QUALITY PALLET-PART YIELDS FROM RED OAK CANTS

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ABSTRACT

The primary objective of this study was to determine yield and quality of pallet-parts from southern red oak cants. A second objective was to evaluate crosscutting methods used in producing pallet lumber. Hopefully, by fulfilling these objectives the following questions could be answered: (1) what are common cants worth in terms of common grades of lumber; (2) whether these cants could produce parts for a pallet selling in the $5-6 price range; and (3) which of two crosscutting methods, gang or select, should be used in resawing the lumber to pallet-part material.

The cants were obtained from a stratified sample of 114 red oak logs that were numbered and graded, using standard U.S. Forest Service factory log grades. Each 4- by 6-inch cant was then sawn from the "heart center" of each log and later resawn into pallet lumber. The lumber was then graded, according to specifications of National Hardwood Lumber Manufacturers' lumber grades, and simulation of gang and select crosscutting methods was used to produce pallet-parts. Using suggested grading rules of the U.S. Forest Service, the resulting 40- and 48-inch pallet-parts were then regraded and grouped into two quality classes. Recovery yields of quality-class parts for gang and select cutting methods were then recorded by lumber grades and cant lengths. Based upon three pallet styles, simulated pallet construction was conducted.

Analysis of the data showed that the cant-lumber grade distribution from grade one, two, and three logs was quite variable, especially in the one and two common lumber grades. Three common lumber yields were fairly consistent, amounting to greater than two-thirds of the cant lumber yield.

Both pallet-part yields and quality class ratios were significantly affected by lumber grades. Higher lumber grades (one and two common) not only produced greater total yields but also a greater ratio of quality class one material.

The length of the cant also had a profound effect on both the yield and distribution of quality pallet-part material. Of the three cant lengths tested (8, 10, and 12 foot), only 12-foot cants provided a positive economic return. When cant monetary yields and values were compared to net lumber values, 12-foot cant values were comparable to the returns from the use of 3A lumber. Based on the monetary yields and values of raw material sources, two common lumber had the greatest dollar return.

Analysis showed that the select crosscutting method in all cant lengths and in the two common and 3A lumber grades could significantly improve or increase quality pallet-part yields. Greater increases from the select method were noted in cants of longer length.

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CHAPTER I

INTRODUCTION

The purpose of this study was to obtain pallet yield information from hardwood cants. It was conducted in cooperation with the U.S. Forest Service Forest Products Marketing Laboratory, Princeton, West Virginia. This study is part of a more extensive pallet research program being conducted at the Forest Products Marketing Laboratory.

I. PALLET INDUSTRY BACKGROUND

The wooden pallet industry is one of the youngest secondary wood product industries. The industry was initiated with the concept of unit transportation and the development of suitable material handling equipment (1). The wooden pallet became firmly established as the base for unit load handling in response to logistic requirements of World War II and has now been incorporated into the logistic systems of many private industries. Major reasons behind the wide spread use and adoption of the wooden pallet by private industries have been the ability to move unit loads at a considerable reduction in time, handling costs, and product damage (2).

Since World War II, pallet production has steadily and rapidly increased at an annual rate of about eight percent. Presently, less than one-fifth of the total volume of merchandise considered economical to unit load is being palletized. Therefore, the growth potential is believed to be great. So great, that the U.S. Forest Service Products Marketing Laboratory, Princeton, West Virginia, has predicted the annual pallet sales to reach the 400 million level by 1985 (3).

II. PROBLEMS IN RAW MATERIAL ACQUISITION

Because of the burgeoning pallet demand, the material handling industry in the Appalachian area* has now become the number two user of hardwood materials. Pallet manufacturing, which now consumes approximately 30-35 percent of the annual hardwood yield, has replaced hardwood flooring as the second most important user of forest products. Although other woods such as maple, beech, ash, rock elm, and pecan are extensively used for pallet construction, the lumber preferred by both manufacturers and buyers is oak (5).

Price Competition

In the Appalachian area the majority of pallet manufacturers either own their mills, where medium grade logs are sawn strictly for pallet material, or obtain their lumber supply from the lower grade logs sawn by neighboring mills (3). Recently, pallet industries have reported that they are facing a serious shortage of their chief raw material, hardwood lumber. The availability problem seems to extend

*The Appalachian area is an eight state area. Over four million commercial forest acres of East Tennessee are included in this area (4).

from the manufacturer's inability to obtain suitable hardwood pallet lumber at prices they want to pay, rather than a scarcity of hardwood growing stock (6).

Over the past several years hardwood lumber prices have generally risen. One reason for this upward trend in lumber prices hinges primarily upon an increased demand for hardwood lumber used in furniture manufacturing (6). In most instances hardwood sawmills have been content to sell their high-grade hardwood lumber to the wood using industries which require the higher grades of hardwood lumber, such as the flooring and furniture industries. Meanwhile, the lower grades of hardwood lumber (3A and lower) were sold to pallet fabricators for a price of $40-50 per thousand. Recently, however, pallet production has increased at a much faster rate than production in the furniture and flooring industries. This has created excessive demands for the lower grades of hardwood lumber. Consequently, prices for pallet lumber have risen to the $65-85 per thousand level (6).

Nonstandardized Sizes

In the Appalachian area the acquisition of wooden raw materials for pallet production may come from one of several sources--logs, lumber, cants, pre-cut stock, and plywood. Past studies have shown that approximately 95 percent of the wooden raw materials have been purchased in the form of lumber (1).

Pallet fabricators have complained that they were unable to obtain the lumber in the grade, species, or dimension that they prefer. Because pallet fabricators are buying hardwood lumber in a market controlled primarily by the sellers, they are often required to take anything that is available. This often means millrun hardwood lumber consisting of random lengths and widths, as well as grade and variable thicknesses. Random width and length require edging and trimming operations to get the lumber to a standard uniform dimension, capable of being processed (6). Due to the costs of purchasing, transporting, and eliminating the residue material, pallet fabricators prefer to buy hardwood lumber by standard cut-to-size lengths, widths, thicknesses, as well as by grade.

Difficulty in obtaining lumber in the correct form or quality has sent pallet manufacturers in search of new sources of raw materials. One alternative would be cut-to-size pallet material sawn from prepared pallet cants. Pallet manufacturers, however, have been reluctant about the direct purchasing of the cant because they prefer not to do the resawing of the cant. A possible solution for both parties would be the purchasing of the cant by the pallet manufacturer and then have the sawmiller resaw the cant on contract into cut-to-size pallet material.*

III. PALLET EXCHANGE PROGRAM

Due to the ability of a high quality pallet to be reused, many attempts at the establishment of a pallet exchange program have been

*Source: Study plan, designed and presented to the University of Tennessee Forestry Department by the Forest Products Marketing Laboratory, Princeton, West Virginia.

been made. Every participant in the exchange program is expected to ship out a large portion of the pallets he has bought. Concurrently, he is expected to receive his daily pallet requirement from other participants in the program. If a participant is to receive a pallet of equal quality in exchange for those shipped out, he has to purchase pallets of a quality consistent to those pallets purchased by other participants (7).

Quality standards have thus far played a significant role in the development of an integrated exchange program. In the exchange program, the quality level of pallets is determined when the quality and the cost of a pallet are deemed equal to the benefits obtained in the exchange. Many problems, however, were created when the costs of pallet material rose but were not met by an increase in the purchase price paid for pallets by the participants. Since there were no provisions for the policing of pallet quality between the exchange participants, pallets of inferior quality were introduced into the exchange system. Participants, paying for higher quality pallets than they received, objected and in some instances severed all ties with the exchange program.

The controversy over the quality of pallets to be used in the exchange program seemed to be theoretically solved when the Grocery Manufacturers of America adopted a set of pallet specifications. However, adherence to these quality specifications on the part of the purchasing agent and the pallet manufacturer has been erratic due to the following reasons: (1) pressures to keep initial pallet costs down on the part of the purchaser, (2) pressures to price competitively on the part of the pallet manufacturer, (3) lack of technical knowledge to properly inspect pallet quality on the part of the purchasing agents, and (4) pallet specifications being stated in general terms and subject to a variety of interpretations. A further restriction to the successful expansion of the pallet exchange concept has been the lack of definitions of quality standard pallet-part material. Lack of data concerning literally thousands of possible quality combinations and construction sizes, has limited the ability of industries to establish realistic quality standards (2).*

Other restrictions hampering the successful adoption of a national exchange program have been the vague and inconsistent ideas of a standard pallet design. The many pallet designs presently on the market have been the results of conforming pallet design to meet an individual firm's product and handling system. Changing to common pallet sizes and designs in most cases would mean a complete restructuring in both product design and handling equipment used in a firm's logistic system. Adoption of a common pallet size will neither be an overnight process, nor an inexpensive one, but in the long run, will

*Personal communication with Mr. Hugh Reynolds, Forest Products Marketing Laboratory, reveals that since the completion of this manuscript, the pallet exchange program has been progressing at a rapid rate. The Forest Service and private industry are involved in an intensive study that will last four months and which is expected to result in a successful establishment of a pallet pool using two standardized pallets.

be necessary if firms are to realize the full benefits of a completely integrated exchange system (7).

IV. THE NATIONAL PALLET POOL

The most significant step toward a workable pallet exchange program is a national pallet pool. From locations throughout the country, industries will be able to acquire standardized high quality wooden pallets without a purchase price cash outlay. Based upon the number of pallets and the time needed, a leasing fee ranging from one to six cents a day will be charged (8).

Through a national leasing system, John Stroble, of the Better Management Services, is attempting to eliminate many of the limitations now facing a national exchange system. Criteria for evaluating the quality of pallets and pallet-part material were developed and are to be incorporated as a standard for pallet construction under the leasing system.* By placing the responsibility of establishing and monitoring quality standards in the hands of one agency, pallets of "equal quality" may be maintained (2).

The basic element of the national leasing system is a pallet of standard dimension, 40 by 48 inches in size, constructed of high quality pallet parts, selected from a combination of quality classes. It is

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*Developed by Dr. Walter B. Wallin of the Forest Products Marketing Laboratory, Princeton, West Virginia (9).

hoped that a pallet of this quality will sell in the $5-6 range, depending on the percent of higher quality material in the pallet.

