PHYSICAL PROPERTIES OF CORSICAN PINE GROWN IN NEW ZEALAND

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ABSTRACT

The physical properties of Corsican pine (**Pinus nigra,** Arnold) were examined using increment cores and wood discs from 41 sites. Two main classes of stand were sampled:—

(1) Grown from seed imported from overseas in the 1920s; lots HO 26/1, HO 27/27 and HO 28/112.

(2) Second generation stands; i.e., from seed collected in New Zealand; lots NM 46/427 and NM 47/451.

Apart from the age differences between the two groups, variation between seedlots was found to be small, probably due to the fact that crops grown in New Zealand seem to be of mixed var. **calabrica** and var. **austriaca** origins.

Wood density was consistently higher than that found in other commercially grown exotic conifers, and outerwood densities were observed to decrease with increasing altitude and latitude. A strong correlation was found between outerwood density at breast height and tree mean density.

Resin content was very high, particularly in the heartwood, where it was over 20% in individual stems; this will affect the economics of pulping the older crops. However, heartwood development commences late and progresses slowly. Tracheid lengths were intermediate between those previously found for radiata pine and lodgepole pine.

INTRODUCTION

Corsican pine (*Pinus nigra* Arnold), was formerly considered in New Zealand to be one of the most promising species available as an alternative to radiata pine (*Pinus radiata* D. Don), especially on sites too harsh for the latter. Seed was imported mainly from Corsica through the British Forestry Commission until the late 1920s, but was found to have no advantage over seed from older stands of unknown seed source already existing in New Zealand. An increasing proportion of the State plantings consisted of Corsican pine up to about 1940, when 30% of the area planted was in this species. Since then, the proportion has steadily fallen off, due partly to increasing confidence in the monoculture of radiata pine, but mostly to the realisation that growth rates and disease resistance of Corsican pine are poorer than in many other commercial species.

The turning point in regard for Corsican pine came with the build-up of needle blight (*Dothistroma pini* Hulbary) in the early 1960s, when it was discovered that this species is susceptible to attack throughout its life, whereas radiata pine is only at risk

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up to about age 15. The planting of Corsican pine has now virtually ceased in State forests, apart from small amounts in parts of the Canterbury Plains, where conditions are too severe for radiata pine, and where needle blight is so far absent.

In established stands the various forms of Corsican pine seem to occur in all seedlots, which accounts for the lack of broad distinctive features between crops as can be seen in some other species. The var. *calabrica* form is predominant in most crops, although at least one of the imported seedlots has a high proportion of the more undesirable var. *austriaca* form (seedlot No. HO 27/27).

As at March 1971, the area of State forest under Corsican pine was 29,600 hectares, representing 10% of the total exotic forest area. Thus, within the next 50-60 years, considerable quantities of Corsican pine timber will be put on the market, and it is desirable to obtain information on the quality of this timber, with special reference to variations in physical properties.

Several factors limit the current uses of Corsican pine, notably the slow growth rate, resulting in produce of small diameter and the high resin content. Only from the best of the older crops can sawlogs be obtained, and much of the outturn is used at present for posts or pulpwood. The timber is unsuitable for pulping by the groundwood process on account of the high resin content which causes pitch problems during grinding. At present, Corsican pine is used commercially in the kraft process only in mixture with radiata pine. Laboratory tests confirm that it could be used to produce a chemical pulp of reasonable quality (J. M. Uprichard, pers. comm.) but it is regarded as being inferior to radiata pine as a pulping species.

OBJECT AND SCOPE OF THE STUDY

A survey was undertaken of the intrinsic wood properties of Corsican pine grown in New Zealand on a wide variety of sites (*see* Fig. 1). All the important seedlots were sampled at least once and intensive sampling of one widespread type was carried out to yield information on the variation of wood properties caused by altitude and latitude.

The main seedlots investigated can be grouped as in Table 1. Since seedlot numbers were not recorded prior to 1928, crops planted before this date are of unknown origin. Thus it is not possible to determine with certainty the origins of the New Zealand seed stands. The most widely planted seedlots in terms of geographical scatter are from

TABLE 1—Common New Zealand Corsican pine seedlots

	Seedlot	Origin
Imported	HO 26/1	Corsica
	HO 28/112	Corsica
	HO 27/27	Corsica
Collected in New Zealand	R 30/181 R 50/437 } and others from Whakarewarewa	Unknown
	NM 46/427 NM 47/451 } and others from Dumgree	Unknown
	Other South Island sources, e.g., Hanmer	Unknown

Dumgree, particularly NM 46/427 and NM 47/451, which can be found from North Auckland to Southland. Therefore these seedlots were chosen for the study of environmental effects on intrinsic wood properties, although their average age is only about 20 years compared with 40 years for the imported seedlots. The Dumgree seed stands, planted 1904-7, are known to contain varying proportions of the var. *calabrica* and var. *austriaca* forms with the result that seed collections from year to year may be genetically different.

