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QUALITY IN THE SECOND GROWTH WHITE PINE OF NEW ENGLAND.

Introduction

In the earlier stages of the lumber industry in New England, White Pine, pinus strobus, had, by far, the widest commercial utilization of any of the soft woods. Indeed, for many years following the American Revolution, it was the only soft wood on the market. The square edge and dimension lumber produced in those earlier times, however, differed in quality from that obtained in the second growth stands of the present day. In the best logs from virgin stands all knots are located near the heart with much clear width surrounding them. In the grading rules of the wholesale associations, under which most of the original timber has been sold, the quality of a board is governed fundamentally by the number and size of the knots. Thus in the case of the old growth timber, lumber of the upper grades consists of practically clear wood.

The present second growth Pine is, in the main, too young to have produced clear wood outside the knots. All of it has originated since 1840-50, and eighty per cent of the timber cut today is between fifty and sixty years old. After the virgin pine

became exhausted about 1870, these stands began to be increasingly utilized by industries which were able to use lumber of inferior quality and in a great variety of small pieces. Under these conditions, it became the general practice to saw logs through and through into round or "wany-edged" lumber. This resulted in a much more complete utilization of the tree but precluded any classification according to the existing wholesale grades. Today the great bulk of the New England White Pine lumber is bought and sold with only such vague definitions of grade as are conveyed to experienced persons by the terms "box boards, sash and blind stock, butt cuts, etc." This does not mean, however, that there is no such thing as a range in quality in the timber. On the contrary, the prices paid and the requirements of various industries indicate a very considerable range of quality. This cannot be defined by the terminology of the market, but only in the terms of the life history of the timber.

Since the side branches in the White Pine develop from buds growing in whorls at the beginning of each season's growth, the knots occasioned by their development occur in groups at more or less irregular intervals. It will be readily seen, therefore, that the longer the annual growth or internode in the original tree, the greater the distance

between the whorls of knots and the fewer the knots in any one log or piece of lumber. The size of the individual knot is regulated by the growth and age of the branch that caused it. Short lived branches produce small, red and usually sound knots. Branches which attain a greater diameter are more detrimental to the quality of the lumber. The longer the life of the side branches, the poorer will be the quality of the lumber manufactured from the trunk. The term "good quality", therefore, as applied to the second growth White lc Pine timber, signifies long internodes and early death of the lc side branches; "poor quality" the reverse. From the point of view of forest management, and marketing, it is necessary to secure some more exact analysis of quality which will cover both the range in price and requirements exhibited by the consuming industries and the silvical factors which govern the production of the timber.

Utilization as Governed by Quality.

A study made of the lumber used by important industries in Eastern and Central Massachusetts, Southern New Hampshire and Maine, including woodenware, box, toy, match, sash blind and door manufacture, pattern sawing and the making of piano cases, discloses the fact that length of internode is the primary factor determining quality in purchase and manufacture.

The following table shows a summarized comparison of the logs and round edged lumber utilized in some of these industries. It is based on the measurement of the internodes in thirty-five different lots found in mill yards. The internodes are divided for convenience into six inch classes, the relative frequency of occurrence of each being shown on a percentage basis.

TABLE I

Lengths of Internode	1"-6"	7"-12"	13"-18"	19"-24"	25"-30	31"-36"	37"-42"
Woodenware Manufacture	8.4%	38.3%	19.3%	5.4%	1.3%		
Box "	7.1	27.3	39.7	21.3	3.9	1.7	
Toy "	5.2	20.5	38.6	30.9	3.5	1.1	
Match "		32.1	37.1	22.5	5.9	2.4	
Sash and Blind "		16.8	31.6	34.7	6.9	4.1	5.9

It is obvious that the lumber in the industries here tabulated varies progressively as to length of internodes. The sash and blind lumber, representing the most carefully selected material, shows for that reason a higher percentage of long annual growths.

A sure index to the quality requirements of an industry is the standard set for the manufactured product. In the manufacture of wooden containers, pails, etc., a clear idea

of the character of the logs required can be got from a consideration of the quality of stave demanded. One firm requires clear staves in lengths varying from seven up to seventeen inches. Only in one case, that of a fourteen inch stave, is any allowance made for the inclusion of knots. Where, however, ice cream freezers are made staves are in demand in clear lengths up to 31 inches. Logs containing material for a 31 inch stave are few and far between.