Pallets of a standard dimension and constructed of quality material offer a host of advantages to the user. A standard dimensioned pallet will allow a common system of handling equipment to exist among industries. Damage to palletized goods, resulting from poor quality pallet-part material, will be greatly reduced. Down time, caused by deterioration or failure of a pallet while in use, will also be shortened. Due to fewer knots, less splitting, and less material preparation time, graded quality material, although costing considerably more, should decrease production time.

V. RESEARCH NEEDS

> As the demand for pallet material continues to increase, prices will increase, and the quality specification will demand more attention. Annual contracts for cut-to-size pallet-parts will become commonplace. Centrally located pallet-assembly plants will draw parts from many sawmillers. It is estimated that prices will rise to $140/MBF for guaranteed quality parts ready for assembly (10).

Rising cost of cut-to-size pallet material has forced the pallet industry to look for a new source of quality pallet material at a cost reduction. Although past policies have dictated the procurement of wooden raw materials in the lumber form, many forest economists now feel that greater profits can be realized by both the sawmiller and the pallet manufacturer through the production and reuse of a common grade cant.

Lawrence D. Garrett found that when pallet manufacturers will accept the common grade cant from the sawmiller, the combined production of both lumber and timbers from physically suited logs can yield a greater dollar return than from the production of lumber alone. Major reasons for this finding are that sawing time per log is decreased while the total recovery is increased (11).

Greater demands for quality control have led to a need for a more standardized system for defining and measuring criteria which determine quality pallet material. The separation of pallet-parts into defined quality classes is a new concept developed by Dr. Walter B. Wallin of the Forest Products Marketing Laboratory. By grading pallet material into quality classes and then using the better material in the high impact areas of the pallet, a stronger, longer lived pallet can be produced (10).

At the initiation of this study only two such quality classes were proposed. Since then, the Forest Products Marketing Laboratory has expanded the number of quality classes used in the separation of pallet-part material. Future research and development on quality pallet-part material may indicate further refinement of those quality classes.*

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*Recent developments, as reported by the Marketing Laboratory, indicate that standards for the high strength parts should be increased while the specification for the other parts may be relaxed. As a result, the total yields from 3B lumber probably would be substantially greater.

Being relatively new, quality class grading rules have not been applied on a commercial level. Neither has the common cant, as a source of quality pallet material, been studied. With research lacking in these two areas, there was no published data with which to compare the findings of this study. Hopefully, this study will provide the pallet industries with a greater knowledge of quality pallet standards and a more flexible acquisition program of quality pallet-part material.

VI. OBJECTIVES OF THE STUDY

Before a cant process can be incorporated into a successful pallet operation, knowledge of both cant yields and pallet-part quality must be determined. The primary objective of this study was to determine yield and quality of pallet-parts from southern red oak cants. A second objective was to evaluate crosscutting methods used in producing pallet lumber. Hopefully, by fulfilling these objectives the following questions could be answered: (1) what are common cants worth in terms of common grades of lumber, (2) whether these cants could produce parts for a 40- by 48-inch pallet of the quality required for a pallet selling in the $5-6 price range, and (3) which of two crosscutting methods, gang or select, should be used in resawing the lumber to pallet-part material.

CHAPTER II

METHODS AND PROCEDURES

The purpose of this study was to determine yield and quality of pallet-parts from southern red oak cants. Selected southern red oak logs were processed to timber cants, the cants resawn to graded lumber, and subsequently graded into quality pallet-part material. Simulation of gang and select crosscutting was used to determine pallet-part yields. Once the data for the "quality class (QC)" pallet-parts had been obtained, pallet construction of three pallet styles was simulated.

I. LOCATION AND FACILITIES

The study was conducted at the University of Tennessee sawmill at the Ames Plantation. The Ames Plantation is an 18,000 acre area located approximately 50 miles east of Memphis, Tennessee. The Ames Plantation was chosen for two pragmatic reasons: first, the log supply could be controlled by cutting the desired species, sizes, and grades; and secondly, the sawmill was immediately available.

The location factor did however introduce two problems. First, the Ames sawmill is a circular mill with a 1/4-inch headrig kerf. Most sawmills or pallet manufacturers operate a line-bar resaw with a 1/8-inch kerf. In an attempt to compensate for this excess kerf, "thin" lumber was cut. For example, 2-inch boards were cut 1-7/8 inch in thickness. Second, it was hoped the study would be representative of the Appalachian region. However, southern red oak was the most available lumber and was used in place of northern red oak.

II. SPECIES SELECTION AND SAMPLING DESIGN

In Appalachia the largest percentage of pallets are constructed from a various assortment of low grade hardwood species. However, because of their availability and importance to the pallet industry, only southern red oak logs (Quercus falcata Michx.) were used. A study conducted by the U.S. Forest Service revealed that millrun log distribution for the Appalachian area yielded 22 percent factory grade 1 sawlogs, 40 percent factory grade 2, and 38 percent factory grade 3. The Ames study showed yields which correspond to this distribution (Table I).

A total of 114 red oak logs, representing 8,585 board feet, were selected for this study and were stratified with respect to log grade, diameter, and length distribution. Log lengths of 8, 10, and 12 feet were chosen. Within each log length, five diameter classes were systematically selected--ranging from 8 to 18 inches in intervals of two-inch diameter classes. Replications were made to include at least three logs from each possible combination of log length, grade, and diameter class.

TABLE I

COMPARISON OF FACTORY LOG GRADE DISTRIBUTION BETWEEN APPALACHIAN MILLS TO AMES STUDY SAMPLE

Factory Grade	Appalachian Mills (Percent)	Ames Study Sample (Percent)
No. 1	22	16
No. 2	40	38
No. 3	38	46

III. CONVERSION PROCESS

Logs to Cants

Once the log diameter and length had been measured, each log was numbered and graded by the U.S. Forest Service log grade rules. International 1/4 Log Rule was used in calculating board foot volumes. The log number was later used to identify the cant and its respective yield. Each log was then sawn into a single cant with care exercised to "box" the center portion of the log into a 4-3/8 inch by 6-1/4 inch cant. Because of cost and time restrictions, the lumber outside the 4-by 6-inch cant was not tallied. Regardless of the diameter of the log, no more than a single 4- by 6-inch cant was cut from any one log.

Cants to Lumber

In resawing the 4- by 6-inch cant, each 4-inch face was checked for soundness and to determine if it was away from the pith. In the construction of a pallet, lumber of the following dimensions is required: 2 by 4's for stringers, 1 by 6's for edge deckboards, and 1 by 4's for center deckboards. Due to the disproportionate amounts of stress applied to the different pallet areas, those areas receiving the greatest degree of abuse and stress require pallet-parts of high quality. Consequently, good 2 by 4 lumber took first cutting priority, followed by 1 by 6 and 1 by 4 lumber.

Regardless of pallet style, construction of a 40- by 48-inch pallet requires parts in the ratio of one 2 by 4 by 48, two 1 by 6 by 40, and three 1 by 4 by 40. In an attempt to control the expected yield of the sample in this one-two-three ratio, the number of cants for each cutting pattern was regulated. Two sawing patterns were used. Sawing pattern A yielded four "thin" 1 by 4's and a 2 by 4; sawing pattern B yielded four 1 by 6's. As each 4- by 6-inch cant was resawn in the prescribed sawing pattern, the lumber was tallied by thickness, width, and lumber grade and bundled with the corresponding log (cant) number for later grading into pallet-parts.

IV. SIMULATED CROSSCUTTING

The potential for either increasing or improving the yields of quality pallet-parts through the crosscutting patterns of graded cant-lumber was studied. In order to compare the yields from two cross-cutting methods (gang and select), crosscutting of the cant lumber board was simulated. To facilitate the simulated crosscutting, a grading table was employed (Figure 1). The grading table was constructed with a tilting frame which had pre-set lengths marked off, 40 inches apart for the 1-inch lumber, and 48 inches for the 2-inch lumber.

Gang Method

After a board was placed upon the table and positioned lengthwise to "Gang Cut" around the worst end defects, the frame was tilted, indicating the position of the simulated gang cut. Once the initial crosscutting of the board had begun, all the following cuts were made at 40- and 48-inch intervals. These simulated 40- and 48-inch pallet-parts were then graded according to quality class specifications developed by Dr. Walter B. Wallin of the Forest Products Marketing

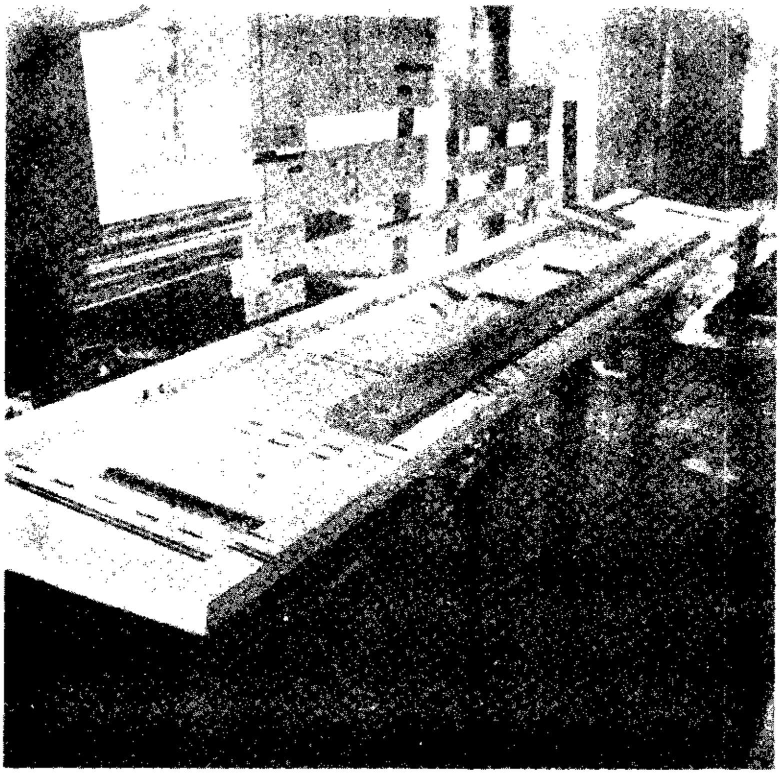

Figure 1. A pallet-part grading table, designed and constructed by the Forest Products Marketing Laboratory, Princeton, West Virginia.