A more comprehensive study of proverance characteristics will be possible when current extensive trials are more mature (Miller and Thulin, 1967).

METHODS

Since wood density is normally accepted as being the most useful parameter in wood quality surveys, this was the main property assessed at each site chosen for the study. Recent investigations (Cown, unpublished data) have established that the most efficient method of sampling the wood density variable, i.e., crop breast height mean and standard error, is to remove one increment core from each of 30 randomly selected trees per site. This procedure was used for most areas, other than Auckland and Rotorua Conservancies where the survey commenced and the previously used method of extracting two cores from each of 50 trees was employed. The main features of the survey were:

1. The selection of crops for sampling in the major State forests of New Zealand. In most cases, seedlot numbers were known, but where, as in Kaingaroa Forest, large areas were planted before 1928, stands of unknown seed origin were chosen.
2. The collection of one breast height increment core from each of 30 randomly selected trees on each site (with exceptions as above), avoiding severely malformed stems. In the laboratory, the outer 10 growth rings were removed, measured for width, and basic density estimated using the maximum moisture content method (Smith, 1954).
3. On the basis of the above preliminary survey, five sample trees were chosen on each of five North Island sites to allow intensive study of within-tree variations in wood properties. These trees were stratified with respect to wood density and stem diameter, i.e., one of high density, one of low density and three with about average density, and whose mean diameter was within ± 10 mm of the crop mean diameter.
4. Discs were collected from every fifth internode of the selected sample trees and used for detailed measurement of physical properties and resin content according to the method used by Harris (in press).
5. At selected South Island sites, five 10-mm increment cores were collected from stems stratified for diameter (as for density in 3 above) to provide material for densitometric studies. This was a compromise between the felling of trees and transport of sample discs on the one hand, and the complete disregard of information on the within-tree variations on the other hand. The data thus obtained were treated so as to be directly comparable with the densitometric data from the North Island sample sites.

6. Tracheid length measurements were taken for growth rings Nos. 2, 10, and 25 from the pith at breast height level (1.37 m) in all sample trees and at the 15th and 25th internode levels in trees from site 12. Additional breast height samples were taken from some of the 10-mm cores from South Island sites.

RESULTS

Fig. 1 and Table 2 give details of all the stands sampled and indicate those from which sample trees were selected and those from which 10-mm increment cores were taken.