In the process of manufacture the first step consists in the removal, on the bolting saw, of the whorls of knots directly from the logs. Where the latter are more knotty they are cut into heading bolts for the bottoms and covers of the containers. The staves are sawed from the bolts on a cylindrical "stave saw". Since, from the nature of the case, much heading is needed, the more knotty logs find a ready use. It is plain, however, that ordinary log run lots of pine are usually suitable for such purposes. White Pine used in this industry is purchased in Southern New Hampshire at $15. per decimal cord (100 cubic feet) delivered at the factory. Double price is paid for logs with very long internodes.

In the manufacture of boxes no attention is paid to clear length or size of knots. The fundamental requirement is simply that the knots should be sound. The lowest grade of box, manufactured in plants attached to large establishments

for the shipment of such products as slaughterhouse meat, where it would be impossible, from the nature of the case, to use the box a second time, is made from poorer box lumber. For this purpose, round edge plank is bought in log run lots which do not include the butt logs or the lumber manufactured from them. Often shooks are made from mixed lumber combining spruce, hemlock and pine. In such cases the appearance of the package counts for little. The main idea is to produce a strong, inexpensive box which will get the contents to its destination. The cost of such lumber ranges between $30. and $40. per thousand board feet.

In the manufacture of boxes for ordinary commercial purposes a very close utilization of all lumber is made. It is possible, especially where the whole process is done mechanically, to use every square inch of a round edged board, whether it is clear or knotty. The plank or board is first cut into "plugs" or pieces of a fairly uniform length but of varying width. These are grooved and glued together into blocks. From these blocks after they are trimmed the shooks are cut either on a "merry-go-round" or a band resaw. The waste material left from the manufacture of the larger shooks is glued together and used to make the smaller.

In extraordinary instances, where it is necessary to make boxes of a superior quality for some particular purpose more care is used in manufacture. Typical of such a case are the

boxes required by the United States War Department. "Nailed and locked corner boxes" must be well manufactured from lumber which is sound (free from decay and dote) and well seasoned. Lumber must be free from knotholes and loose or rotten knots greater than 1 inch in diameter. Knots whose diameter exceeds one third the width of the board -- will not be permitted and no knots will be permitted which will interfere with the proper nailing of the box."(1) To make boxes of the grade required here greater discrimination is necessary in the selection of material. During times of pressure as much as $55. per thousand board feet has been paid for round edge box boards of a superior quality. The cost of round edge box boards averages about $35. per thousand board feet in log run lots. Where, however, a particularly good grade of lumber is in demand, as much has been paid as $45. per thousand board feet.

In the making of toys there is little need for any greater amount of discrimination than in the box industry. Clear lumber is necessary, to be sure, wherever odd shapes have to be cut out, as for instance, the heads of rocking horses or wherever knots would injure the appearance of the manufactured product. It would seem that for the bulk of the articles manufactured, size and soundness of knot is of secondary consideration wherever paint, varnish or putty can smooth over the defect. Manufacturers try to secure a good grade of

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(1) See Supply Circular #32, "Standardization of Boxing and Crating Specifications."

box plank. This is purchased in Northern Massachusetts for $35. per thousand board feet.

In the manufacture of match blocks the main requisites in the lumber are straightness of grain and fairly long internodes. The plank is sawed round edge 1/8 inches in thickness. In order to avoid waste in manufacture, it is advisable to have lumber as clear of knots as possible. Much of the pine, since it is delivered log run at the factory, is, of necessity, unfit for match blocks. Hence the manufacture of some by-product, such as box shooks, is necessary to utilize the remainder. In order to facilitate an even daily output of the main product, it is desirable that a log run lot of pine contain at least 45% of material suitable for match blocks. In the process of manufacture the plank is planed, cut into bolts and sorted. Those bolts suitable for match blocks then go to the block saws where the whorls of knots are cut out and the balance of the plank is sawed across the grain into match blocks.

