CLEARWOOD YIELDS FROM TENDED 26-YEAR-OLD, SECOND-CROP, RADIATA PINE

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ABSTRACT

Fifteen pruned dominants (mean d.b.h. 23.4in.) of a 26-year-old radiata pine second rotation stand were sawn predominantly to boards. The stand sampled had received intensive silvicultural management following natural regeneration but the results presented are not representative of the stand as a whole. Altogether, seventy-four 18ft logs were sawn, the average conversion factor being 6.7. Butt logs yielded a percentage average grade out-turn of 37% Clear and 32% Factory grades. The entire sample yielded 13% Clear and 23% Factory grades.

A regression for the total clear wood available from the butt logs was calculated:

clear wood volume (in bd ft) = 92.26 B.A. — 44.49

where B.A. = tree basal area (in sq ft).

The incidence of defects was generally consistent with earlier studies on older crops but large bark encased knots were few.

INTRODUCTION

Earlier timber grade studies of radiata pine (*Pinus radiata* D. Don) in New Zealand have dealt largely with imperfectly tended, or untended crops (Fenton and Familton, 1961; Fenton, 1967). An exception was the study of the well pruned stand at Waierua (Fenton, 1968), but the particularly intensive pruning done by the individual owner, and the unusual height/diameter/age development of the few trees involved necessitate modification of these results before they can be used in economic analyses of more typical management. The grades resulting from current tending schedules are of fundamental significance in evaluating silviculture. The stands originating from natural regeneration after the first large-scale fellings in 1939-40 are amongst the oldest "second-rotation" crops available; they have in the main been pruned, and investigation of their grade out-turn is required to extend results from the earlier studies, to test the efficiency of present tending schedules, and to make an accurate projection of the likely out-turn from such stands for use in national planning.

Present-day silviculture and management prescribes long rotations (to 135-145ft top height in 35-45 yr) for radiata pine (Bunn, 1963). Yield table projections show mean final crop (80 stems per acre (s.p.a.)), diameter at breast height (d.b.h.), of 22-23in. over bark (o.b.) for these rotations. The profitability of such schedules has been evaluated (Fenton and Grainger, 1965; Fenton *et al.,* 1968a) as a basis for comparisons with agriculture (Ward *et al.,* 1966); and forest profitability is naturally affected by rotation length. Proposals to produce trees of similar diameter in 25-26 yr have been made recently (Fenton and Sutton, 1968), and an integral part of the case rests on the grade out-turn from trees of this age and size. The study reported here provides these grade data.

METHODS

1. *Stand Description*

Known details of the stand history are given in Table 1; the site index is 103 (Lewis, 1954). The area sampled had originally been felled by April, 1940; ring counts showed the sampled trees had come from regeneration in 1940, 1941, and one tree from 1942. Details of stocking density up to 1950 are sparse, but growth analyses

TABLE 1—Stand history, Waiotapu Compartment 28

Regeneration	Old crop clear felled 1939 - April 1941
Spacing	Thinned to 4 ft x 4 ft spacing, 1946-7
Pruned to	6-8 ft
at age	5-7 yr
at top height	29 ft*
s.p.a.	all
Second pruning to	18 ft
at age	8-10 yr
at top height	46 ft*
s.p.a.	100
Third pruning to	18 ft and higher - varying from 20 ft to 55 ft
at age	17-19 yr
at top height	96 ft*
s.p.a.	Varying from 5 to 40 per ac above 18 ft, an unknown number were pruned to 18 ft
First thinning to	250 s.p.a.
at age	8-10 yr
at top height	46 ft*
Second thinning to	80 s.p.a.
at age	17-19 yr
at top height	96 ft*
At time of felling	March, 1968†
Age	26-27 yr
Mean top height	132 ft
Site index	103 ft‡
Stocking/ac	73 stems
B.A./ac	165 sq ft
Vol./ac (to 8 in. top)	7,300 cu ft
Mean tree d.b.h.	20.3 in.

* From height/age graph drawn from stem analysis (agrees with Lewis, 1954)

† Based on 16 randomly located 0.5 ac plots

‡ Estimated from yield tables

showed relatively restricted diameter growth up to age 7 yr on most trees; so presumably stocking was initially dense. Hence the knotty-core diameter for the 0/6-8 ft pruning lift was small, despite the relatively late pruning.

Stand data from 1950 onwards are accurate.

2. *Stem Selection*

Most of the present stand had been pruned to 18 ft at age 17-19, and not at age 8-10 yr. Many stems pruned to 18 ft in the earlier operation had presumably been removed in the second thinning and the later pruning had often occluded sufficiently to make differentiation between the stems which had received the two 18-ft pruning operations a problem. Sampling was therefore subjective; fifteen normal form, dominant trees were chosen, two of which later proved to have been 18 ft pruned at age 17-19 yr. Mean d.b.h. of the trees sawn was 23.4 in. o.b.; diameters ranged from 20.0 to 26.5 in.

It must be stressed that the results obtained are therefore from the large, dominant trees; they are not representative of the stand as a whole.

3. *Logging and Milling*

All logs were cut 18 ft 4 in. long. Volumes of the butt logs were calculated as: 5/6 (5 × basal area at 2 ft 6 in. + basal area at 5 ft) plus 13/6 (basal area at 5 ft + 4 × basal area at 11 ft 6 in. + basal area at 18 ft); viz. Newton's formula for the portion 5-18 ft, and Newton's formula for the bottom 5 ft modified by omitting stump basal area and substituting that at 2 ft 6in. Volumes of second and higher logs were calculated from Newton's formula: (Length /6) (basal area big end + 4 × basal area centre point + basal area small end). All volumes are given under bark. These detailed measurements are necessary as finding the value per cu ft is a fundamental part of any grade study, and the earlier tree volume and taper tables may not be applicable to trees grown under these conditions. Mean log volumes and diameters are given in Table 2.

Annual rings were identified by marking freshly felled log ends with indelible pencil. These marks, which were protected during extraction by old X-ray film pinned over the log ends, survived logging and milling. Thus the years in which each piece of timber was produced could be determined; this facilitated accurate interpretation of the pruning and occlusion history.

A description of the log numbering may help in other studies. Each log and tree was allocated a number; the first one or two numerals in each log number being the tree number, and the last numeral being the log height class. Thus log 135 would be the fifth log of tree 13. Log numbers were marked by:

(1) Aluminium tags at each end;
(2) Numbers in indelible pencil on the face of three axe notches in the log circumference;
(3) Painted numbers on the X-ray film overlaying the log ends;
(4) Painted numbers on the bark.

Log painted numbers were colour coded by log height class to facilitate log sorting at the mill, end-lift drivers being asked to deliver, say, "yellow" logs rather than particular numbers. Aluminium tags, X-ray film, etc., were removed when the logs were finally assembled on the head-saw skids. The order of sawing—by log numbers—

TABLE 2—Volume results by log height classes (L.H.C.)