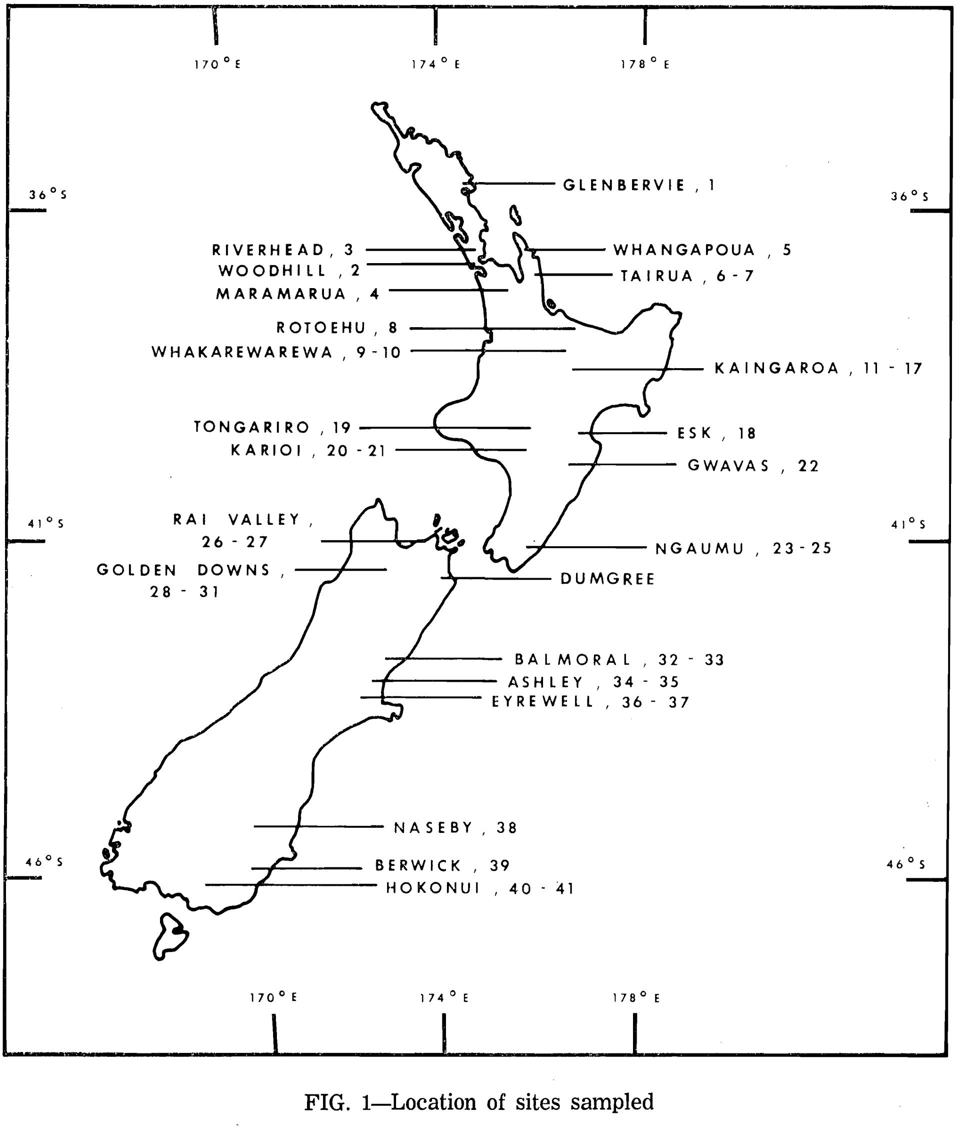

FIG. 1—Location of sites sampled

TABLE 2—Details of sample crops

Site No.	Forest	Cpt	Age Yr	Latitude °S	Altitude m	Seedlot	Seed Source	Thinning Yr or Unthinned (-)
1	Glenbervie	14	21	35.6	170	NM 47/451.	Dumgree	-
2	Woodhill	97	28	36.6	70	Unknown		-
3	Riverhead	22	41	36.7	130	HO 26/1	Corsica	-
4	Maramarua	29	40	37.2	70	R 30/181	Whakarewarewa	-
5	Whangapoua	2	22	36.8	20	NM 46/427	Dumgree	-
6	Tairua	135	39	37.1	280	HO 28/112	Corsica	-
7	Tairua*	144	21	37.2	30	NM 47/451	Dumgree	-
8	Rotoehu	27	26	37.9	230	NM 39/310	Dumgree	-
9	Whakarewarewa	17	62	38.2	370	Unknown		1941, 1951-63
10	Whakarewarewa	18	59	38.2	800	Unknown		1952-56
11	Kaingaroa	1109	57	38.3	600	Unknown		Thinned
12	Kaingaroa*	1115	46	38.4	600	Unknown		-
13	Kaingaroa	76	42	38.5	390	Unknown		-
14	Kaingaroa*	381	41	38.6	500	HO 26/1	Corsica	1955
15	Kaingaroa	427	41	38.7	620	HO 26/1	Corsica	
16	Kaingaroa	550	37	38.7	700	R 30/181	Whakarewarewa	-
17	Kaingaroa*	647	37	38.8	820	R 30/181	Whakarewarewa	-
18	Esk+	3	19	39.2	470	NM 46/427	Dumgree	-
19	Tongariro+	4	22	39.1	920	NM 46/427	Dumgree	-
20	Karioi	21	16	39.4	850	R 50/437	Whakarewarewa	-
21	Karioi	30	41	39.4	870	HO 28/112	Corsica	1958-59
22	Gwavas	3	20	39.7	530	NM 47/451	Dumgree	-
23	Ngaumu+	2	22	41.2	300	NM 46/427	Dumgree	1967-68
24	Ngaumu*	9	20	41.2	300	NM 47/451	Dumgree	1969-70
25	Ngaumu	16	16	41.2	320	R 50/437	Whakarewarewa	-
26	Rai Valley	4	21	41.2	170	NM 46/427	Dumgree	-
27	Rai Valley+	8	18	41.2	270	NM 47/451	Dumgree	-
28	Golden Downs	15	41	41.5	380	HO 26/1	Corsica	-
29	Golden Downs	50	39	41.5	470	HO 28/112	Corsica	1958
30	Golden Downs	62	40	41.5	570	HO 27/27	Corsica	-
31	Golden Downs+	97	21	41.5	400	NM 46/427	Dumgree	1967
32	Balmoral	10	43	42.8	330	Unknown		-
33	Balmoral+	26	17	42.8	270	C 51/236	Hanmer	-
34	Ashley+	8	22	43.2	300	NM 46/427	Dumgree	-
35	Ashley	20	20	43.2	380	C 47/183	Hanmer	-
36	Eyrewell	29	39	43.4	150	C 29/78	Hanmer	-
37	Eyrewell+	44	41	43.4	130	HO 26/1	Corsica	-
38	Naseby+	2	18	45.0	670	NM 48/494	Dumgree	-
39	Berwick+	52	19	45.9	130	NM 47/451	Dumgree	-
40	Hokonui	3	40	46.1	50	HO 26/1	Corsica	-
41	Hokonui	14	39	46.1	50	HO 28/112	Corsica	-