Sash blind and door manufacturers endeavor to eliminate all possible knots from the finished product. This is done by sawing the plank into bolts of requisite length (about 33 inches) and, wherever possible, making bolts from entirely clear portions of the plank. It is the prime object of the manufacturer to obtain lumber which shall contain as much

clear length as possible between the knots. The bolts thus made are edged into styles, -- those for sash 1 1/2 inches wide and those for blinds 1 3/8 inches wide. They are graded into No. 1 styles, which are absolutely clear, and No. 2 styles, which may have sound knots. Instead of buying lumber in log run lots, the main tendency among manufacturers is to purchase selected butt and second cuts obtained from trees showing exceptional length of internode. These are purchased at prices ranging from $45. to $70. per thousand board feet. In the neighborhood of large cities graded White Pine is used to a great extent. This costs at wholesale rates from mill operators $65. to $70. per thousand board feet, or in retail yards from $75. to $95. per thousand board feet. Great difficulty is experienced, on the part of manufacturers, in obtaining satisfactory second growth lumber.

Pattern sawing is another industry demanding the best of New England pine. In the process of manufacture the central idea is to cut out all the knots. In very large patterns, where it is practically impossible to use entirely clear lumber, the outside pieces are made as clear as possible and the coarser lumber is used in parts which are not on the surface. For piano cases too, the very best native pine is used. Pine with the longest internodes and smallest knots, only, will fill the requirements. For the purpose of manufacture the pine is cut into five foot lengths. These must be of material as clear as can be obtained.

Although, as previously stated, the second growth pine lumber is largely ungraded round edge, still a certain amount of square edge lumber is manufactured for both building and industrial purposes. This is graded for retail distribution in large cities by a set of grading rules compiled by the White Pine Association of the Tonawandas, Tonawanda, New York. This set of rules, made primarily for lumber from virgin forests, designates sixteen different grades. The average second growth native pine will fit into the last four of these grades only -- "Nos. 1, 2, and 3 Barn and No. 1 Box". In exceptionally good timber, however, a very limited amount of "Fine Common, and Nos. 1 and 2 Cuts" may be obtained. The specifications for these grades are given in order, as follows:

"Fine Common"

This is the third grade of White Pine. It is put up 8 inches and wider, and 10 to 16 feet long, admitting of bright sap covering half the face of the board, some stain on the back and occasionally a little running over on one or two edges. It admits of a few pencil knots varying in size and number according to the width and thickness of the piece. The board must be practically free from shake, but a slight shake is permitted showing only on one side or end of the piece. The grade is usually free from stain.

No. 1 Cuts

This grade is put up 6 inches and wider, and 10 to 16 feet long. It is put up with a view of cutting good sized sections of clear lumber, and must cut 66 2/3% or more clear except for bright sap in reasonable length sections. This grade is not intended for use in the full length of the board, but cuts up reasonably well for pattern lumber shop use or any purpose where clear lumber is wanted.

No. 2 Cuts

This is graded the same as No. 1 Cuts, except that the percentage of cutting required is from 50 to 66 2/3% in somewhat shorter sections.

No. 1 Barn

This grade may contain any reasonable number of small round knots, usually red, largely round, but admitting of an occasional branch knot of small size. The board must be free from shake or stain, the size of the knots varying with the width. The 5/4 inches and and thicker admits of slightly larger sound knots than 1 inch boards.

No. 2 Barn

This grade admits of larger knots than No. 1 Barn. The board should be practically all red knotted and free from shake or stain, also free from any knots which will impair its strength.

No. 3 Barn

Coarse sound knots are admitted in the grade. The board should be free from knots which will knock out in dressing and practically free from shake. Stain is permitted where the board is otherwise No. 2 Barn and better for knot.

No. 1 Box

This grade admits of coarse knots regardless of size, also a reasonable amount of shake or stain. The Tonawanda grade of No. 1 Box is a good practicable board for coarse work, including the manufacture of high grade boxes, shelving, flask purposes and cheap flooring. Also it is very desirable for sheathing and sub-floors for high grade houses where lasting qualities are desired."