Laboratory (See Appendix, Table VIII). The pallet-parts were then tallied by size, quality class, and the log (cant) number. The tally thus obtained was the "Gang Crosscut" tally.

Select Method

To obtain the "Select Crosscut", the frame was raised and the board was repositioned upon the grading table. In an attempt to selectively improve either the quality class grade or the total board foot yield, the board was moved so that the select crosscut would eliminate both the largest and the greatest number of defects in the board. There was no limit to the number of cuts or the position where a cut could occur, as long as the resulting pallet-part was of an accepted quality and dimension. The yield was then tallied in the same manner as the gang crosscut tally.

It should also be pointed out that in the use of the quality class grading rules, two areas need further explanation. These are the classification of "knot size" and the "number of knots". Due to the emphasis placed on strength in quality class material, any knot, regardless of size, was classified as a "knot" and subject to the specification regarding knots. In evaluating the "number of knots" permissible per length, a literal interpretation was applied. No more than one knot per 8 or 12 inches of length was interpreted as not permitting more than one knot in any 8- or 12-inch length section of a pallet-part.

V. SIMULATED PALLET CONSTRUCTION

Once the graded pallet-part yields had been obtained from the two crosscutting methods, simulated pallet construction was attempted. As a guideline for the construction of high quality pallets, specifications developed by the U.S. Forest Service Products Marketing Laboratory were used. Pallet-part requirements (Tables II and III) are expressed in terms of footage of parts and number of parts required for the construction of three styles of pallets. Each of the three pallet styles represents a certain mix of quality class material. The better the style, the higher the ratio of quality class one material; therefore, the greater the cost for that individual style.

VI. STATISTICAL ANALYSIS

A chi-square statistical test was employed to compare the lumber grade yield distributions with respect to the number of boards from three log grades. A chi-square test was also employed to compare the gang and select yield distributions with respect to the number of boards in the five lumber grades.

To test the hypothesis that select yields (b_2) were greater than or equal to gang yields (b_1), a one-tailed paired T-test was used. The actual yields tested were those of mean board foot yields for both lumber grades and cant lengths. Two T-tests were used: the first, to assess the increase in total board foot yields; the second, to assess the improvement in quality class material from selectively crosscutting pallet lumber. The first T-test involved a comparison of

TABLE II

PALLET PART REQUIREMENTS[a]--BY FOOTAGE OF PARTS

Pallet Style	Part Sizes and Quality Class						Total
	1x4x40 inch		1x6x40 inch		2x4x48 inch		
	QC1	QC2	QC1	QC2	QC1	QC2	
1	0	12.21	6.68	0	5.34	2.67	26.90
2	4.44	2.22	3.34	10.02	5.34	2.67	28.03
3	8.88	2.22	0	10.02	5.34	2.67	29.13

TABLE III

PALLET PART REQUIREMENTS[a]--BY NUMBER OF PARTS

Pallet Style	Part Sizes and Quality Class					
	1x4x40 inch		1x6x40 inch		2x4x48 inch	
	QC1	QC2	QC1	QC2	QC1	QC2
1	0	11	4	0	2	1
2	4	2	2	6	2	1
3	8	2	0	6	2	1

Pallet Style 1: QC1 parts = 44% QC2 parts = 56%
Pallet Style 2: QC1 parts = 46% QC2 parts = 54%
Pallet Style 3: QC1 parts = 48% QC2 parts = 52%

[a]Pallet-part requirements supplied by the Forest Products Marketing Laboratory, Princeton, West Virginia.

"quality class one (QC1)" and "quality class two (QC2)" yields for gang and select methods; the second, a comparison of only QC1 yields for gang and select.

Since the prime concern was with factors affecting both the change and the improvement of quality class material, multiple regression of the form $Y = b_1X + b_2X^2$* was used as a measure of the statistical relationship between Y (quality class yields in board feet**), X (cant volume in board feet divided by two), and X^2 (cant length in feet).

In the regression analysis, the hypothesis was tested that changes in QC yields (gang and select) were significantly affected by changes in cant volume and cant length (12). In tests where X^2 (cant length) failed to prove a significant factor in cant yield at the 0.05 level, the variable was dropped, and the simple linear model with the single variable X (cant volume) was used.†

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*Since all cants were of the same 4- by 6-inch dimension, the board foot volume of the cant was exactly twice that of its length. Consequently, the variables, cant volume and cant length, were perfectly correlated and, therefore, statistically equal. To expedite computations, cant length was used as an index of volume input. To measure the actual impact of cant length on quality class yields, length squared was used. X and X^2 will be referred to as cant volume and cant length, respectively. In using the equation for prediction purposes, X = L (length) or V/2 (volume in board feet divided by two), while X^2 equals L^2 (length squared).

**Gang and select equations were run separately for the following group of dependent variables: total yields, log grades, and cutting patterns and are noted by subscripts s and g on the dependent variables.

†Services of the University of Tennessee Computing Center were used in all statistical analysis.

CHAPTER III

RESULTS AND DISCUSSION

I. LUMBER GRADE YIELD DISTRIBUTION BY LOG GRADES

Results of the chi-square test failed to show that log grade significantly affected the distribution of graded lumber yields of the resawn cants. The calculated chi-square value was 9.51 with eight degrees of freedom. The critical value needed for significance was 15.51.

Table IV indicates the percent distribution of lumber grade yields by log grades tested. They are also compared to the 1969 Yield Study (USFS) conducted by Garrett, where some association between log grade and lumber grade distribution was found. The comparison indicates a striking departure in percentage yields of the "one common (1C)" and "two common (2C)" lumber grades from number two and three grade logs. Number two and three grade logs of the Ames Study gave much higher yields in one common and better lumber than the previous lumber yield study of hardwood cants by Garrett. However, this was more of a trade-off in the two higher grades of lumber than an increase in total grade yield. For example, three common and lower grades of red oak lumber represented approximately 68 percent of the cant yield and was in general agreement with the 64 percent red oak yield reported by Garrett. A complete breakdown of the lumber grade distribution by log diameter, log length, and log grade, indicated that the increase in the one common and better

TABLE IV

COMPARISON OF CANT-LUMBER GRADE DISTRIBUTION BY LOG GRADES OF 1969 YIELD STUDY BY GARRETT (USFS) WITH CURRENT AMES YIELD STUDY

Log Grade	1C and Better	2C	3A and 3B Below	Total
	(Percent)			
No. 1				
USFS All Species	6	40	54	100
USFS Red Oak	8	34	58	100
Ames Study	9	24	67	100
No. 2				
USFS All Species	8	40	52	100
USFS Red Oak	6	36	58	100
Ames Study	17	18	65	100
No. 3				
USFS All Species	2	32	66	100
USFS Red Oak	1	23	76	100
Ames Study	15	13	72	100

lumber was associated with logs of longer length and larger diameters, especially in the lower grade log groups. Another possible explanation for the higher yields was the difficulty in "boxing" the heart center of the larger, poorer quality red oak logs; resulting in a miscutting of the actual pith center and a more variable lumber grade distribution than previously reported. It should be noted, however, that the Ames Study would have been expected to have greater variability since a stratified distribution of all diameter size classes and length of logs were included. The U.S. Forest Service Study was based on a representative millrun sample.

Results of the lumber grade distribution by log grades indicate that the use of U.S. Forest Service log grades to predict the lumber grade distribution from cant material were less than adequate for one species--southern red oak. Log grades, based primarily on the exterior features of the log, did not, in all cases, properly estimate the correct distribution of lumber grade material from cants cut from the center portions of the log. This may indicate the need for a grading system for pallet-cants.

II. QUALITY PALLET-PART YIELDS BY GRADED RED OAK LUMBER

Table V, representing graded pallet-part recovery, indicates that lumber grade had a significant effect upon quality pallet-part yields. For the gang crosscutting method, 1C lumber had the highest percentage yield of 85 percent, followed by 2C, 3A, and 3B with yields of 70 percent, 44 percent, and 16 percent, respectively. For the

TABLE V

GRADED PALLET-PARTS RECOVERED FROM GRADED RED OAK LUMBER

Lumber Grade	Lumber Tally (Bd.Ft.)	Maximum Pallet Stock (Bd.Ft.)	Cutting Yield (Percent)	Graded Pallet Yields: Gang (Bd.Ft.)	Gang (Percent)	Select (Bd.Ft.)	Select (Percent)
1 Common	328.32	293.18	89	249.27	85	252.05	86
2 Common	385.36	343.92	89	240.87	70	260.77	76
3 A	737.94	671.65	91	294.34	44	319.80	48
3B and Less	626.35	554.96	89	87.37	16	91.82	17

select crosscutting method, 1C lumber yielded the highest percent return with 86 percent, followed by 2C, 3A, and 3B lumber yields of 76 percent, 48 percent, and 17 percent, respectively.

Table VI, representing the breakdown of pallet-part yields into quality classes, indicates that not only did the lumber grades significantly affect the total yield for gang and select groups but also the percentage ratio of yields of QC1 and QC2 material within each crosscutting method. As the lumber grade declined, the ratio of QC1 material to QC2 material for both gang and select methods also declined. In all lumber grades the select crosscutting method maintained either a higher total yield, a higher QC1 yield, or both.*

Distribution of pallet-parts recovered for total gang and select, and gang and select QC1 indicates that in all four chi-square tests** lumber grades had a highly significant effect on both the recovery and the distribution of graded pallet-parts† (Appendix, Tables IX–XII). Pallet-part yields of 50 percent or greater were produced by nearly all of the 1C and 2C lumber (95.8 percent and 86.7 percent, respectively) cut by the gang method, while only 30 percent of 3A and and 8.2 percent of 3B produced 50 percent or more. For the select cutting method, the results were in the same order. Of the 1C and 2C

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*Percent yield in Table V is the yield ratio of graded pallet yields to maximum pallet stock; in Table VI, graded pallet yields (board feet) of quality class one to quality class two material.