* Sample trees felled in these compartments

+ 10-mm increment cores taken

Table 3 summarises the stem and growth characteristics of the trees felled for intensive examination of wood properties. The figures for the heights from which the sample discs were removed (internodes 5, 10, 15, etc.) give the approximate height increments at 5-yearly intervals.

Three of the sites represent three different seedlots (HO 26/1, R 30/181, and one unknown) from the central North Island pumice lands, whereas the other two represent the same seedlot (Dumgree NM 47/451) growing at opposite ends of the North Island. Site 17 (R 30/181) has the poorest height increment of the Kaingaroa sample crops, but is growing at a much higher altitude (*see* Table 2). Of the two crops of Dumgree seed source, site 7 has by far the poorer growth rate. In broad terms, the figures show a trend of increasing height growth rate with increasing latitude within the North Island which confirms the visual impression gained from visiting the sites.

TABLE 3—Average stem and growth characteristics of felled sample trees

Site No.	Total Height	D.b.h. O.b.	% Live Crown	Height (m) to centre of internode above stump					
	(m)	(mm)		5	10	15	20	25	30
7	11.4	206	73	1.6	4.8	7.8			
24	14.4	204	54	1.5	5.7	9.9			
12	25.5	327	33	2.2	5.7	8.9	12.5	15.9	18.9
14	22.1	393	53	2.0	5.1	8.6	12.1	15.2	18.1
17	17.2	306	48	1.5	4.0	7.1	9.9	12.9	

Wood Density

The results of the initial wood density survey using increment cores are presented in Fig. 2. The site means, standard errors and ranges shown refer to the density of the outer 10 growth rings at breast height. Fig. 3 shows the actual relationship determined between average stem density to 100 mm i.b. and outerwood density at breast height for the 25 trees felled. There is obviously a fairly close correlation between the two sets of measurements, not only over all sites ($r = 0.896$) but also within sites. Thus there is ample justification for using breast height density as a parameter of crop density.

Fig. 2 shows there is considerable variation between and within seedlots and sites. However, two definite effects can be identified, due respectively to (a) environmental factors and (b) age effects. Since the sites are numbered more or less according to latitude there are clearly distinct trends in wood density from north to south. These relationships are not linear, as density falls off with increasing latitude down to about 40°S, then tends to remain at the same level or even increase slightly southwards. Deviations from the observed latitudinal trends can be related to both crop age and altitudinal effects.

Figs. 4a and 4b show the variation in wood density as affected by altitude and latitude for the two major groups of seed sources (and hence age groups). In both cases