Log Height Class (L.H.C.)	Log Data S.e.d. in.	Vol. cu ft	CF	Grade Results - % of L.H.C. Box	Merch.	Dress.	Factory* F1	F2	Clear	IF	IIF
Butt†	18.8	42.6	6.8	12	8	11(1)	21	11	37	0	0
Second	16.7	31.8	7.4	22	26	13(6)	18	16	0	3½	2
Third	14.6	24.2	6.4	33	43	7(12)	4	8	0	6	1
Fourth	12.1	17.8	6.2	31	55	6(11)	1	3	0	17	15
Fifth‡	8.5	10.9	5.6	28	37	2(0)	0	0	0	17	15
Overall		1,886	6.7	22	27½	9½(6)	13	10	13	3½	1½

S.e.d. = Small end diameter

CF = Conversion factor

Merch. = Merchantable grade

Dress = Export Dressing grade; the bracketed figures are the extra percentage of boards which would come from Merchantable grade allowing tight encased knots.

IF = No. 1 Framing grade

IIF = No. 2 Framing grade

* = Factory grade which would otherwise be Box or Merchantable.
F1 = 66% or more in 2-ft clear cuttings.
F2 = 50% to 66% in 2-ft clear cuttings.

† = Results corrected to allow mean of 15 logs

‡ = Fourteen logs

was posted on blackboards in the mill to facilitate board numbering by the study team. Boards were lettered to enable them to be identified individually.

Sawing was done at the Timber Industry Training Centre Mill at Waipa, Rotorua. Cutting patterns for butt logs required 1 in. cutting until a defect appeared; the logs were then turned 180° and the process repeated. The remainder of the log was subsequently reduced to a cant of commercial width (if it had not been produced already) and conventional through and through sawing proceeded. Sawing of other log height classes generally followed the standard procedure for New Zealand exotic mill studies (Fenton and Fairburn, 1966). The cutting (all flat sawing) was largely on a vertical band headrig fed by a Pacific carriage. A circular breast bench resaw was used for edging and a small amount of resawing. All timber was docked normally and pieces less than 6 ft long discarded in grading results.

4. *Grading*

Full data were recorded as in the standard procedure given for grade studies (Fenton and Fairburn, 1966); these data included the grade (NZ Standards Institute, 1967). The procedure has been modified to record all clear lengths of 1 ft or more in units of 0.1 ft, the number of such clear cuttings per board, and the longest length of clears. Any upgrading from the recent pruning above 18 ft was ignored, the boards sawn being graded as if the appropriate defect was present. Two of the butt logs were found to have been pruned to 18 ft in 1959-60, and their grade out-turns could not be satisfactorily adjusted to allow for this; consequently results from these two logs are excluded. Six other butt logs had not been pruned to full length (18 ft) in 1950-51, but degrade due to the residual whorl was ignored. (In straight pruned logs, the defect core including occlusion in any one pruning lift is of greatest diameter at the bottom of the lift; so provided the logs maintained comparably straight axes there was no optimistic bias in assuming the same occlusion extent in the belatedly pruned whorl, as in the whorl immediately below it.)

The grading rules for export timber are more stringent than for the domestic market and as justification for forest expansion rests largely on export potential, the export grades or better have been used here. For example, while domestic Dressing grade accepts "two tight encased knots in pieces up to 12 ft long; three in longer with a maximum of $\frac{3}{4}$ in. in diameter", the grade is purportedly "for machining into weatherboards . . . to be usable in full length supplied" (NZFS, 1967)—mutually improbable specifications. The export "No. 1 grade" does not allow such tight encased knots. The amount of timber which would be graded in Merchantable, rather than Dressing grade is shown in Table 2. To avoid confusion between "No. 1 Framing grade" and "No. 1 export board grade" the convention "Export Dressing" grade has been used in this paper. Similarly Factory grade for export has to comprise 60% and not 50% of its length in 2 ft clears or longer; it has been found easier to estimate a 2/3 length (66%) in 2 ft clears, and the two grades of Factory are shown in Table 2 —Factory 1 comprising 66% or more in 2 ft clear cuttings; Factory 2 comprising 50% to 66%. Results have been given for both categories of Factory grade combined in the remainder of the paper.

Prices from the Waipa State Sawmill wholesale domestic price list as at May 1968 were used in value calculations; net amounts were used ($7\frac{1}{2}$% merchants' and $2\frac{1}{2}$% cash discounts being subtracted). Clears were valued at $2 per 100 bd ft gross above Dressing grade.

RESULTS

Seventy-four logs (another broke in felling) totalling 1,888 cu ft and yielding 12,700 bd ft of timber were used in the study. The results are given in Tables 2-12.

TABLE 3—Two-inch sawing results

Log Height Class (L.H.C.)	% of bd ft sawn per L.H.C.	Total vol. Bd ft	2 in. grades as % within framing grades Box	IF*	IIF*
Second	5.4	189	0	66	34
Third	15.6	359	12	65	23
Fourth	28.7	479	69	24	7
Fifth	41.4	323	22	41	37

* See notes to Table 2.

TABLE 4—One-inch sizes sawn, by percentages of each grade

Width:	Up to 6 x 1 in.		7 x 1 in. and over	
Length:	Up to 12 ft	Over 12 ft	Up to 12 ft	Over 12 ft
Butt				
Clear	14	18	10	58
Factory	1	5	0	94
Dressing (export)	1	9	5½	84½
Merchantable	2	3	1	94
Box	0	9½	0	90½
Second				
Factory	4	20	1½	74
Dressing (export)	4	10	0	86
Merchantable	2½	1	1½	90
Box	3	3	2	92
Third				
Factory	14½	16	4	65
Dressing (export)	15	8	7	70
Merchantable	4	14	3	79
Box	3	6	2	89
Fourth				
Factory	9	55	0	36
Dressing (export)	10	43½	0	46½
Merchantable	10	15	4½	70½
Box	6	8	3	85
Fifth				
Dressing (export)	57	43	0	0
Merchantable	20	42	4½	33½
Box	16	39	11	34

TABLE 5—Values; by grade and log height class

Log Height Class	% Value by L.H.C. and Grade						
	Box	Merch.	Dress (export)	Fact.	Clear	IF*	IIF*
Butt	5.7	5.5	11.6	32.3	44.6	0.3	—
Second	13.5	23.5	16.8	40.7	—	3.8	1.7
Third	21.1	44.1	10.7	17.3	0.4	5.2	1.2
Fourth	22.9	56.4	9.7	5.3	—	5.3	0.4
Fifth	19.9	36.2	3.3	—	—	23.1	17.5

* See notes to Table 2.

