Examination of sectioned logs revealed the effects of log sweep, pruning scars, natural clear-shell deviation, and radial growth rate upon the yield of select grades of lumber.

Major controllable factors affecting pruning-scar size and healing rate and pruning costs were defined.

Pruning returns from second-growth white pine can be increased considerably over those reported here by pruning straight logs only, cutting branches flush with the bark, and pruning fast-growing trees with branches of 1-inch diameter or less. The cost of treatments, such as thinning, necessary to maintain or increase the growth rate would reduce pruning profit.

Log size at pruning and subsequent radial growth had no consistent effect upon lumber value in this study, for reasons that can be inferred from the results of log-sectioning and from pruning-scar evaluation.

Taper sawing had no effect on unit value but resulted in a 5-percent reduction in lumber recovery and considerably lower sawmill productivity. Perhaps a larger clear shell resulting from a faster growth rate or a longer period of time between pruning and harvesting or from both would make taper sawing advantageous. It must be remembered, however, that to be economically attractive, the increase in lumber value must more than offset lower volume yield and lower sawmill productivity.

ACKNOWLEDGMENT

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APPENDIX 1   STEM-ANALYSIS DATA - TREES AND LOGS

	Group											
	TP		CP		TU		CU		Combined pruned		Combined unpruned	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Total height (feet)	80.00	5.64	80.00	5.24	82.00	7.34	80.00	5.97	80.00	5.39	81.00	6.63
Age (years)	73.00	6.65	71.00	6.38	78.00	10.92	74.00	9.38	72.00	6.46	76.00	10.09
Clear bole (feet)	42.00	8.88	39.00	7.90	46.00	6.75	43.00	5.91	40.00	8.33	44.00	6.29
Crown width (feet)	20.00	6.03	23.00	6.37	24.00	4.38	23.00	4.77	22.00	6.14	24.00	4.54
Live crown (percent)	48.10	10.99	51.00	10.03	44.30	6.71	45.70	7.28	49.60	10.43	45.00	6.94
Present dbh outside bark (inches)	13.41	2.44	14.04	2.54	14.23	2.45	14.16	2.62	13.72	2.47	14.20	2.51
Present dbh inside bark (inches)	12.29	2.09	12.82	2.32	12.91	2.20	12.92	2.35	12.55	2.19	12.92	2.26
Double bark thickness at dbh (inches)	1.12	0.40	1.22	0.28	1.32	0.32	1.24	0.32	1.17	0.34	1.28	0.32
Past dbhib[a] (inches)	7.91	1.32	7.56	1.42	8.53	1.70	8.56	1.86	7.73	1.36	8.56	1.77
Present sdob[b] (inches)	11.93	2.05	12.52	2.13	12.52	2.07	12.53	2.26	12.22	2.07	12.52	2.15
Present sdib[c] (inches)	11.18	1.91	11.72	2.00	11.64	1.96	11.71	2.09	11.45	1.94	11.68	2.01
Double bark thickness at small end of log (inches)	0.75	0.18	0.80	0.20	0.88	0.16	0.82	0.23	0.78	0.18	0.85	0.20
Past sdib (inches)	6.94	1.39	6.66	1.27	7.72	1.81	7.61	1.78	6.81	1.32	7.68	1.78
Radial growth at sd (inches), decade before treatment	0.72	0.22	0.73	0.20	0.71	0.22	0.76	0.22	0.72	0.21	0.73	0.22
Radial growth at sd[d] (inches) (27 years)	2.12	0.56	2.53	0.75	1.96	0.42	2.05	0.55	2.32	0.66	2.00	0.48
Radial growth at breast height (inches) (27 years)	2.19	0.60	2.63	0.85	2.19	0.60	2.18	0.63	2.41	0.73	2.18	0.61
RGI (27 years)	0.97	0.11	0.96	0.10	0.90	0.16	0.94	0.10	0.96	0.10	0.92	0.13
Shell-to-core ratio	0.63	0.20	0.79	0.26	0.53	0.16	0.57	0.25	0.71	0.23	0.55	0.21

[a] dbhib = diameter at breast height, inside bark.

[b] sdob = small-end diameter, outside bark.

[c] sdib = small-end diameter, inside bark.

[d] sd = small-end diameter of log.

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APPENDIX 2 1966 WHOLESALE PRICES[a] FOR 4/4 WHITE PINE ($/M fbm)

Width	Length	C Select	D Select	Cuts 1 & 2	Cuts 3	1	2	3	4	5
4"	6'/7'	198	188	192	120	138	105	102	84	74
4"	8'/16'	260	244	–	–	192	159	102	84	74
5"	6'/7'	198	188	–	–	138	105	102	95	74
5"	8'/16'	260	244	–	–	187	154	102	95	74
6"	6'/7'	198	188	–	–	138	105	112	95	74
6"	8'/16'	260	244	–	–	187	154	112	95	74
7"	6'/7'	198	188	–	–	138	105	112	95	74
7"	8'/16'	260	244	–	–	187	154	112	95	74
8"	6'/7'	229	205	–	–	138	105	112	97	79
8"	8'/16'	291	244	–	–	187	154	112	97	79
9"	6'/7'	229	205	–	–	138	105	112	97	79
9"	8'/16'	291	244	–	–	187	154	112	97	79
10"	6'/7'	229	205	–	–	138	105	112	97	79
10"	8'/16'	302	255	–	–	212	164	120	97	79

[a]F.o.b. customer.