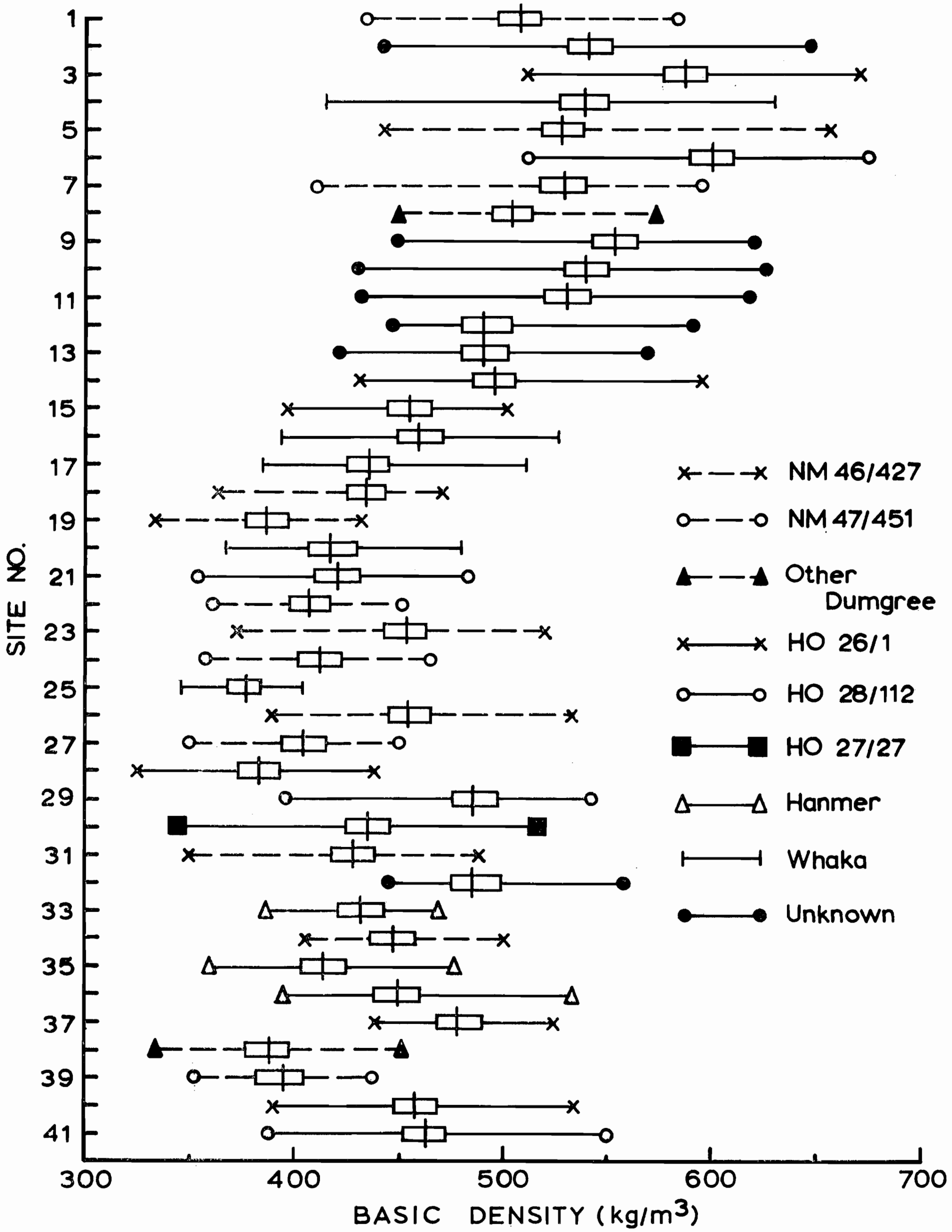

FIG. 2—Wood density parameters for the outer 10 growth rings at breast height (1.4 m) for each stand, showing the mean value (vertical line), range, and two standard errors on either side of the mean (boxes).

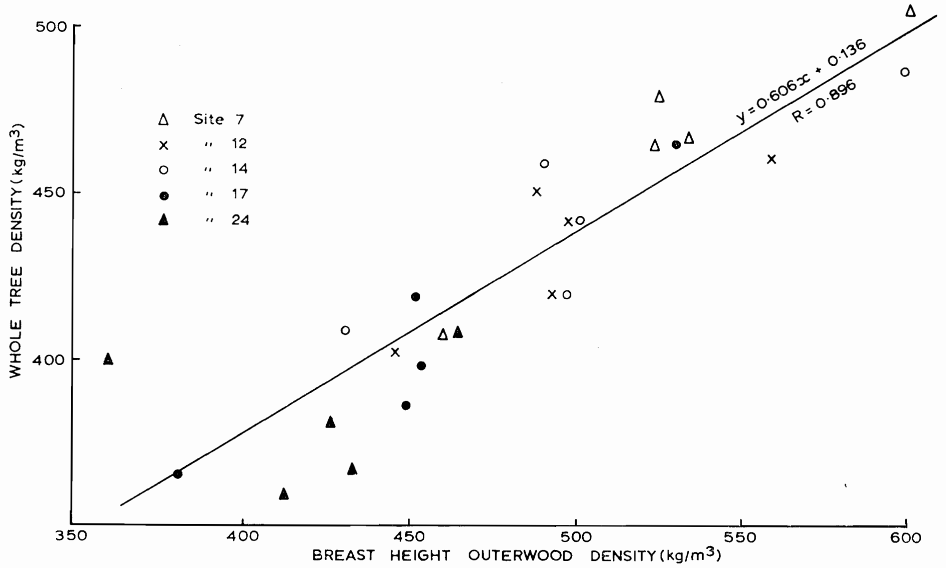

FIG. 3—Relationship between increment core density (outer 10 growth rings) at breast height and the weighted mean density of the tree stem to 100 mm diameter i.b.