TABLE 6—Timber values per unit and overall

Log Height Class	% of total values	Per 100 bd ft ($)	Per cu ft (cents)
Butt	43.3	9.16	62.7
Second	26.5	6.94	51.5
Third	15.5	6.22	39.4
Fourth	10.0	5.55	34.7
Fifth	4.7	5.57	31.5
Overall	100	7.31	49.1

TABLE 7—Yields of clear cuttings*; percentages within grades

Log Height Class	From Grade					
	Box†	Merch.†	Factory	I & II Framing	Mean‡ of Total	Dressing (export)
Butt	67	69	85	(100)	82	92
Second	68	62	79	72	71	71
Third	56	61	76	66	62	67
Fourth	60	55	77	47	57	65
Fifth	48	50	—	36	44	75§

* With minimum yield of 1.0 ft, in units of 0.1 ft.

† Of boards which were free of pith.

‡ Excluding Dressing grade.

§ Only a total of 17 bd ft of Dressing grade is included.

TABLE 8—Finger jointing data; percentages of clear cuttings by L.H.C. in each grade

Log Height Class (L.H.C.)	From Grade Box*	Merch.*	Factory	Framing
Butt	4½	16	79	½
Second	15½	32	45	7½
Third	15½	55	19	10½
Fourth	14	74	6	6
Fifth	12	46	0	42

* Free of pith.

TABLE 9—Board-foot volume, and length per piece of clear cutting

Log Height Class	Grade					
	Box*	Merch.†	Factory	Framing	Total†	Dressing (export)
	(a) Board feet per piece of clear cutting					
Butt	1.32	1.45	3.56	-	2.84	3.35
Second	1.32	1.37	1.72	1.51	1.53	1.34
Third	0.93	1.14	1.57	1.23	1.19	1.20
Fourth	0.93	0.94	0.98	1.22	0.96	1.00
Fifth	0.63	0.69	0	0.90	0.74	0.63
	(b) Mean length in ft, per piece of clear cutting					
Butt	2.04	2.61	4.54	-	3.86	5.02
Second	1.98	2.00	2.77	2.50	2.37	2.29
Third	1.59	1.77	2.84	1.69	1.95	2.19
Fourth	1.80	1.67	2.78	1.69	1.78	1.98
Fifth	1.48	1.43	0	1.16	1.36	2.08

* Free of pith

† Excluding Dressing grade

TABLE 10—Major causes of degrade

Log Height Class	Percent of Log Height Class Degraded by			
	Large b.e.k.*	Small b.e.k.*	Cone holes	Pith
Butt	7.5	21.1	0	17.0
Second	25.9	34.8	2.2	11.3
Third	6.0	32.2	15.8	16.2
Fourth	0.4	28.8	33.2	20.7
Fifth	0	16.4	36.1	21.5

* b.e.k. = bark encased knots.

TABLE 11—Defect frequency or size

Log Height Class	Pith boards per log	Maximum*		Incidence per 100 bd ft	
		i.s.k. in.	b.e.k. in.	c.h.	s.b.e.k.
Butt	3.13	pruned		pruned	
Second	2.80	1.5	1.1	1	11
Third	2.86	1.7	0.9	7	13½
Fourth	2.43	1.6	1.0	24	10½
Fifth	2.33	1.6	—	67	8

* Mean of largest recorded from total number of logs.

i.s.k. = intergrown sound knots.

b.e.k. = bark encased knots (over 0.5 in.)

c.h. = cone holes.

s.b.e.k. = small bark encased knots (0.5 in. and under)

TABLE 12—Butt log clears yields in detail

D.b.h. o.b.	S.e.d. i.b.	Log deviation		Cant cut	C.f.†	Diam. core‡	Timber Clear	Timber Clear cuttings	Total C. + C.c.	Remarks
in.	in.	in.	at ft*	in.		in.	bd ft	bd ft	bd ft	
22.5	18.0	2.5	9	9	7.03	10.9	84.5	132.0	216.5	
21.2	16.5	1.0	9	10	6.34	§	Excluded			Late pruned
20.0	16.6	1.5	9	8	7.06	10.6	80.7	129.4	210.1	
26.0	20.1	0	0	7	6.87	§	195.3	103.3	298.6	
22.2	17.8	0	0	6	7.24	9.2	107.3	130.3	237.6	
24.3	19.0	1.5	9	9	6.33	10.6	78.0	131.0	209.0	Flute at butt end; 3 in. depth
22.1	18.2	0.5	9	7	6.72	§	87.4	130.5	217.9	
26.0	22.0	2.0	9	9	7.20	11.8	82.4	214.4	296.8	Minor whorl unpruned
22.3	18.0	3.5	7	8	6.73	11.4	68.6	138.7	207.3	
22.6	18.5	1.5	9	11	6.64	10.9	95.7	90.5	186.2	
22.4	18.0	§		7	5.88	8.6	101.2	86.9	188.1	Cant mis-sawn
22.6	17.5	0	0	10	7.12	§	Excluded			Late pruned
22.3	18.0	0	0	7	7.07	9.2	150.8	102.4	253.2	Very good form
24.6	20.3	1.0	9	9	7.05	9.6	114.7	158.1	272.8	
26.5	22.0	0	0	8	7.00	11.6	181.7	119.2	300.9	
18.0	14.6	0	0	7	6.07	9.1	27.0	84.0	111.0	
16.0	14.0	0	0	8	6.09	§	23.9	57.6	81.5	
21.0	16.0	1.5	9	6	6.02	9.2	80.0	71.5	151.5	
17.7	14.7	1.0	9	7	6.41	8.3	33.1	83.9	117.0	
19.9	15.0	0	0	9	6.03	10.4	34.2	84.5	118.7	
19.6	15.5	0	0	6	6.53	8.7	74.7	72.6	147.3	
15.8	12.5	1.5	5	6	5.42	7.6	22.0	47.3	69.3	
20.8	16.5	0	0	8	6.67	9.6	86.3	89.4	175.7	
16.4	13.0	0	0	8	6.97	§	54.5	54.8	109.3	
18.0	14.0	2.0 1.5	5 12	8	5.83	10.8	10.1	74.4	84.5	"S" kink
20.3	16.7	0	0	6	7.27	§	129.7	57.6	187.3	
21.0	17.5	§		6	6.62	§	75.2	118.6	193.8	Very good form
18.8	14.3	1.0	9	9	6.82	10.6	57.8	64.8	122.6	
18.3	14.0	1.5	9	7.5	6.39	11.1	21.1	104.4	125.5	
17.8	13.6	1.5	9	7	6.17	9.1	42.5	72.1	114.6	

From butt end

Conversion factor

Derived from reassembled logs after sawing. The diameter listed is of the cylinder required to include knots and occlusion defect over the whole log length; an appropriate allowance was made for saw kerf.