Some dealers use their own systems of grading which are understood by their particular customers. As a whole, grading is applied only locally in large cities or towns where retail yards exist. Some dealers do not think it worth while to apply a close system of grading and sell their lumber in lots of "No. 3 Barn and better." In second growth pine, No. 1 Barn is the highest grade obtainable in any large quantity. Even this is thought of as hard to get. Besides square edge lumber, retail yards handle round edge butt and second cuts for sash and blind and pattern manufacturers. These are sometimes sold

on grade. The wholesale prices paid by the retailer for log run lots of square edge lumber vary from $40. to $60. per thousand. The location of the yard has an influence in the matter. Yards located at large cities have to reckon with higher wholesale prices, but the cost of handling is not always so great. Graded square edge is sold in log run lots as follows:

TABLE II

Price per M. wholesale

No. 1 Barn 5-11 inches wide	$75
No. 2 Barn 5-11 " "	$70
No. 3 Barn 5-11 " "	$60
Box ----------	$55

Price per M. retail

Width	No. 1 Barn	No. 2 Barn	No. 3 Barn	Box
5" or less	$80 to $85	$75 to $78	$60	4"to9"
6"	$81 to $86	$77 to $78	$60 to $65	11" $43
7"	$82 to $85	$75 to $78	$60 to $63	10" $53
8"	$82 to $86	$77 to $81	$60 to $65	
9"	$85	$75 to $81	$60 to $68	
10"	$85 to $88	$78 to $83	$62	
11"	$84 to $98	$75 to $82	$60	
12"	$90 to $93	$82	$65	
Planed Lumber				
8" or less	$110	$100	$90	
10"	$115	$105	$95	
12"	$120	$110	$100	

From this survey of the utilization of second growth pine it is apparent that in spite of the absence of grading in most round edge lumber, the idea of grade is always present, and makes itself felt in a wide range of wholesale and retail prices, varying from $35. per M. for round edge ungraded box boards to $70. for Butt Cuts and No. 1 Barn. This variation of quality and price is to a great extent independent of width in the lumber. The main criterion for quality is internodal length, except for the relatively small percentage of lumber, mostly square edge, which is sold on grade. In the latter case in accordance with the standard grading rules, the classification and prices are based quite as much on size of knot. The fact that a wide variation of quality occurs in lumber cut from forests with a narrow variation in age makes it desirable, from the point of view of forest management, to analyze the silvical factors which affect height growth and natural pruning.

The Factors Producing Good Quality in the Growth of Timber.

The quality of growing timber is affected both by the factors of site and by certain silvical factors closely related thereto. A forest site may be defined as "an area considered as to its physical factors with reference to its forest producing powers." Quality of site or site class may

be defined as "a designation of the relative productive capacity or quality of different sites with reference to the species employed; the volume or height produced at a given age being used as a standard for classification. In Europe 5 classes, in United States only 3 classes are differentiated, designated by Roman numerals, Quality 1 representing the most productive site class."(1) It is generally considered that the best criterion for site quality is yield per acre. This, however, in the strictest sense, will apply only to fully stocked stands. In partially stocked stands this does not hold true. Generally speaking, when stands of varying degrees of stocking are to be considered, the height growth of the dominant trees is found to be a much safer index to quality of site." Of all the factors of yield, height growth is much the best expression of the physical components of the site. It is the most convenient since it makes possible the identification of sites by a determination of the age and height of the dominant trees. In the case of forest lands not well stocked it is the only possible factor which could be employed without laborious and as yet impracticable studies of the physical factors themselves." (2)

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(1) Journal of Forestry, Jan. 1, 1917, "Forest Terminology".
(2) Journal of Forestry, Apr.,1921, p. 374.

To form a basis for the comparison of the effects of the site and silvical factors in various locations, fifty one-quarter acre sample plots were taken in as many varying situations as possible. The lengths of the internodes were measured in the first twenty-four feet of a sufficient number of trees to obtain figures representative of the plot. As indicating the rate of natural pruning the diameter of the knots and side branches were measured on the first twelve feet of height growth. The minimum number of internodes measured in any one plot was two hundred and fifty. These were tallied in six inch classes, seven in number ranging from 1"-6" (inclusive), the lowest class, up to 37"-42", the highest class. The number of trees (per acre basis), the soil moisture, depth and composition, the exposure of the site, ground cover, etc., were also noted. In each plot heights at five year intervals were taken on five to ten dominant trees. From the figures thus obtained, a curve was constructed representing the rate of height growth for the plot, and the plots were thrown into site classes on the basis of the heights of the dominant trees.