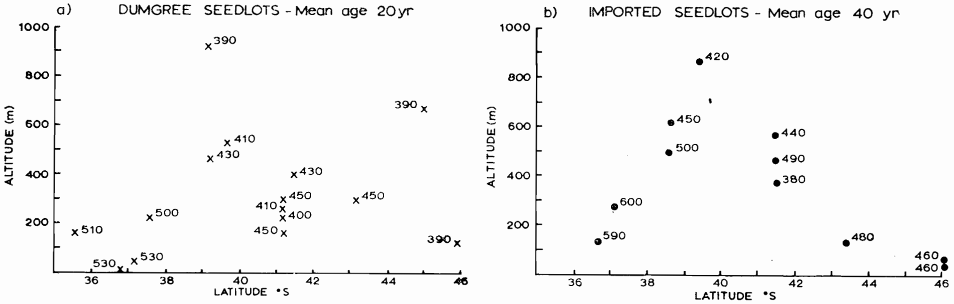

FIG. 4—Effect of altitude and latitude on outerwood density (kg/m³).

the pattern is the same, i.e., decreasing density with increasing altitude and latitude. On the basis of these trends it can be calculated that, neglecting site factors such as soil type and exposure, the fall off in mean outerwood density is about 15 kg/m^3 per degree of latitude irrespective of crop age. The effect of altitude increases with crop age. Thus at 20 years the decrease in outerwood density is about 15 kg/m^3 per 100 m, whereas at age 40 years the corresponding figure is 20 kg/m^3. These latter estimates depend on the assumption that there are no major differences in response to altitude between the two groups. Similar latitudinal and altitudinal effects were found by Harris (1965) when radiata pine crops were sampled throughout New Zealand.

Details of basic, air-dry and green densities of individual sample trees are given in

Table 4, and in Table 5a the radial trends in basic density are presented. The figures show only minor differences in density between four of the crops sampled, but that of site 7 stands out as being greater than the others. Since the seedlot numbers of sites 7 and 24 are identical, the contrasts in wood properties must be attributable primarily to environmental effects.

Differences in density between crops can best be demonstrated by means of densitometer records which allow measurement of three important growth ring properties, i.e., earlywood minimum density, mean density, and latewood maximum density. When these figures are plotted against distance from the pith, a very good graphical presentation of the components of density variation is obtained. Such charts were prepared for the

TABLE 4—Mean physical properties of felled sample trees

Site no.	Tree volume	Heart-wood	Weighted mean density kg/m^3			Percentage shrinkage from green to air dry (12%)				to oven dry				Moisture content %
	(m^3)	(%)	Basic	Air dry	Green	Vol.	Tan.	Rad.	Long.	Vol.	Tan.	Rad.	Long.	
7	0.14	0.3	465	556	1021	6.1	4.3	3.1	0.00	11.0	7.1	4.7	0.13	121
24	0.17	1.1	384	452	1027	4.9	3.8	2.5	-0.04	9.7	6.4	4.0	0.19	168
12	0.75	9.1	435	535	1047	8.9	4.3	2.0	0.11	12.4	8.0	4.1	0.29	141
14	1.01	4.5	444	534	1056	5.5	4.6	2.4	0.50	10.0	7.8	4.3	0.89	139
17	0.45	6.9	407	480	1015	5.3	4.3	1.5	0.10	8.7	6.7	2.6	0.24	152

TABLE 5—Variation in wood properties from pith to bark

Site No.	Growth ring numbers from pith					
	1-5	6-10	11-15	16-20	21-25	26+
(a) Variation in basic density (kg/m^3)						
12	480	410	440	460	500	530
14	440	410	450	480	510	530
17	420	380	410	460	480	
7	390	480	540			
24	360	410	430			
(b) Variation in ring width (mm)						
12	6.8	5.8	4.0	2.4	1.3	1.3
14	6.8	6.7	5.3	4.6	3.2	2.3
17	5.9	5.6	4.4	2.8	1.6	
7	6.9	5.4	3.8			
24	7.6	5.0	3.7			
(c) Variation in latewood (%)						
12	16	21	29	34	35	37
14	14	23	32	40	40	43
17	12	18	25	35	38	
7	23	48	52			
24	18	32	34			