Not assessed

DISCUSSION OF RESULTS

1. Limitations

As the butt logs were pruned, their sawn conversion was exclusively to 1-in. timber (boards). The proportion of timber from which 2-in. (framing) data are available is limited, and largely confined to fourth and fifth logs. The recovery of wide (10 × 1 in. and 12 × 1 in.) boards was not as high as it could have been, largely due to an inexperienced mill crew. This has reduced total timber values. Similarly, the use of the domestic price list, and the more stringent Dressing grade defined also make the values conservative; and further, no increased price has been allowed for the superior Factory grade recoverable.

The clear wood yields—whether as full lengths, or re-cut clears—are not affected by these limitations.

2. Cubic Volume, Tree Form

The butt and second log volumes show marked differences in form to the pattern recorded in taper tables for unthinned stands (Duff, 1954). The net effect is a 10%-12% greater volume in the butt and second logs than for trees of the same d.b.h. and height from unthinned stands. Total merchantable stem volume was slightly (2.3%) higher. This redistribution of log volumes is desirable as the already favourable preponderance of values in the lowest log height classes is increased; these are the easiest log height classes to control silviculturally; and logging breakage is least in the lowest logs. The arguments for concentrating management on butt and second log characteristics (Fenton and Sutton, 1968) are reinforced.

3. Overall Grade Results

The results from 1-in. cutting are consistent with other studies (Fenton and Familton, 1961; Fenton, 1967), with the greatest concentration of Factory grade in the lower logs, decreasing up the tree. Much the same proportion (23%) of Factory grade was recovered as from earlier studies at Kaingaroa. The only truly uninodal second log produced 86% Factory grade (one sixth of the total Factory grade out-turn from this log height class) and had a gross value per 100 bd ft 24% above the average for all the second logs sawn.

Export Dressing grade, although only a tenth of the out-turn, was much more abundant than from the old (39 and 42 yr) Kaingaroa trees studied (Fenton, op. cit.), and this better recovery is probably due to the relative absence of bark encased knots in the younger stand studied here. (Full data on degrading defects will be published in further papers.) As in all other radiata pine studies, cone holes (strictly: stem-cone stem-holes) and small bark encased knots (of less than 0.5-in. diameter) precluded recovery of much Dressing grade from the higher log height classes; the net result is a high proportion of Merchantable grade from the top logs.

A limited amount of 2-in. timber was sawn. The high proportion (69%) of Box grade 2-in. in the fourth log was due to sloping grain in the largest log sawn to 2-in. timber. The other point of interest in this small sample is the relatively large percentage of No. 1 Framing grade produced despite the large branch sizes attained by these dominant trees. In the large diameter second and third logs the explanation appears to be that much of the framing was sawn in the chord between two branches, as in fig. 6 of Fenton, 1967. In the fourth and fifth logs, however, branch diameter was well above the maximum knot size recorded in the sawn timber, the logs being too small in diameter to have contained the maximum branch size. Further studies are required to define more precisely the interaction between knot size, knot distribution, log size, and Framing grade recovery.

4. *Clear Wood Yields*

Thirty-seven percent of the butt log timber was of "full-length" clears with a minimum board length of 6 ft. The yield of "full-length" clears by tree basal area class is shown in Fig. 1, which includes data from 15 small butt logs also taken from

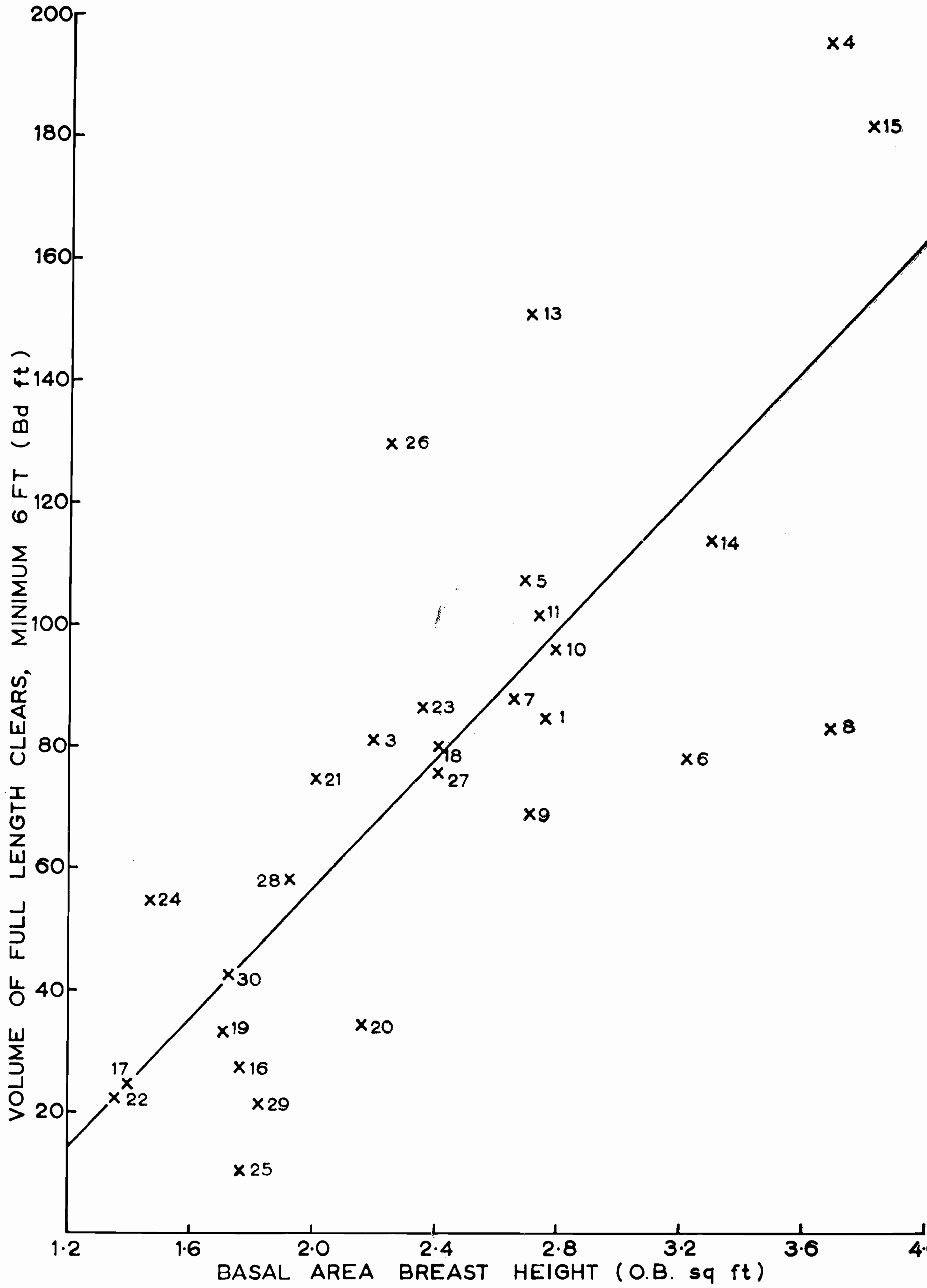

FIG. 1—Relationship between butt log size and "full-length" clears recovery.

the compartment. Variation of "full-length" clear yields between logs is considerable (Fig. 1) as, apart from log diameter, the clear yield depends on the diameter of the occluded core and its straightness, on final log straightness, log taper, sawn conversion factor, and degree of care in doing the pruning. Log length and cutting pattern can also affect "full-length" clear yield. Length was held constant for this study, and cutting pattern was constant for all except log 11.