**Refer to page 18.

†Nonsignificant refers to ($P > 0.05$); significant refers to ($0.05 \leq P \leq 0.01$); and highly significant refers to ($P \leq 0.01$).

TABLE VI

BREAKDOWN OF PALLET-PART YIELDS INTO PALLET GRADE CLASSES
BY RED OAK LUMBER GRADES

	Gang			Select		
	Graded Pallet Yields	Quality Class		Graded Pallet Yields	Quality Class	
Lumber Grade	(Bd.Ft.)	1 (Percent)	2 (Percent)	(Bd.Ft.)	1 (Percent)	2 (Percent)
1 Common	249.27	71	29	252.05	74	26
2 Common	240.87	64	36	260.77	69	31
3A	294.34	47	53	319.80	47	53
3B and Less	87.37	35	65	91.82	34	66

lumber 97.3 percent and 93.3 percent, respectively, produced 50 percent or more of pallet-parts, while 40.5 percent and 8.2 percent, respectively, of the 3A and 3B yielded 50 percent or more of pallet-parts.

Because of the mutually exclusive properties of QC1 yields from the gang and select crosscutting method, the distribution of pallet-part material among five lumber grades was greatly shifted. The distribution of QC1 yields were still highly associated with lumber grades. With gang crosscutting method, 70.8 percent and 63.4 percent, respectively, of the 1C and 2C lumber yielded 50 percent or more QC1 parts. For the 3A and 3B grades 17.8 percent and 4.1 percent of the lumber yielded 50 percent or more. By comparison, the select crosscutting method, 79.1 percent and 63.3 percent of the 1C and 2C lumber yielded 50 percent or more. For 3A and 3B lumber grades 22.6 percent and 4.1 percent of the lumber yielded 50 percent or more.

Analyses indicate that 1C and better and 2C lumber produced the greater yields. At the present, pallet manufacturers use practically no 1C and 2C lumber for pallet operations. This is due primarily to the relatively high costs of the higher grade lumber. The extremely low yields from the 3A and lower grades of lumber, grades more often used in pallet construction, can be partly attributed to the rather strenuous QC grading rules employed. This does not, however, discredit the high association found between lumber grades and QC pallet-parts.

III. QUALITY PALLET-PART YIELDS BY CROSSCUTTING METHODS

By Lumber Grades

The one-tailed paired T-test indicated that total yields from the select crosscutting method were significantly higher than yields from the gang method in the 3B lumber grade and highly significant in the 2C and 3A lumber grades. When QC1 yields from gang and select crosscutting methods were compared, the results showed a highly significant improvement in the select group for 1C, 2C, and 3A lumber grades.

By Cant Lengths

Results of the one-tailed paired T-test on the mean board foot cant yield showed that in all three cant lengths there was a highly significant increase in the total board foot yields from the select crosscutting method. Analysis also indicated that there was a significant increase in the QC1 pallet material from select crosscutting of all lengths.

IV. PREDICTION MODELS OF QUALITY PALLET-PART YIELDS

By Log Grades

Results of the regression analysis for grade one, two, and three logs, indicate that gang and select cant yields were affected by cant volume, but not by cant length. Yields from log grades one, two, and three were not significantly different. It is quite possible, however, that a cant yield study of longer cant lengths would show a stronger association between the effects of cant length as a variable (measured by length squared) and board foot yield for the individual log grades. The predicted cant yields by log grade and cant length for gang and select crosscutting methods are presented in the Appendix, Tables XIII-XVI.

By Total Gang and Select Crosscutting Methods

Since log grade had no significant effect on cant yields, the yield data were combined into total gang and select groups. Results of the predicted cant yield by cant length for gang and select crosscutting methods are illustrated in Table VII and Figure 2. For the select crosscutting method, 12-foot cants yielded 31 percent QC1 material and 17 percent QC2 material, followed by 10- and 8-foot cants with QC1 and QC2 yields of 23 percent and 16 percent, and 17 percent and 14 percent, respectively. For the gang crosscutting method, 12-foot cants yielded 29 percent QC1 material and 16 percent QC2 material, followed by 10- and 8-foot cants with QC1 and QC2 yields of 21 percent and 16 percent, and 12 percent and 17 percent, respectively.

When gang and select cant yields were analyzed by quality classes, QC2 yields were affected by cant volume. On the other hand, QC1 yields were affected by both volume and length of the cant. Table VII and Figure 2 illustrate the higher proportional yields of quality class material from longer cant lengths. This greater than proportional increase in QC1 material was sufficient to make the total gang and select yields (QC1 and QC2) from longer cants significantly different. Although there appears to be no apparent reason for expecting greater

TABLE VII

PREDICTED CANT YIELDS BY CANT LENGTH FOR GANG AND SELECT CROSSCUTTING METHODS

Quality Class Material	Prediction Equation	R^2	Cant Length in Feet (Bd.Ft.) 8	10	12
	Gang Crosscutting				
Gang, Quality Class 1	$Yg_1 = -0.4307X + 0.0844X^2$	0.6370	1.96	4.14	6.99
Gang, Quality Class 2	$Yg_2 = 0.3278X$	0.6227	2.62	3.28	3.93
Total Yield/Cant			4.58	7.42	10.92
	Select Crosscutting				
Select, Quality Class 1	$Ys_1 = -0.0418X + 0.0873X^2$	0.6493	2.24	4.56	7.55
Select, Quality Class 2	$Ys_2 = 0.3304X$	0.6311	2.64	3.30	7.86
Total Yield/Cant			4.88	7.86	11.55

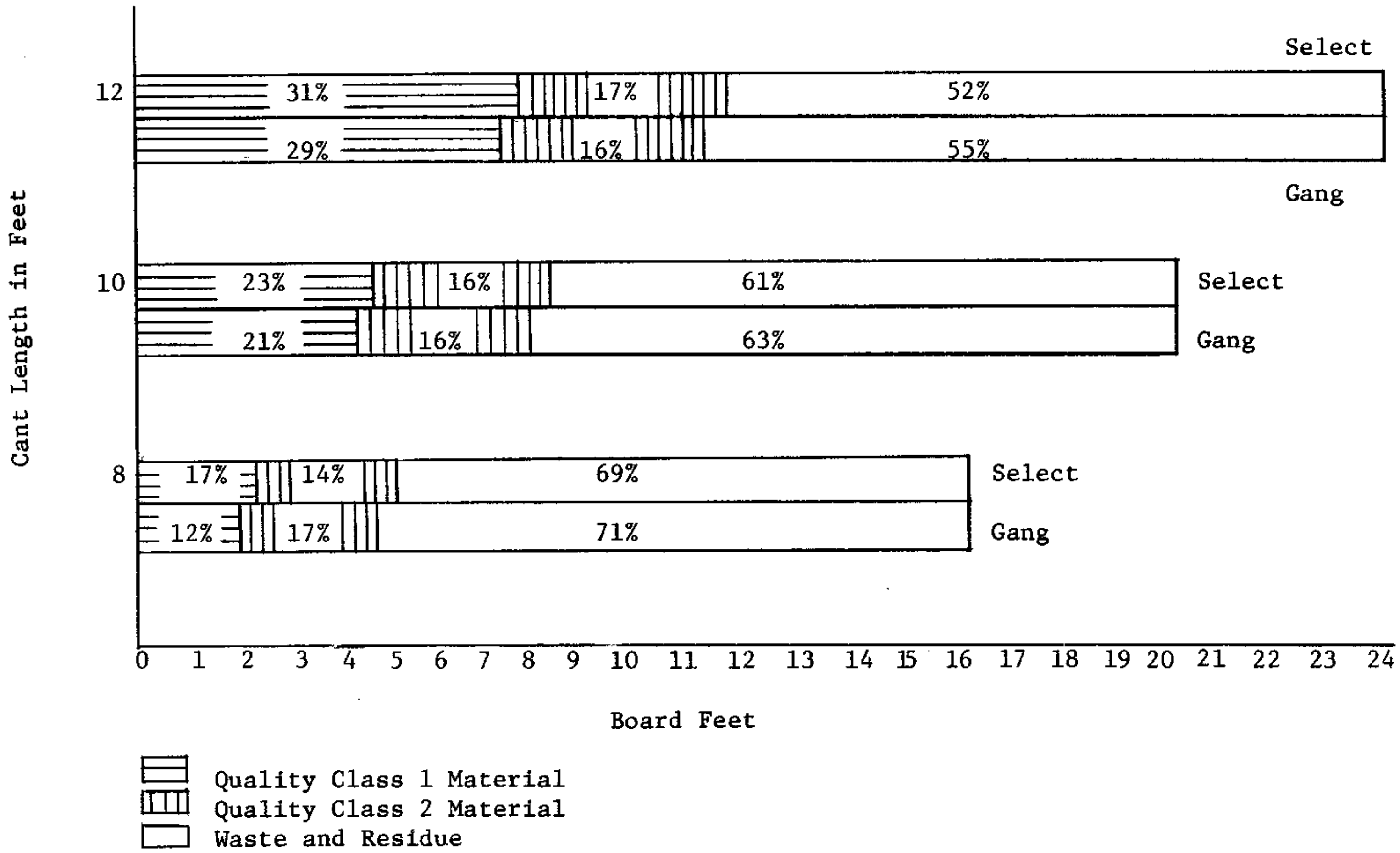

Figure 2. Predicted cant yield for gang and select crosscutting methods, illustrating the higher proportional yields of quality class one material from longer cant lengths.

cant lengths to increase QC1 material, it seems that cant length may be functioning as an index of the critical factors which discriminate between quality class material.

Due to the different effect of cant length upon quality class material, the prediction equation was broken into two categories. The QC1 prediction equation was found to be a two variable equation and QC2, a one variable equation.

By Cutting Patterns

When cant yields were grouped by the two cutting patterns, the effects of cant length on board foot yields were identical to those of total gang and select yields. Both cant volume and cant length were significant factors in the yield of QC1 material. Only cant volume was found significant in explaining the yield of QC2 material.