TABLE 5—Contd. Variation in wood properties from pith to bark

Site No.	Growth ring numbers from pith					
	1-5	6-10	11-15	16-20	21-25	26+
(d) Variation in latewood ratio (mean minimum and maximum densities shown in brackets)						
12	.34 (388-718)	.34 (300-724)	.38 (294-752)	.39 (334-712)	.45 (390-636)	.45 (465-656)
14	.31 (330-654)	.34 (276-702)	.36 (266-774)	.43 (292-820)	.45 (368-750)	.42 (422-835)
17	.36 (350-554)	.37 (312-600)	.36 (300-676)	.41 (326-716)	.43 (380-668)	
7	.36 (342-620)	.38 (350-824)	.44 (384-924)			
24	.43 (312-582)	.35 (308-718)	.39 (334-712)			
27	.37 (352-568)	.33 (296-634)	.38 (308-744)			
39	.37 (332-550)	.32 (300-640)	.38 (334-664)			
37	.39 (388-576)	.35 (324-622)	.37 (350-638)	.38 (366-644)	.46 (406-610)	.44 (423-630)
(e) Variation in volumetric shrinkage from green to air-dry (%)						
12	8.0	8.7	9.6	10.0	11.6	9.5
14	4.3	4.9	5.3	6.3	7.3	6.8
17	4.2	4.2	5.6	6.5	7.3	
7	5.0	6.7	7.7			
24	4.1	5.3	6.4			
(f) Variation in tangential shrinkage from green to air-dry (%)						
12	3.1	4.1	4.7	4.9	5.1	6.0
14	3.8	4.3	4.3	5.1	5.1	5.3
17	3.1	4.1	4.9	5.2	5.5	
7	3.4	4.8	5.6			
24	2.9	4.5	5.1			
(g) Variation in radial shrinkage from green to air-dry (%)						
12	1.8	1.5	1.8	2.7	2.9	3.1
14	1.8	1.9	2.3	2.9	3.8	3.6
17	1.5	1.2	1.4	1.4	2.0	
7	2.8	3.3	3.7			
24	2.0	2.9	3.1			

(h) Correlations between properties

D = 529 — 16.91 RW r = -0.648 * * *
D = 350 + 3.36 LW r = 0.736 * * *
D = 180 +700.58 LR r = 0.589 * * *
LW = -37 +173.35 LR r = 0.666 * * *

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* * * = Significant at the 99% level
D = Basic density, kg/m^3
RW = Ring width, mm
LW = Percentage latewood
LR = Latewood ratio

felled sample trees and also for selected crops in South Island from which 10-mm increment cores were collected. All charts can be compared directly to quantify differences in density development attributable to genetic or environmental factors.

However, certain deficiencies in the Beta ray method used (Harris, 1969) are brought out when dealing with very narrow-ringed material such as the outerwood portions of the older crops sampled here. With sites 12 and 17 in particular, the 0.5-mm scanning beam is being used on rings less than 2 mm wide (Table 5b) and any deviation from the vertical in the wood grain will reduce resolution of density variations considerably. The result is that the mean within-ring range of densities appears to decrease with distance from the pith. Experience with the apparatus has shown that this is an artifact which must be recognised when dealing with samples which contain narrow growth rings.

Figs. 5a, 5b, 5c, 5e, and 5f represent the five North Island sites and Figs. 5g and 5h are of seedlot NM 47/451 respectively from Rai Valley and Berwick. Fig. 5d gives the results from a crop of seedlot No. HO 26/1 from Eyrewell Forest. Thus Figs. 5e, 5f, 5g, and 5h show the density characteristics of one seedlot widely planted throughout the country; Figs. 5c and 5d allow comparison of seedlot HO 26/1 at two very different sites.

Of the Kaingaroa crops (Figs. 5a, 5b, and 5c), sites 12 and 14 display very similar density patterns, i.e., the mean and earlywood minima decrease slightly for the first 10 rings or so from the pith, then tend to increase out to the bark. The latewood maxima increase gradually with distance from the pith to about 20 rings from the pith after which the above-mentioned effects of ring width start to occur and invalidate further crop comparisons. However, the observed trends appear to be similar to those reported for lodgepole pine (Harris, 1973).

Figs. 5e, 5f, 5g, and 5h show the effects of environment on the wood density development of seedlot NM 47/451. All three measured parameters display a clinal decrease from site 7 to site 39, and in fact the mean densities for site 7 are almost equivalent to the latewood maxima for site 39. The gradient in latewood density with distance from the pith also appears to decrease with increasing latitude. Outerwood densities from sites 14 and 37 were very close (Fig. 2) but a comparison of Figs. 5c and 5d shows that the range of densities within growth rings is greatly reduced at the Eyrewell site due to a combination of higher earlywood and lower latewood values. Thus environmental factors can affect wood density by influencing either earlywood or latewood production.

There is no evidence of major differences between seedlots in wood density patterns due entirely to genetic constitution, which suggests that either (a) there is little variation among the natural populations of Corsican pine, or (b) the seed imported into New Zealand all came from similar populations. Detailed study of established provenance trials (Miller and Thulin, 1967) should enable firm conclusions to be drawn. However, differences in wood density between crops to be marketed in the near future are clearly due more to environmental factors than to genotypic variation.