Details of the pruned butts by tree d.b.h., log s.e.d., conversion factor, core

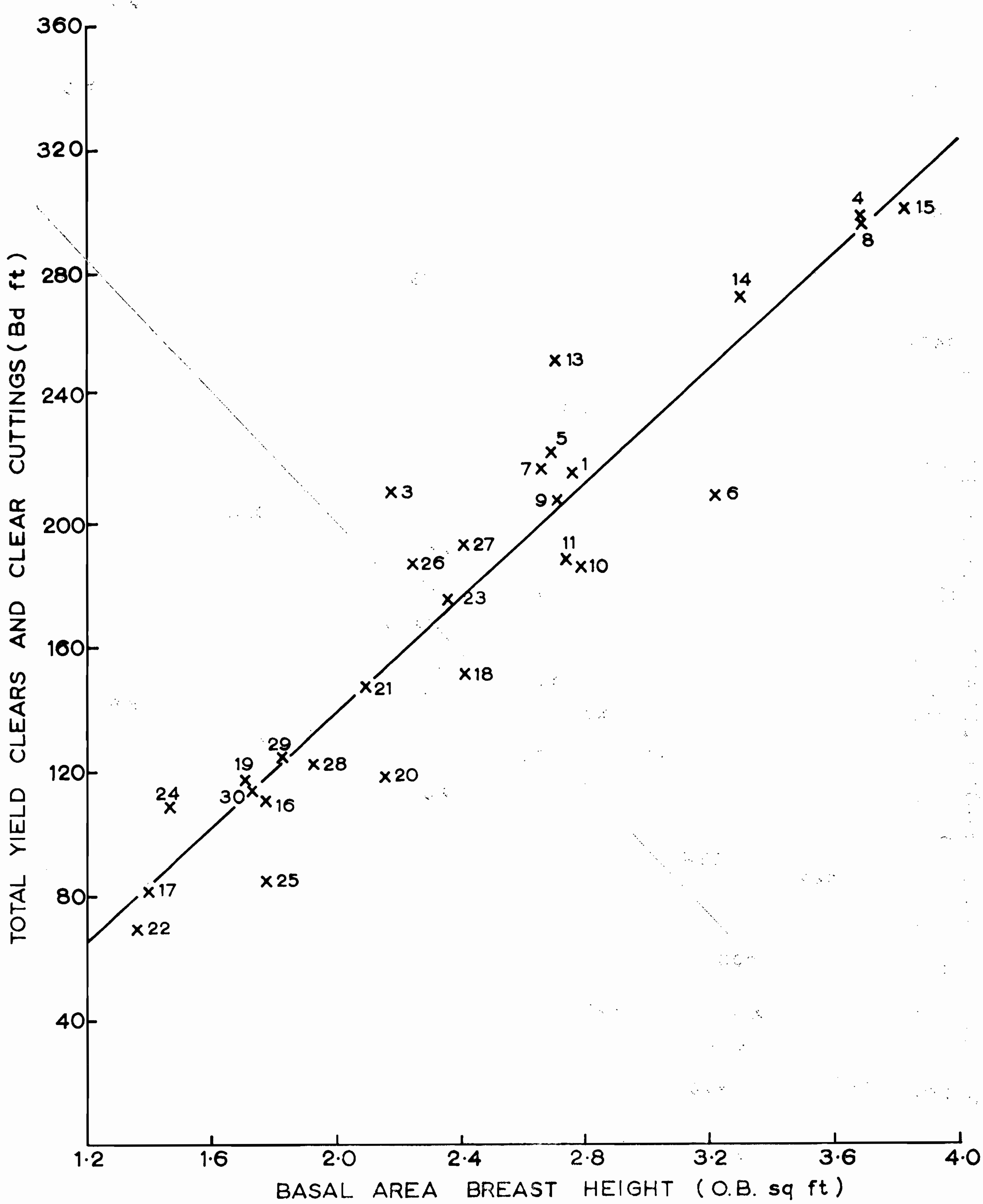

FIG. 2—Relationship between butt log size and "full-length" clears and clear cutting recovery.

diameters, cants sawn, clears and clear cuttings, and log deviations are given in Table 12.

The data (28 logs) are insufficient to warrant analysis for all these variables, but explanations can be given for some individual variations.

Log 8 (Fig. 1) included a whorl of small branches which was not removed in pruning; hence long lengths of clear cuttings, instead of full length clears, were produced; the yield of clears plus clear cuttings was about average for the tree size concerned (Fig. 2).

Trees 4, 24, and 26 were straight and gave above-average yields of clears, but the possibility remains that, as they were not originally pruned to 18 ft their clear yields have been increased by assuming the same clear wood radius as given by the highest correctly-timed pruned whorl. When clear plus clear cuttings are considered together, results are consistent with the general trend.

Trees 6, 18, and 25 were swept to some degree and had lower conversion factors than for other logs of comparable sizes. Tree 25 had an "S" kink; tree 6 was fluted Nevertheless by commercial mill standards, all logs were of "normal" form.

Tree 11 had a mis-sawn cant, and its conversion factor should have been equivalent to 6.25 and not 5.88 if corrections had been made for this.

The best result, relative to diameter, was from butt 13, termed "very good form" before sawing. The equation for Fig. 1 is:

Volume of full length clears in bd ft = 53.33 × tree basal area—50.21; (Basal area is in sq ft) (The correlation coefficient r = 0.795).

When clear-cuttings of 1.0 ft and over, in units of 0.1 ft, are added to the "full length" clear recovery (taken to the nearest foot only), variation is reduced and the relationship for Fig 2 is:

Volume of "full length" clears + clear cuttings (of 1.0 ft +) = 92.26 × tree basal area — 44.49; where basal area is in sq ft, and r = 0.94.

Thus silvicultural management directed towards recovery of "full length" clear boards is subject to considerable risk. Further, a relatively high (32%) proportion of the "full length" clears were 12 ft or less in length. Total clear recovery from butt logs is substantially increased when clear-cuttings are included, as in results elsewhere (Fenton, 1967; 1968).