The effects of cutting pattern on predicted cant yields (Appendix, Tables XVI and XVII, and Figures 4 and 5) indicated that cutting pattern A (1 by 4's and 2 by 4's) had a higher percentage yield than did cutting pattern B (1 by 6's). In both gang and select methods cutting pattern A yielded from 2 to 8 percent greater total board foot yields than did cutting pattern B. Analysis showed that the increase in yields from cutting pattern A was due solely to the increase in QC1 material. Again, the longer the cant length, the greater the proportional increase in predicted QC1 yield. At the same time little change was noted in QC2 material from either cutting pattern.

V. MONETARY EVALUATION OF RAW MATERIAL SOURCES

Red Oak Lumber

To determine the most economic form of raw material, the value of simulated pallet yields was computed in terms of monetary yields per 1000 "board feet measure (b.f.m.)" of red oak lumber input (Appendix, Tables XVIII-XXIV). When lumber grades were compared, 2C lumber had the highest dollar return per 1000 b.f.m., followed by 1C, 3A, and 3B. Results showed that the simulated yield of high quality pallets from 3B and less lumber grades were too low to recover raw material costs.* Net monetary gain was based solely upon red oak lumber costs. If lumber costs per 1000 b.f.m. change, as they have during the previous months, both unit cost of lumber per pallet and the profitableness of the individual lumber grade would change. When the cost-value relationship of the select and gang crosscutting yields were compared, the greatest increase was in the 2C and 3A lumber grades. The 1C and 3B lumber grades offered little opportunity for improvement using select cross-cutting.

Red Oak Cants

In the comparison of simulated pallet yields from the cant form of raw material, both the unit cost and value added per pallet were directly related to the length of the cant and the cost per 1000 b.f.m.

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*Value added per 1000 b.f.m. was based upon green f.o.b. mill prices of November 15, 1971.

of red oak cant material. The longer the cant, the higher the proportional yield. Therefore, of the lengths tested 12-foot cants offered the greatest opportunity for a monetary gain.

As long as cant costs remain at $70 per 1000 b.f.m., the same cost as 2C lumber, it seems unlikely that pallet manufacturers will turn to a pallet-cant operation to obtain high quality pallet material. However, in the past months both the costs of the cant and the costs of individual lumber grades have fluctuated quite significantly. An increase in the cost of graded lumber or a decrease in the price of cants could easily make another particular lumber grade or a cant operation more competitive.

Based upon the monetary evaluation of raw material sources, 8- and 10-foot red oak cants seem to have little future in the sole production of high quality pallet-part material. Extremely low yields, low pallet-part quality, and high raw material costs combine to make any operation where the entire cant must be resawn into quality 40- by 48-inch material impractical.

CHAPTER IV

SUMMARY

I. SCOPE OF STUDY

The purpose of this study was to measure quality pallet-part yields from graded lumber, sawn from common 4- by 6-inch red oak pallet cants. The cants were obtained from a stratified sample of 114 red oak logs, numbered and graded, using standard U.S. Forest Service factory log grades. Each 4- by 6-inch cant was then sawn from the "heart center" of each log and later resawn into pallet lumber. The lumber was then graded, according to specifications of National Hardwood Lumber Manufacturers' lumber grades and simulation of gang and select crosscutting methods was used to produce pallet-parts. Using suggested grading rules of the U.S. Forest Service, the resulting 40- and 48-inch pallet-parts were then regraded and grouped into two quality classes. Recovery yields of QC parts for gang and select cutting methods were then recorded by lumber grades and cant lengths. Based upon three pallet styles, simulated pallet construction was conducted. Both quality class grades and pallet styles, while pertinent to this study, should be considered tentative, since the pallet industry is undergoing rapid changes.

The primary objective of this study was to determine yield and quality of pallet-parts from southern red oak cants. A second objective was to evaluate crosscutting methods used in producing pallet lumber. Hopefully, by fulfilling these objectives the following questions could be answered: (1) what are common cants worth in terms of common grades of lumber, (2) whether these cants could produce parts for a pallet selling in the $5 to $6 price range, and (3) which of two crosscutting methods, gang or select, should be used in resawing the lumber to pallet-part material.

II. PRINCIPAL FINDINGS

An analysis of red oak cant-lumber yields indicated that lumber grade yield distributions from grade one, two, and three logs were highly variable and did not decline with lower grade logs. Yields from 1C and better lumber were offset mainly by a reduction in 2C lumber yields. Also they were considerably higher than previous red oak cant yields published by the U.S. Forest Service. Yields of 3A and 3B lumber grades were in more general agreement with those previously published.

For the select crosscutting method, 1C red oak lumber from cants had a grade pallet-part yield of 85 percent, followed by 2C, 3A, and 3B grade lumber with pallet-part yields of 70 percent, 44 percent, and 16 percent, respectively. In comparison, for the gang crosscutting method, 1C red oak cant-lumber yielded 86 percent grade pallet-part material, followed by yields of 76 percent, 48 percent, and 17 percent for 2C, 3A, and 3B red oak lumber grades. The greatest significant increase in graded pallet-part yield from select crosscutting was in 2C and 3A red oak lumber grades.

Lumber grades also affected the breakdown of pallet-part yields into quality classes. The higher the lumber grade, the greater the ratio of quality class one material obtained.

An analysis of total gang and select yields by cant lengths indicated that quality 40- by 48-inch pallet-part yields from cant material were extremely low.* Twelve-foot cants, representing the greatest proportional return, yielded 45 percent (gang, quality class one and two) and 48 percent (select, quality class one and two). Eight- and 10-foot cants returned lesser proportional yields of 37 percent and 29 percent for the gang method and 39 percent and 31 percent for the select method. In all cant length groups, select pallet-part yields were significantly increased.

A cost-return analysis based on existing lumber and cant costs and the estimated prices for three styles of quality pallets, indicated that 2C lumber offered the greatest opportunity for a successful high quality, cut-to-size pallet-part operation.** The returns of a 12-foot cant were highest in overall cant yields and compared closely to those of the 3A lumber grade. However, the returns of 2C lumber were considerably higher than those of the 3A lumber grade. Based solely upon the graded yields of two quality class (40- by 48-inch) pallet-parts, 8- and 10-foot cants offered little opportunity for a successful recovery of high quality pallet-parts, notwithstanding further utilization of residues.

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*Based solely upon the use of the cant for the production of quality 40- and 48-inch parts. This does not include alternative uses for residue material, such as shorter pallet-parts.

**Based solely on net raw material costs.

III. CONCLUSION

Based upon the relatively low yield recoveries of this study and current raw material costs, it appears that the best source of quality class pallet-part material for the pallet producer may be graded red oak lumber, rather than low yielding 4- by 6-inch red oak cant material. In general, the better grades of lumber resulted in a higher quality and quantity of pallet-parts. Although 1C and better lumber gave the greatest quality yields, a series of cost-price trade-offs resulted in the 2C lumber grade appearing to offer the best financial alternative.

In evaluating the monetary returns from raw material sources, only the cant-lumber suitable for quality 40- and 48-inch pallet-parts was considered usable. However, even under current marketing conditions, the residue material may be quite useful in other areas of pallet production. Many pallet industries are currently adopting a standard 40- by 48-inch pallet. However, for years to come many other quality pallet sizes will probably be in demand. Pallet material which does not qualify for a quality 40- or 48-inch pallet-part could be used as a quality pallet-part in a pallet of smaller dimension. Since many pallet buyers would want to pay only for the quality which they can use, much of the residue cant material may be used in a 40- by 48-inch pallet operation where less emphasis is placed on quality standards. And last, residue cant material not meeting the specifications of the above alternatives might be used as chipping material.

Although under the quality class specifications and assumptions used in this study, the residue cant material was considered as waste material, it could have economic value. It is quite possible that if markets for residue material were available, a pallet-part operation utilizing the cant form of raw material might become an increasingly important element in the production of pallet material. On the other hand, further studies may show that quality class one and two grading rules, tentatively proposed by the U.S. Forest Service, may prove too strenuous for a successful quality pallet operation involving low grade cant material.

IV. RECOMMENDATIONS FOR FURTHER STUDY

Although this study has given additional insight about quality yields from red oak cants, greater knowledge of both cant yields and quality classes is needed before the idea of quality pallet-part yields from red oak cants can be commercially accepted. Areas where further research are recommended include:

1. Further research on the effects of longer lengths upon pallet stock yields from cants and the use of length as a possible index for developing cant grades.
2. Further study on pallet stock yields from cants of other usable species.
3. Research on the optimum number of quality classes and greater clarification of those quality classes presently proposed.
4. Research on the utilization of the high quantities of residue cant material found in this study.

5. Additional research on the most economical method of sawing 40- and 48-inch pallet-parts from different 4- by 6-inch cant lengths, including other sawing patterns.
6. Marketing analysis on the acceptability of the pallet-cant as a possible source of graded pallet material.
7. Research on the utilization of a 7- by 9-inch tie as a source of pallet stock material.

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TABLE VIII

SPECIFICATIONS FOR PALLET-PART MATERIAL

Grading Factors		Minimum Requirements
Class 1: These Parts are High Strength Parts to be Used in the Impact Areas of the Pallet--The Pallet Sides and Ends.		
Knot Size	:	No knot may be greater than one-fourth the width of the part.
Number of Knots	:	No more than one knot per 12 inches of length.
Knot Location	:	No knots in nailing areas of 1-inch-thick parts. No knots on edges of parts.
Holes and Unsound Knots	:	Must be no more than one-half the knot diameter measured across the width.
Wane, Decay, Splits, Shakes	:	Not permitted.
Cross Grain	:	1 in 12 or greater.
Dimensions:		
Thickness	:	1 inch, 13/16, ± 1/32, planed two sides 2 inch, 1-5/8, ± 1/16, planed two sides
Width	:	4 inch, 3-5/8, ± 1/16, ripped two sides 6 inch, 5-5/8, ± 1/16, ripped two sides
Moisture Content	:	Green as sawn.
Species	:	NWPCA Class "C", Dense hardwoods; oak, beech, birch, hickory, hard maple.
Class 2: These Parts are of Normal Strength and are to be Used in the Interior of the Pallet. Class 1 Parts in Excess of Requirements May be Used as Class 2 Parts.		
Knot Size	:	No knot may be more than one-half the width of the part.
Number of Knots	:	No more than one knot per 8 inches of length.