The following table shows how length of internodes and size of knots varies with the site class. The figures are based on measurements from fifty-one sample plots. Only butt and second logs are considered since it is in this part of the tree alone that superior quality can be expected.

TABLE XI.

Distribution of Internodal Lengths on Butt and Second Logs.

	1"-6"	7"-12"	13"-18"	19"-24"	25"-30"	31"-36"	37"-42"
Average for Site Class I	12.4%	26.5%	33%	20.2%	4.4%	3.2%	.3%
" " " II	18.6	34.8	32	11	1.7	1.7	
" " " III	37.7	31.8	19.2	9.6	1.5	1.2	

TABLE XII.

Distribution of Knots as Related to Size.

Size	Site Class I	Site Class II	Site Class III
1/2"	49%	54%	62.9%
1"	24.5	25	16.6
1 1/2"	15.7	12.2	12.3
2"	3.3	3	3.5
2 1/2"	4.2	2	1.5
3"	1.6	2	2.4
3 1/2"	.5	1.2	1.4
4"	.3	.6	.1

The longest internodes occur necessarily on Site Class I. On Site Class II there are more trees to the acre at every stage of growth. (See Table VII). Hence a greater percentage of small knots would normally occur. As, however, the internodes

on this site quality are very much shorter, the absolute number of knots per log is greatly increased. The same holds true with Site Class III. In this case, however, the greater number of small knots is due to lack of vigor in growth. From this it is plain that the best lumber fit for such purposes as match, sash and blind, or pattern stock and other kindred uses, is obtained only from Site Class I.

From the data as to height growth, it was found that all stands classified as in Site Class I were situated on the lower and more protected parts of slopes, in valleys and more or less close proximity to lines of surface drainage, perennial or otherwise. Without exception, these locations have either rich loamy soil of considerable depth liberally supplied with humus or exceptional advantages as to protected location and soil moisture.

In order to determine how excessive soil moisture affects the growth of White Pine, figures were taken representing the average height growth of the dominant trees at various ages in three of the sample plots, each a quarter acre, situated at various degrees of elevation above a Spruce-Tamarack swamp.

TABLE III

Age Years	Height in Feet		
	Plot 1 At swamp level	Plot 2 Above swamp 50ft.	Plot 3 Above swamp 80ft.
40	31 ft	40 ft	50 ft
50	42	53	68
60	52	67	80
70	62	79	86

From observations here tabulated it is obvious that, since at seventy years of age the height of the dominant trees on the plot located on the borders of the swamp was but 62 feet, on a nearby elevation, 17 feet greater, and on a slightly higher elevation in the vicinity 24 feet greater, a poorly aerated mucky soil characteristic of a swampy site is not conducive to long internodes.

The influence of exposure was investigated by the measurement of height growth on four of the sample plots located on all four sides of a rugged hill in Southern Maine where the gradient was uniform and the soil a rather coarse, shallow, sandy loam. The elevation above sea level was 740 feet. The results disclose the fact that the growth on the south side surpassed that on all others, while that on the north slope was inferior to all. The comparative rates of growth are given in the following table.

TABLE IV.

Age Years	South Exposure Height ft.	North Exposure Height ft.	East Exposure Height ft.	West Exposure Height ft.
10	4	2	2.5	2.5
20	12	7	7.5	9
30	34	12	15	20
40	36	20	26	30
50	46.5	31	40	39
60	54	39	49.5	47
70	61	46	57	54

On less exposed eminences, however, it is a common occurrence to find pine on the north slope with very satisfactory growth. Where soil and moisture conditions are more favorable than in the plots here considered, exposure has but slight influence.