The tabulated data on clear cuttings is for the information of finger-jointing plants. The yields of clear cuttings are illustrated by average length, and volume per piece of cutting in Figs. 3 and 4. Segregation of logs by log height classes is most worthwhile for the Factory and Dressing grade of the butt logs, as the mean length and volume of the clear cuttings is 50% to 100% greater than from unpruned, higher logs. While Box and Merchantable grades also yielded better sizes and lengths of clear cuttings in the butt logs, the differences were less marked. In pruned butt logs, the innermost boards are usually of Box grade, then Merchantable or Dressing further out from the pith; as pruning defects decrease in incidence with increasing distance from the core all grades give increasing recoveries of clear cuttings, and Factory grade yields rise. Ultimately full length clear boards are produced; the length of these full length clears

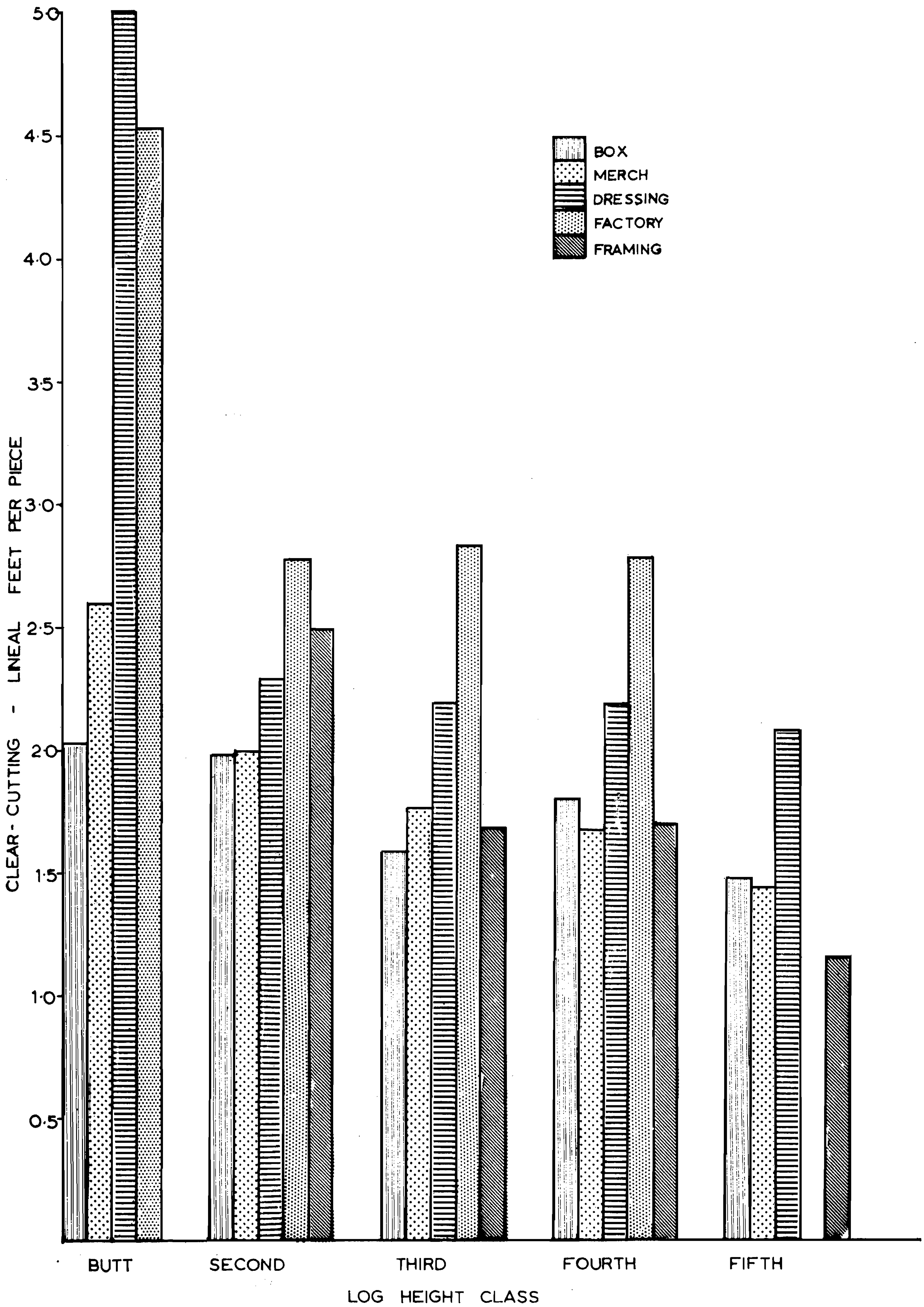

FIG. 3—Mean lengths of clear cuttings, by grades, for each log height class.