TABLE VIII (continued)

Grading Factors		Minimum Requirements
Knot Location	:	Sound knots no more than one-fourth the width allowed in the nailing area or on edges of parts.
Holes and Unsound Knots	:	Must be no more than one-half the knot diameter measured across the width.
Wane	:	No more than one-fourth the length, one-sixth the width, one-half the thickness. Two by four stringers can have wane no more than one-fourth the thickness.
Decay	:	None.
Splits and Shakes	:	No more than 2 inches long.
Cross Grain	:	1 in 8 or greater.
Dimensions	:	Same as Class 1.
Moisture Content	:	Same as Class 1.
Species	:	Same as Class 1.

Source: Reynolds, Hugh W., and Charles J. Gatchell. _The Sholo Mill: Make Pallet Parts and Chips from Low-Grade Hardwoods_, U.S. Forest Service Research Paper NE-180, 1970, p. 5.

TABLE IX

DISTRIBUTION OF TOTAL PALLET-PART YIELD RECOVERY FOR GANG CROSSCUTTING METHOD AMONG FIVE LUMBER GRADES OF RANDOM LENGTH LUMBER

	Pallet-Part Yield Recovery[a]						
Lumber Grade	0.0	33.3	50.0	66.7 (Percent)	100.0	Total[b]	Total[c]
1C	1.4	2.8	5.6	26.3	63.9	100.0	13.9
2C	0.0	13.3	21.1	31.2	34.4	100.0	17.3
3A	17.2	30.7	22.1	19.6	10.4	100.0	31.3
3B	60.7	23.4	9.7	5.5	0.7	100.0	27.9
Cull	100.0	0.0	0.0	0.0	0.0	100.0	9.6
Total							100.0

[a]The above percent yields represent discrete recovery rates due to the constraints of board length (8, 10, 12) and the required 40- and 48-inch lengths of pallet-parts.

[b]Total pallet-part yield recovery.

[c]Total lumber grade distribution.

TABLE X

DISTRIBUTION OF QUALITY CLASS ONE PALLET-PART YIELDS FOR GANG CROSSCUTTING METHOD AMONG FIVE LUMBER GRADES OF RANDOM LENGTH LUMBER

	Pallet-Part Yield Recovery[a]						
Lumber Grade	0.0	33.3	50.0	66.7 (Percent)	100.0	Total[b]	Total[c]
1C	11.1	18.1	8.3	31.9	30.6	100.0	13.9
2C	13.3	33.3	23.4	23.3	6.7	100.0	17.3
3A	49.7	32.5	11.7	6.1	0.0	1 0.0	31.3
3B	85.6	10.3	3.4	0.7	0.0	100.0	27.9
Cull	100.0	0.0	0.0	0.0	0.0	100.0	9.6
Total							100.0

[a]The above percent yields represent discrete recovery rates due to the constraints of board length (8, 10, 12) and the required 40- and 48-inch lengths of pallet-parts.

[b]Total pallet-part yield recovery.

[c]Total lumber grade distribution.

TABLE XI

DISTRIBUTION OF TOTAL PALLET-PART YIELD RECOVERY FOR SELECT CROSSCUTTING METHOD AMONG FIVE LUMBER GRADES OF RANDOM LENGTH LUMBER

Lumber Grade	Pallet-Part Yield Recovery[a] 0.0	33.3	50.0	66.7	100.0	Total[b]	Total[c]
	(Percent)						
1C	1.4	1.4	5.6	26.3	65.3	100.0	13.9
2C	0.0	6.7	16.7	33.3	43.3	100.0	17.3
3A	17.2	22.7	19.6	26.4	14.1	100.0	31.3
3B	60.6	22.8	8.3	6.2	2.1	100.0	27.9
Cull	100.0	0.0	0.0	0.0	0.0	100.0	9.6
Total							100.0

[a]The above percent yields represent discrete recovery rates due to the constraints of board length (8, 10, 12) and the required 40- and 48-inch lengths of pallet-parts.

[b]Total pallet-part yield recovery.

[c]Total lumber grade distribution.

TABLE XII

DISTRIBUTION OF QUALITY CLASS ONE PALLET-PART YIELDS FOR SELECT CROSSCUTTING METHOD AMONG FIVE LUMBER GRADES OF RANDOM LENGTH LUMBER

	Pallet-Part Yield Recovery[a]						
Lumber Grade	0.0	33.3	50.0	66.7	100.0	Total[b]	Total[c]
	(Percent)						
1C	11.1	9.8	8.3	37.5	33.3	100.0	13.9
2C	13.3	23.4	17.8	31.1	14.4	100.0	17.3
3A	49.1	28.3	10.4	10.4	1.8	100.0	31.3
3B	85.5	10.4	3.4	0.7	0.0	100.0	27.9
Cull	100.0	0.0	0.0	0.0	0.0	100.0	9.6
Total							100.0

[a]The above percent yields represent discrete recovery rates due to the constraints of board length (8, 10, 12) and the required 40- and 48-inch lengths of pallet-parts.

[b]Total pallet-part yield recovery.

[c]Total lumber grade distribution.

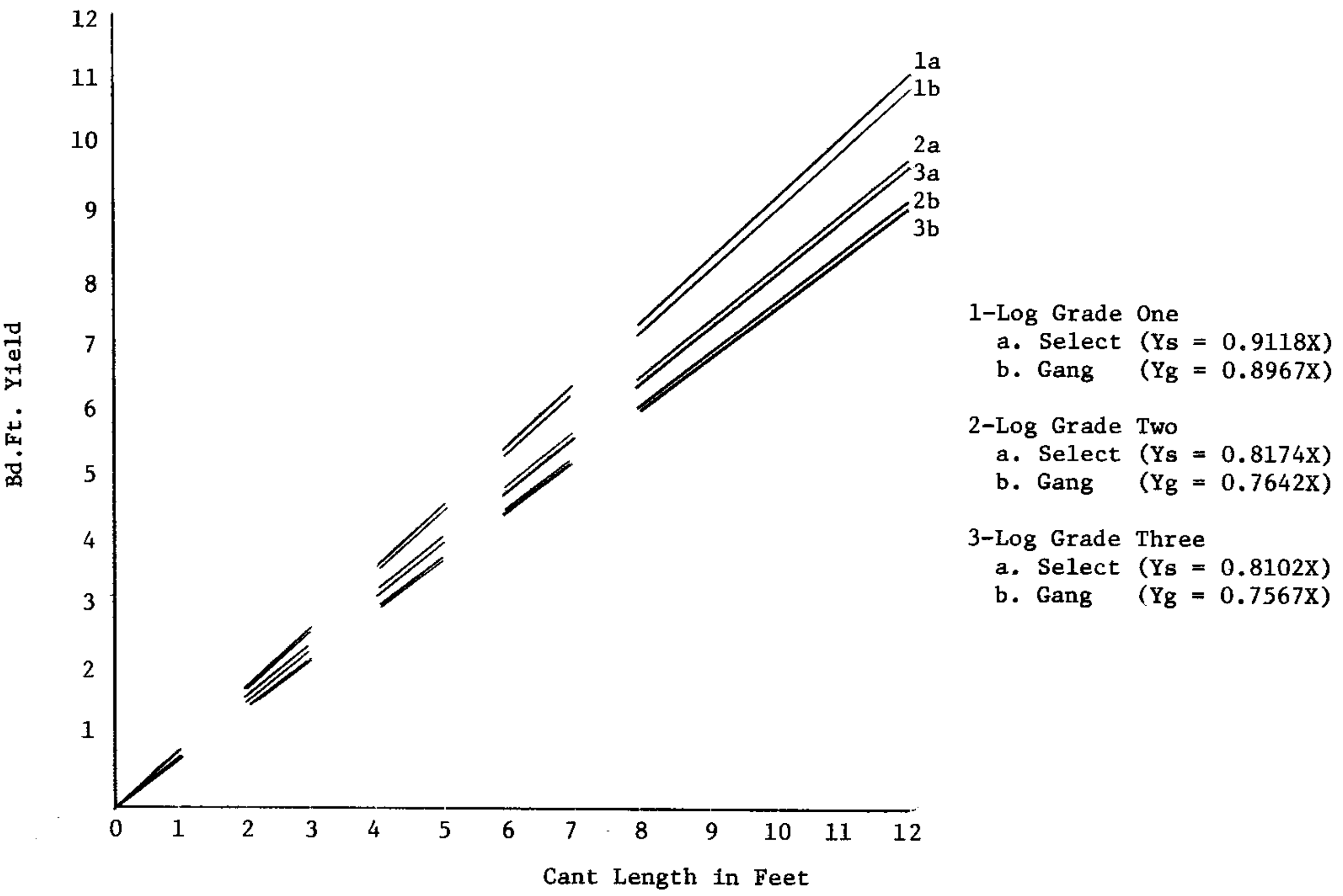

Figure 3. Predicted cant yields by log grade and cant length for gang and select cross-cutting methods.