Thus far the effect of the physical factors of site on the height growth or internodal length has been considered. Scarcely less significant is the size to which the side branches on the butt and second logs attain before being killed by over-head shade, i. e., the rate of natural pruning. To analyze this factor the diameters of the side branches and knots measured on the fifty-one sample plots were divided into half inch classes, those 1/2 an inch or less in diameter forming the smallest diameter class. Obviously, the percentage of knots of the smallest size class may be regarded as an index to the rate of natural pruning. Since natural pruning is caused mainly by shade, it is fair to assume that it is connected with the promptness with which the forest cover closes and consequently with the number of trees per acre. For convenience in comparison the relative frequency of occurrence of the knots in each size class was reduced to a percentage basis in the case of each sample plot. By using the percentage of the total number of trees measured as an ordinate and the number of trees per acre as abscissa, it was possible to trace out on graphs a direct relation between the relative frequency of the 1/2 and 1 1/2 inch

knots and the number of trees per acre. Despite the fact that the plots varied in age from twenty up to eighty years, this relation was always consistent. By the graph on the opposite page it will be seen that the greater the number of trees per acre the greater the number of knots in the 1/2 inch class and fewer the 1 1/2 inch knots.

In order to eliminate the factor of age, three of the sample plots taken on the same site and in the same even aged stand are here considered. These plots are compared in Tables V and VI.

TABLE V.

Size of Knots as Related to Trees per acre.

Diam of Knots (inches)	Plot 1 220 trees per acre	Plot 2 360 trees per acre.	Plot 3 360 trees per acre
1/2	20.6%	45.6%	45%
1	20.6%	28.3%	34.8%
1 1/2	33.8%	19.5%	17.5%
2	13%	1.5%	.9%
2 1/2	8.6%	3.9%	1.8%
3	2.6%	.7%	-
3 1/2	-	-	-
4	.8%	-	-

The same tendency is here apparent. Where the number of trees per acre is larger a greater percentage of smaller sized knots is found.

A comparison of the rates of height growth on Plots 1, 2, and 3 shows that a relation can be traced out between the number of trees per acre and the growth in height. The rates of height growth on the three plots are here compared.

TABLE VI.

Age years	Plot 1 220 trees per acre.	Plot 2 260 trees per acre.	Plot 3 360 trees per acre.
10	6 ft.	6 ft.	7 ft.
20	16	18	22
30	28	30	35
40	40	40.5	45
50	50	51	54.5

There are two causes for this slight variation in height growth. The first is the natural struggle for growing space which occurs wherever young trees grow together in greater or lesser competition. The other cause lies in the attacks of the White Pine Weevil, Pissodes strobi. The effects of the work of this beetle are more lasting wherever the stand is more open.(1) The trees attacked in the denser part of the stand usually recover. In the more open parts, they show retarded height growth or crooked trunks through the loss or crippling of the leading shoot. In Plot 1 the effects of the weevil's work were very apparent.

(1) Observation of H. B. Peirson.

Up to a certain point the greater the number of trees the smaller the knots and the better the height growth. (See Tables V and VI.) There is a density, however, beyond which growth becomes retarded. In order to determine the optimum density which will produce in the butt logs the best quality of lumber, the sample plots on each site quality which show for various ages the greatest number of small knots, together with the best height growth, were taken as a basis. The following figures represent the average for the best plots. None can be given for Site Quality III, however, as no data were obtained for fully stocked stands of that Site Class.

TABLE VIII.

Age Years	Site Class I (number of trees per acre)	Site Class II (number of trees per acre)
10	1630	1800
20	1300	1460
30	960	1130
40	690	830
50	490	580
60	340	390
70	235	270
80	190	220

Up to this point pure stands only have been under consideration. Yet it is a common observation that the best pine is found growing in mixture with hardwood. The virgin forest was made up, in large part, at least, of hardwoods and softwoods growing together. The present pure pine type springing

up as it has to a great extent on unused agricultural land may be regarded as largely temporary and transitional. The tendency to revert to hardwood, which is obvious on nearly all cut-over land indicates that much of the pine of the future will be grown in hardwood stands. Ordinarily any pine seedlings or advanced growth present at the time of cutting are suppressed and killed by the hardwood, most of which is of sprout origin. Occasionally by the accident of density or by virtue of a few years' start a certain percentage of pine competes successfully with the hardwood in second growth forests. The following table shows a comparison between the natural pruning in such a stand and in a pure stand of the same age and on the same site. The age of each stand was seventy years. The density in the pure stand approached very closely to the optimum for that age. In the mixed stand the pine occurred as single trees and not in groups.