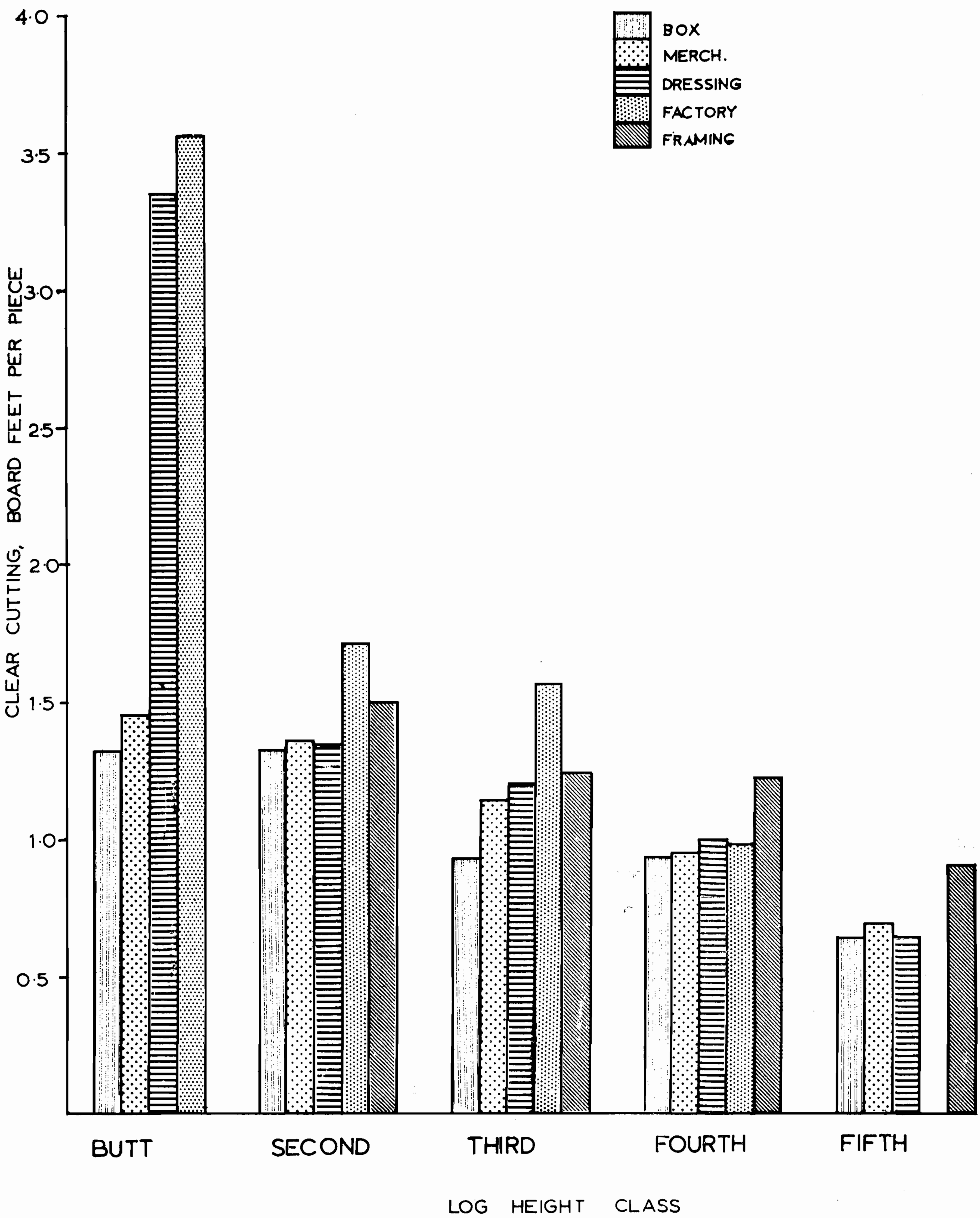

FIG. 4—Mean volumes of clear cuttings by grades, for each log height class.

then shortens as the outside limits of the log are reached, the shortest boards (in straight logs) coming from the flare in the lowest 4 to 6 ft of butt. This is shown by results for a butt log in Fig. 5.

The pattern of clear-cutting recovery in log height classes above the butt logs is consistent, with a general decrease in volume and length recovered in all grades up the tree, as in earlier studies (Fenton, 1967; 1968). The differences in relative clear-cutting yield between Box and Merchantable are small, although Merchantable grade

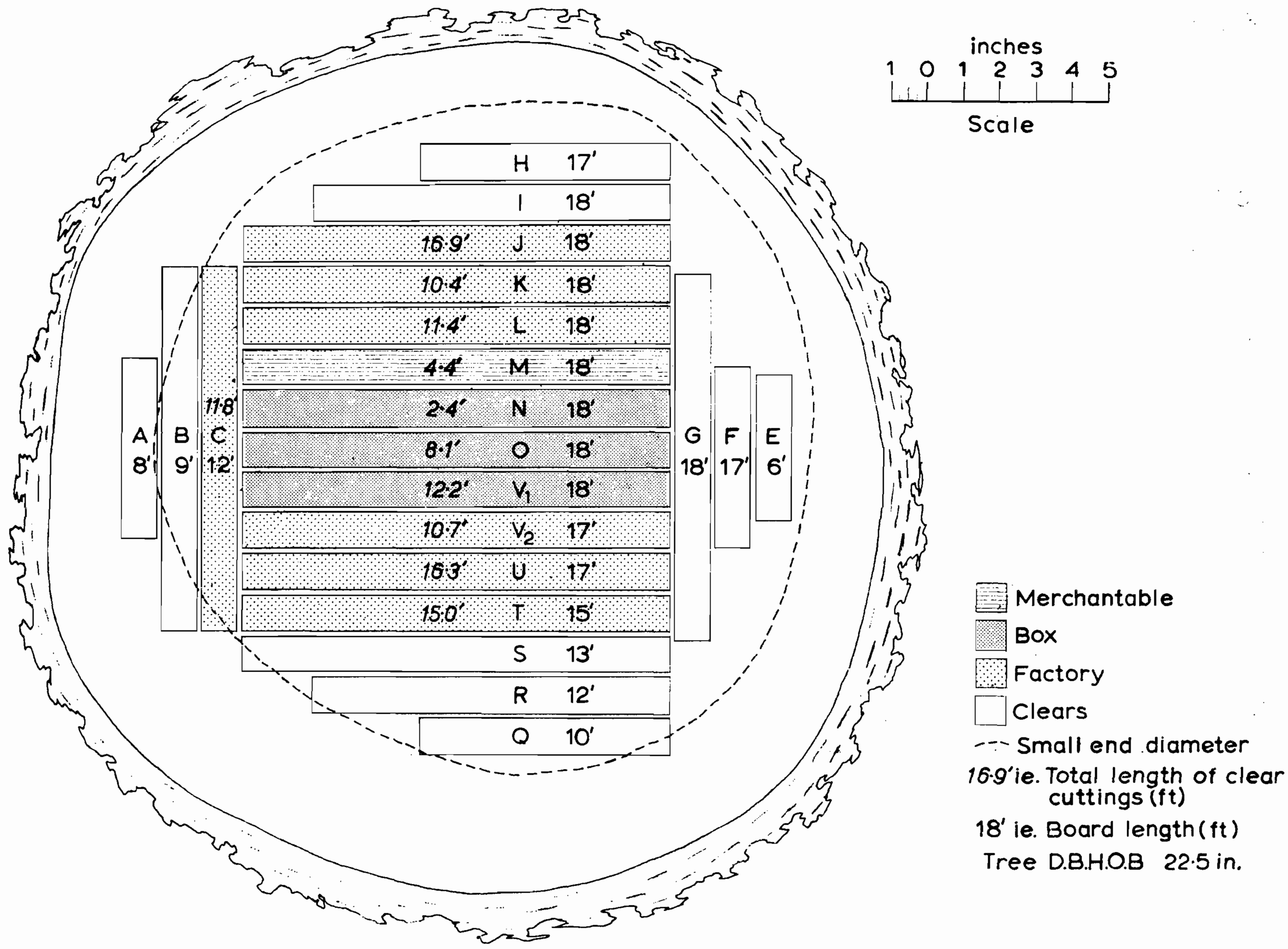

FIG. 5—Grade yield from a pruned butt log.

becomes of increasing overall importance (Table 8) as a source of clear cuttings. In older stands, however, where bark encasement would be more frequent, an increasing proportion would come from Box rather than Merchantable grade.

The recovery of clears is, therefore, heavily weighted to the butt and second logs, 45% of all the timber recovered being full length clears or clear cuttings from these log height classes.