TABLE XIII

PREDICTED CANT YIELDS BY LOG GRADE AND CANT LENGTH
FOR GANG AND SELECT CROSSCUTTING METHODS

Log Grade 1			Cant Length in Feet		
Quality Class Material	Prediction Equation	R^2	8	10 (Bd.Ft.)	12
	Gang Crosscutting				
Gang, Quality Class 1	$Yg_1 = 0.5734X$	0.6589	-	5.73	6.88
Gang, Quality Class 2	$Yg_2 = 0.3232X$	0.7124	-	3.23	3.89
Total Yield/Cant			-	8.96	10.77
	Select Crosscutting				
Select, Quality Class 1	$Ys_1 = 0.6104X$	0.6518	-	6.10	7.33
Select, Quality Class 2	$Ys_2 = 0.3014X$	0.6569	-	3.01	3.62
Total Yield/Cant			-	9.12	10.95

TABLE XIV

PREDICTED CANT YIELDS BY LOG GRADE AND CANT LENGTH
FOR GANG AND SELECT CROSSCUTTING METHODS

Log Grade 2			Cant Length in Feet		
Quality Class Material	Prediction Equation	R^2	8	10 (Bd.Ft.)	12
	Gang Crosscutting				
Gang, Quality Class 1	$Yg_1 = 0.4523X$	0.5764	3.62	4.52	5.43
Gang, Quality Class 2	$Yg_2 = 0.3136X$	0.5914	2.51	3.14	3.76
Total Yield/Cant			6.13	7.66	9.19
	Select Crosscutting				
Select, Quality Class 1	$Ys_1 = 0.4904X$	0.6100	3.92	4.90	5.89
Select, Quality Class 2	$Ys_2 = 0.3255X$	0.6114	2.60	3.26	3.91
Total Yield/Cant			6.52	8.17	9.80

TABLE XV

PREDICTED CANT YIELDS BY LOG GRADE AND CANT LENGTH
FOR GANG AND SELECT CROSSCUTTING METHODS

Log Grade 3			Cant Length in Feet		
Quality Class Material	Prediction Equation	R^2	8	10 (Bd.Ft.)	12
	Gang Crosscutting				
Gang, Quality Class 1	$Yg_1 = 0.4140X$	0.5780	3.31	4.14	4.97
Gang, Quality Class 2	$Yg_2 = 0.3426X$	0.6193	2.74	3.43	4.11
Total Yield/Cant			6.05	7.57	9.08
	Select Crosscutting				
Select, Quality Class 1	$Ys_1 = 0.4626X$	0.5876	3.70	4.63	5.55
Select, Quality Class 2	$Ys_2 = 0.3475X$	0.6428	2.78	3.48	4.17
Total Yield/Cant			6.48	8.11	9.72

TABLE XVI

PREDICTED CANT YIELDS BY CANT LENGTH FROM GANG AND SELECT CROSSCUTTING METHODS FOR CUTTING PATTERN ONE

Quality Class Material	Prediction Equation	R^2	Cant Length in Feet 8	10 (Bd.Ft.)	12
	Gang Crosscutting				
Gang, Quality Class 1					
1 x 4's	$Yg_1 = -0.1328X + 0.0484X^2$	0.6811	2.04	3.51	5.38
2 x 4's	$Yg_1 = -0.2941X + 0.0427X^2$	0.4782	0.38	1.33	2.62
Gang, Quality Class 2					
1 x 4's	$Yg_2 = 0.1997X$	0.5746	1.60	2.00	2.40
2 x 4's	$Yg_2 = 0.1093X$	0.3205	0.87	1.09	1.31
Total Yield/Cant			4.89	7.93	11.71
	Select Crosscutting				
Select, Quality Class 1					
1 x 4's	$Ys_1 = -0.1156X + 0.0504X^2$	0.6902	2.30	3.88	5.87
2 x 4's	$Ys_1 = -0.3043X + 0.0444X^2$	0.4809	0.41	1.41	2.75
Select, Quality Class 2					
1 x 4's	$Ys_2 = 0.2016X$	0.5845	1.61	2.02	2.42
2 x 4's	$Ys_2 = 0.1085X$	0.3159	0.87	1.09	1.31
Total Yield/Cant			5.19	8.40	12.35

TABLE XVII

PREDICTED CANT YIELDS BY CANT LENGTH FROM GANG AND SELECT CROSSCUTTING METHODS FOR CUTTING PATTERN TWO

Quality Class Material	Prediction Equation	R^2	Cant Length in Feet 8	10 (Bd.Ft.)	12
	Gang Crosscutting				
Gang, Quality Class 1	$Yg_1 = -0.3684X + 0.0687X^2$	0.5846	1.45	3.19	5.48
Gang, Quality Class 2	$Yg_2 = 0.3566X$	0.6596	2.85	3.57	4.28
Total Yield/Cant			4.30	6.76	9.76
	Select Crosscutting				
Select, Quality Class 1	$Ys_1 = -0.3531X + 0.0708X^2$	0.5929	1.71	3.56	5.97
Select, Quality Class 2	$Ys_2 = 0.3625X$	0.6628	2.90	3.63	4.35
Total Yield/Cant			4.61	7.19	10.32

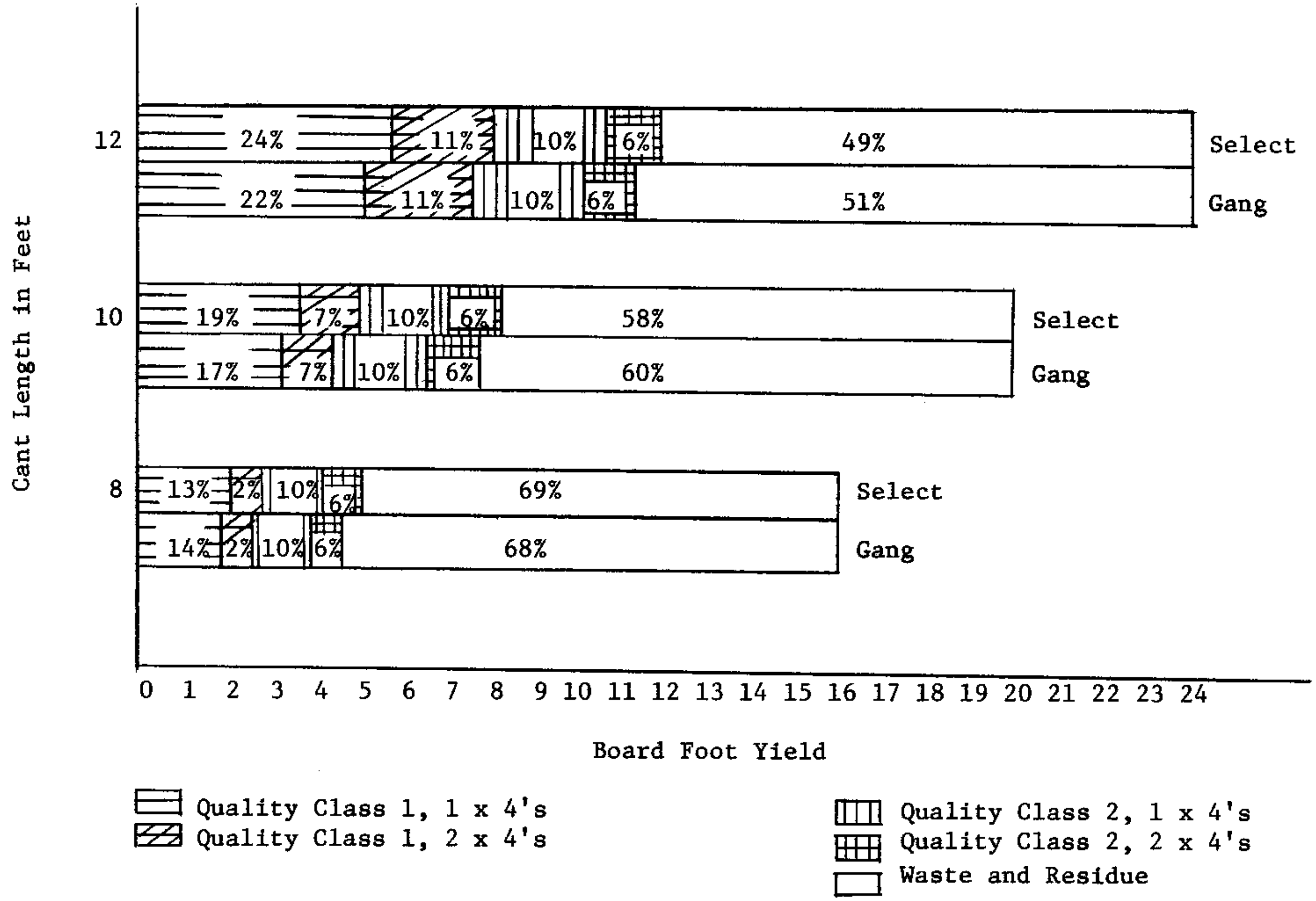

Figure 4. Predicted cant yield for gang and select crosscutting methods, illustrating the higher proportional yields of quality class one material from longer cant lengths for cutting pattern one.