TABLE VIII

	White Pine in Hardwood	Pure White Pine
Average Total Height	85 ft.	80 ft.
" Height to First Live Limb	56.6 ft.	44 ft.
1/2 inch knots	63%	29.3%
1 " "	22.9%	23.3%
1 1/2" "	12.9%	34.5%
2 " "	.6%	7.8%
2 1/2" "	.6%	3.6%
3 " "	-	.5%
3 1/2" "	-	.5%
4 " "	-	.5%

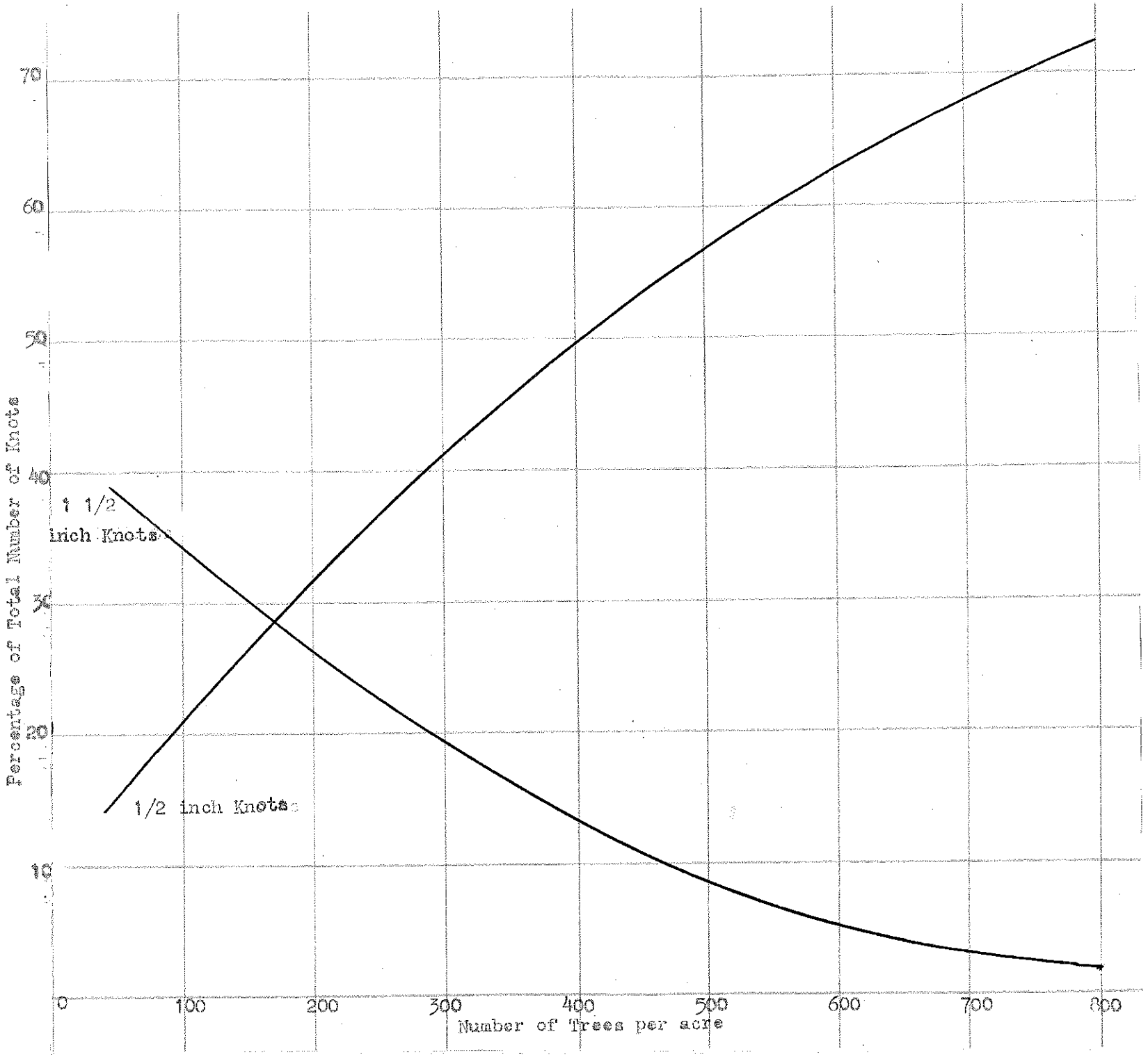
The rate of pruning in the mixed stand is more than twice as rapid as is shown by the fact that there are 33.7% more 1/2 inch knots. Then too, in the mixed stand, the pruning is carried fully 25% higher on the boles of the trees.