5. *Defects*

Relatively full data are available on the incidence of defects in 39-42-yr-old radiata pine (Fenton and Familton, 1961; Fenton, 1967; Fenton, 1968) and some comparisons have already been made between these studies (Fenton and Sutton, 1968). With two exceptions the data in Tables 10 and 11 are consistent with trends in other studies.

The major difference is the relative absence of bark encased knots as the preponderant cause of degrade of 1-in. boards. Though encasement caused a quarter of all degrade of the second logs, its incidence was otherwise low. This is a reflection of the age of the stand (25-26 yr); of the fast growth rate of the predominant trees studied, and of the efficacy of pruning in preventing this degrade. However, pruning was still not early enough to reduce the incidence of encasement degrade to below 5%.

The second difference is the relatively high percentage of degrade (17%) caused by pith in the butt log; as 3.13 boards per log were affected, this is partly due to deviation from straightness in the trees' youth. The index of "boards per log" affected by pith, used in Table 11 is, like others in grade study results, not an absolute measure, and does not entirely reflect the early history of the tree. The index is affected by the way in which deviations in the final saw log straightness are accommodated at the sawmill. In this study, however, as in some earlier ones (Fenton and Familton, 1961; Fenton, 1967) the logs were sawn to the equivalent of cants in which the pith was centred as well as possible—i.e., the cutting was parallel to the pith rather than to the exterior of the log. This corresponds to current commercial practice. It is considered that the evidence for relatively poor stem straightness in the first 4 to 5 years' growth is reasonably clear. The stand studied had dense but not specified initial stocking from natural regeneration up to age 5-6 yr, when it was reported to be reduced to the equivalent of 4 ft × 4 ft spacing. The incidence of pith in butt log boards recorded in studies to date is now:

Spacing (ft)		
to 4 × 4, after regeneration thinning	3.13	
6 × 6 } Planted	2.84	(Fenton, 1967)
8 × 8 } Planted	2.54	(Fenton, 1967)

Further work is required on the relation, if any, of stem straightness in youth to initial spacing. None of the stands in question had comparable histories. All that is known with degree of certainty is that at very dense stocking (of 100,000 + per acre) by regeneration after fire, stem form is sufficiently wavy to preclude recovery of poles; but these are extreme stocking densities.

The full data on defects will be presented elsewhere; as will that on pruning occlusion, and kilning and dressing characteristics of knotty boards. The kilning and dressing characteristics of the full length clear wood produced here was excellent, whether dressed four sides, or given more elaborate shiplap profiles. Distortion was slight, and surface quality good.

The major cause of degrade in boards was of small (less than 0.5 in.) bark encased knots; which although less numerous than in the older timber sawn in other studies (Fenton, 1967) were more important here because of the absence of large encased knots.

Sloping grain should be noted. Few stands which have received any thinning have been sawn to date; and only limited 2-in. sawing was made in this study. The presence of sloping grain in one log of the limited sample sawn to 2-in. timber was sufficient to cause the drop in framing recovery in the fourth log height class.

6. *Values*

The values per 100 bd ft, and per cu ft generally decrease up the tree as the grades, widths, and conversion factors fall. Seventy percent of the gross values are in the butt and second logs; a proportion which would increase if values net of sawing and logging costs were allowed. The Box and Merchantable grades produced were of good (i.e., large) width and length specification, and would be more readily saleable than narrows, so their inclusion in overall results is unexceptional. The trees sawn are of considerable value on today's standards, and have been grown in 25-26 yr.

SIGNIFICANCE OF THE RESULTS

The grades and values given here are not those of the stand represented by Compartment 28, but are of 15 dominant trees, whose pruning to 18 ft has been adjusted to allow for pruning to that height at the average age of 9 yr. The pruning is late, and should have taken place 1-2 yr earlier. The preliminary stand assessment, and the difficulty of finding trees which had been pruned to *ca.* 18 ft by age 9-10 yr indicate that the results from the stand will be inferior to those recorded here. Evidently a large number of the 18-ft pruned stems had been removed in the production thinning at age 20 yr.

The grade study results are consistent with those of earlier studies for the relative volume of recovery by log height classes of Factory grade and for the incidence of pith, small bark encased knots and cone holes. The execution of relatively uniform grade studies on radiata pine has elucidated its pattern of defects and yields, at least for board grades. The studies have led to a board-grade regime being formulated (Fenton and Sutton, 1968) which is designed to get the maximum growth on the valuable butt and second logs.

The "board regime" proposed aims at producing the mean tree sawn here (23.4 in. d.b.h.o.b.) on a site index of 95 (Lewis, 1954) in the same time of 25-26 yr. The grade results from the study trees (or at least their butt and second logs) enabled realisations, and hence profitability, to be calculated for such a regime (Fenton, *et al.* 1968b) which showed a greatly improved profitability compared with current proposals (Fenton *et al.*, 1968a).

If the full potential for current domestic Dressing grade had been allowed, plus premiums for the improved Factory grade, realisations would have been further increased. (Some authorities maintain that considerable yields of No. 1 Framing could come from upper logs; if so, this would further enhance the "board regime".)

The marked increase in the log volume of the butt and second logs in this study when compared with those from the taper tables for unthinned stands, or current log volume tables, is important. An increase of 5 cu ft on the butt log, which is worth around 45c per cu ft net of sawing, hauling and logging costs, would increase land expectation values by $31 per acre, at 7% interest for one 26-yr rotation.

The use, or otherwise, of clear cuttings remains conjectural as finger jointing is currently limited to only four plants in New Zealand. There is a considerable body of opinion that Factory grade is not required, at least in large quantities. If this is correct, then much pruning effort is misplaced, as inevitably the first four to eight boards produced circumferentially after pruning are of Factory grade, and if the stem straightness and/or occlusion zone is abnormal, a greater radial increase than 4 in. would be required before "full-length" clears are produced. Both forest growers and industry should be fully aware that considerable quantities of Factory grade and finger jointing material are produced as the first results of pruning, and this occurs even with belated pruning if the logs are subsequently grown large enough (Fenton, 1967). If the short rotation regime (Fenton and Sutton, 1968) is adopted on half the 52,000 acres afforested annually, the yield of clear cuttings from the butt logs would be 80 (s.p.a.) × 43 (cu ft) × 6.5 (conversion factor) × 80% (yield of clear shorts) × 52% (ex Factory, Merch. and Box) or 9,300 bd ft per acre, totalling 240 million bd ft annually from butt logs and 8,800 bd ft per acre or 230 million bd ft annually from the second logs by 1996. In addition, there would be 8,270 bd ft per acre of "full-length" clears available (even with the imperfect pruning given the study trees) which would total 216 million bd ft annually.

There are far more difficulties in producing quality framing timber, at least from unimproved genetical stock, than are generally realised (Fenton, 1971), and the use of the clear cuttings to produce finger jointed studs is feasible, thereby restoring versatility to the short rotation regime, at the price of increased manufacturing costs.

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