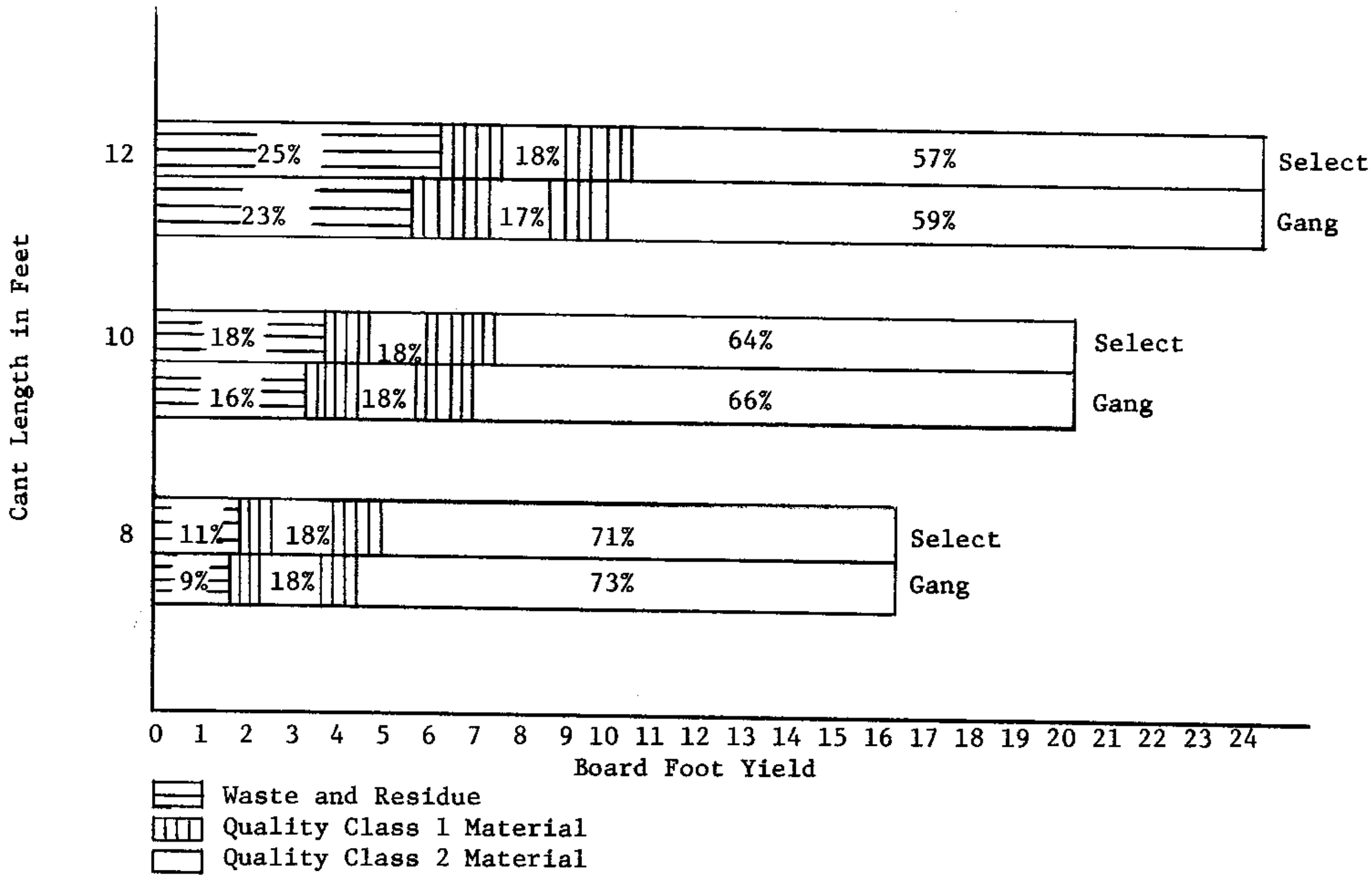

Figure 5. Predicted cant yield for gang and select crosscutting methods, illustrating the higher proportional yields of quality class one material from longer cant lengths for cutting pattern two.

TABLE XVIII

SIMULATED PALLET YIELDS FROM 1C LUMBER FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Lumber[a]	Ratio of Pallet Parts/M b.f.m. of 1C Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Lumber	Unit Cost of Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$105.00	0.8500	31.59	$5.25	$165.84	$3.32	$60.84
Select	$105.00	0.8597	31.96	$5.25	$167.79	$3.29	$62.79
Style 2							
Gang	$105.00	0.8500	30.32	$5.50	$166.79	$3.46	$61.79
Select	$105.00	0.8597	30.67	$5.50	$168.69	$3.42	$63.69
Style 3							
Gang	$105.00	0.8500	29.18	$5.75	$167.79	$3.60	$62.79
Select	$105.00	0.8597	29.51	$5.75	$169.70	$3.56	$64.70

[a]Lumber prices based upon quoted November 15, 1971, F.O.B. mill prices per 1000 Bd.Ft. of green Appalachian red oak lumber for the Middle Tennessee area.

[b]Net of lumber costs only.

TABLE XIX

SIMULATED PALLET YIELDS FROM 2C LUMBER FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Lumber[a]	Ratio of Pallet Parts/M b.f.m. of 2C Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Lumber	Unit Cost of Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$70.00	0.7003	26.03	$5.25	$136.67	$2.69	$66.67
Select	$70.00	0.7582	28.19	$5.25	$148.00	$2.48	$78.00
Style 2							
Gang	$70.00	0.7003	24.98	$5.50	$137.41	$2.80	$67.41
Select	$70.00	0.7582	27.05	$5.50	$148.77	$2.59	$78.77
Style 3							
Gang	$70.00	0.7003	24.04	$5.75	$138.23	$2.91	$68.23
Select	$70.00	0.7582	26.03	$5.75	$149.66	$2.69	$79.66

[a]Lumber prices based upon quoted November 15, 1971, F.O.B. mill prices per 1000 Bd.ft. of green Appalachian red oak lumber for the Middle Tennessee area.

[b]Net of lumber costs.

TABLE XX

SIMULATED PALLET YIELDS FROM 3A LUMBER FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Lumber[a]	Ratio of Pallet Parts/M b.f.m. of 3A Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Lumber	Unit Cost of Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$60.00	0.4382	16.04	$5.25	$84.21	$3.74	$24.21
Select	$60.00	0.4761	17.44	$5.25	$91.56	$3.44	$31.56
Style 2							
Gang	$60.00	0.4382	15.62	$5.50	$85.92	$3.84	$25.92
Select	$60.00	0.4761	16.70	$5.50	$91.85	$3.59	$31.85
Style 3							
Gang	$60.00	0.4382	14.41	$5.75	$82.86	$4.16	$22.86
Select	$60.00	0.4761	15.81	$5.75	$90.91	$3.80	$30.91

[a]Lumber prices based upon quoted November 15, 1971, F.O.B. mill prices per 1000 Bd.ft. of green Appalachian red oak lumber for the Middle Tennessee area.

[b]Net of lumber costs.

TABLE XXI

SIMULATED PALLET YIELDS FROM 3B LUMBER FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Lumber[a]	Ratio of Pallet Parts/M b.f.m. of 3B Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Lumber	Unit Cost of Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$50.00	0.1574	4.63	$5.25	$24.31	$10.80	$-25.69
Select	$50.00	0.1654	4.63	$5.25	$24.31	$10.80	$-25.69
Style 2							
Gang	$50.00	0.1574	4.24	$5.50	$23.32	$11.79	$-26.68
Select	$50.00	0.1654	4.24	$5.50	$23.32	$11.79	$-26.68
Style 3							
Gang	$50.00	0.1574	3.91	$5.75	$22.51	$12.79	$-27.49
Select	$50.00	0.1654	3.91	$5.75	$22.51	$12.79	$-27.49

[a]Lumber prices based upon quoted November 15, 1971, F.O.B. mill prices per 1000 Bd.ft. of green Appalachian red oak lumber for the Middle Tennessee area.

[b]Net of lumber costs.

TABLE XXII

SIMULATED PALLET YIELDS FROM EIGHT-FOOT COMMON GRADE CANT FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Cant Lumber[a]	Ratio of Pallet Parts/M b.f.m. of Cant Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Cant Lumber	Unit Cost of Cant Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$70.00	0.2862	10.19	$5.25	$53.50	$6.87	$-16.50
Select	$70.00	0.3050	11.17	$5.25	$58.64	$6.27	$-11.36
Style 2							
Gang	$70.00	0.2862	9.34	$5.50	$51.37	$7.49	$-18.63
Select	$70.00	0.3050	10.67	$5.50	$58.69	$6.56	$-11.31
Style 3							
Gang	$70.00	0.2862	8.61	$5.75	$49.51	$8.13	$-20.49
Select	$70.00	0.3050	9.85	$5.75	$56.64	$7.11	$-13.36

[a]Cant prices based upon quoted November, 1971, F.O.B. mill prices per 1000 Bd.Ft. of green Appalachian red oak cants of random length.

[b]Net of cant costs.

TABLE XXIII

SIMULATED PALLET YIELDS FROM TEN-FOOT COMMON GRADE CANT FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Cant Lumber[a]	Ratio of Pallet Parts/M b.f.m. of Cant Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Cant Lumber	Unit Cost of Cant Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$70.00	0.3710	13.79	$5.25	$72.40	$5.08	$2.40
Select	$70.00	0.3930	14.61	$5.25	$76.70	$4.79	$6.70
Style 2							
Gang	$70.00	0.3710	13.24	$5.50	$72.82	$5.29	$2.82
Select	$70.00	0.3930	14.02	$5.50	$77.11	$4.99	$7.11
Style 3							
Gang	$70.00	0.3710	12.74	$5.75	$73.26	$5.49	$3.26
Select	$70.00	0.3930	13.49	$5.75	$77.56	$5.19	$7.56

[a]Cant prices based upon quoted November, 1971, F.O.B. mill prices per 1000 Bd.Ft. of green Appalachian red oak cants of random length.

[b]Net of cant costs.

TABLE XXIV

SIMULATED PALLET YIELDS FROM TWELVE-FOOT COMMON GRADE CANT FOR THREE PALLET STYLES, SHOWING MONETARY VALUES AND YIELDS FROM GANG AND SELECT CROSSCUTTING PATTERNS

Pallet Style and Crosscutting Method	Assumed Price/M b.f.m. of Red Oak Cant Lumber[a]	Ratio of Pallet Parts/M b.f.m. of Cant Lumber	Number of Simulated Pallets	Price per Pallet	Cost/M b.f.m. of Cant Lumber	Unit Cost of Cant Lumber per Pallet	Value Added/M b.f.m.[b]
Style 1							
Gang	$70.00	0.4550	16.92	$5.25	$88.83	$4.14	$18.83
Select	$70.00	0.4800	17.85	$5.25	$93.71	$3.92	$23.71
Style 2							
Gang	$70.00	0.4550	16.24	$5.50	$89.32	$4.31	$19.32
Select	$70.00	0.4800	17.12	$5.50	$94.16	$4.09	$24.16
Style 3							
Gang	$70.00	0.4550	15.62	$5.75	$89.82	$4.48	$19.82
Select	$70.00	0.4800	16.48	$5.75	$94.76	$4.25	$24.76

[a]Cant prices based upon quoted November, 1971, F.O.B. mill prices per 1000 Bd.Ft. of green Appalachian red oak cants of random length.

[b]Net of cant costs.

VITA

E. Michael Witt, son of Edwin B. Witt and Raydean (Carver) Witt, was born in Athens, Tennessee, September 16, 1948. He attended elementary school in Loudon and graduated from Loudon High School in 1966. He entered The University of Tennessee, Knoxville, in 1966, and received the degree of Bachelor of Science in Forestry in June, 1970. In June, 1970, he entered the University of Tennessee on a research assistantship to begin graduate work in Forestry, specializing in business and management. He received a Master of Science in Forestry from The University of Tennessee in June, 1972.

He is married to the former Paulette Dillehay of Carthage, Tennessee.