In order to get some clue as to the relative rates of height growth of White Pine and hardwoods of seedling origin figures were obtained as to height growth on trees of various species as they were felled in a lumbering operation. The stand was even-aged, on a good quality of site, and originated on abandoned farm land. The results of these measurements are recorded in the following table.

TABLE IX.

Age (Years)	White Pine	Red Oak	Yellow Birch	Beech	White Ash	Black Cherry
10	5 ft.	17 ft.	10 ft.	15 ft.	19 ft.	16 ft.
20	24	30	18	23	30	26
30	39	40	25	30	42	34
40	52	50	31	36	53	42
50	65	58	36	41.5	62	48
60	76	66	41	46	68	53
70	85	73	45	51	72	56

It is obvious that in the first ten years all the hardwoods would have overtopped the pine wherever the crowns were competing for the same space. In the present stand the pine



Curves Illustrating the Variation in Number of 1/2 and 1 1/2 inch Knots occuring with different Densities of Stocking.

which survived to maturity stood in groups separated from the hardwood. The table shows, however, that beginning about the twentieth year, the height growth of pine is sufficient to keep pace with that of any of the associated hardwoods.

The effect produced by Spruce and Hemlock on the growth and natural pruning of White Pine was investigated in a somewhat similar manner on two sample plots taken on the same site, one in pure Pine and the other in Mixed Pine, Spruce, Hemlock and a few scattered hardwoods. The results are recorded in the following table.

Comparison of Height Growth

Plot 1. Age years	White Pine 100% Height ft.	Plot 2 Height ft.	White Pine 22%, Red Spruce 49%, Hemlock 18%, scattered Hardwoods 11%.
10	5	6	
20	22	23	
30	37.5	39	
40	53	55	

Comparison of Size of Knots

Plot 1. Knots inches	Percentages	Plot 2. Percentages
1/2"	30.2%	57.2%
1"	41.%	30.8%
1 1/2"	20.6%	12%
2"	1.9%	-
2 1/2"	4.4%	-
3	.7%	-
3 1/2"	.6%	-

Two facts are here apparent,-- first, that the height growth in the mixed stand is as good, if not better, than in the pure stand; second, that the size of the knots is much reduced in the mixed stand. The height growth of Spruce and lc Hemlock is relatively slow, and they are trees which, because of their tolerance of shade, usually form an understory to a mixed stand. This is especially true of Hemlock. By this increase in the number of trees per acre and in the depth of the crown canopy, the rate of natural pruning is greatly accelerated.

The foregoing analysis of quality may be summarized as follows:

First, the fundamental criterion for quality in second growth White Pine is length of annual growth or internode. This is because most of the knots on such lumber reach the outside of the log. Lumber from timber of the same age may range in price nearly 100 per cent.

Second, length of internode is determined by the site factors and to a lesser extent by density of stocking.

Third, size of knot, which is a secondary factor of quality, is controlled by rate of natural pruning.

Fourth, natural pruning is most rapid in mixed stands and in pure stands the rate varies with the number of trees per acre up to an optimum density. (See Table VII.)

Fifth, the production of pine in mixture with hardwood can be managed in natural stands by the necessary weeding during the first ten to fifteen years, and in plantations by advanced planting. In mixture with any of the local soft woods White Pine will hold its own from the start.