The vertical distribution of mean cross-sectional wood density was examined in the sample trees felled. The pattern varied somewhat between individual trees but was very similar between compartment means. In all cases, mean density decreased with increasing height in the stem, and the gradient per unit length becomes less marked as the trees

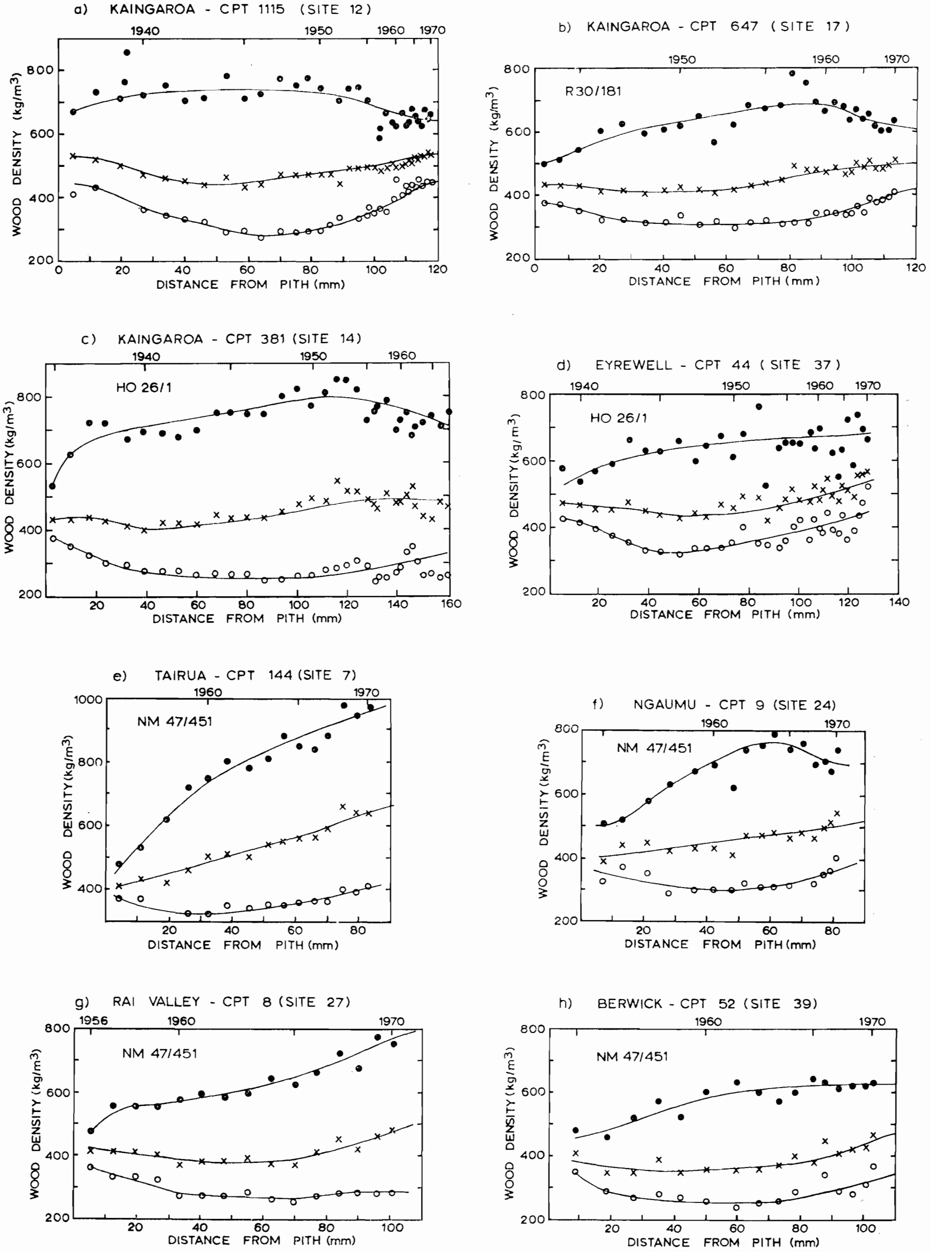

Fig. 5 Radial patterns of wood density variation. The upper line represents the maximum (latewood) density, the centre line weighted mean density, and the lower line minimum (earlywood) density of each growth ring.

a, b, Sites 12 and 17
c, d, Sites 14 and 37
e, f, Sites 7 and 24
g, h, Sites 27 and 39

grow older and the effects of density variation within the corewood becomes less influential.

The wood density values determined in this study are consistently higher than previously established figures for other commercial exotic species in New Zealand.

Radial Growth Rates

Corsican pine has a reputation in New Zealand for being a slow-growing species, especially in Auckland Conservancy where most crops have a stunted appearance. The bulk of the older stands are in the Rotorua area and have not been tended to attain maximum growth rates, and in fact, most stands in Kaingaroa Forest have remained unthinned for 40 years or more.

Table 5b gives the radial variation in ring width for the areas sampled. Sites 12 and 17 have received no thinning, and ring width diminishes rapidly after the first 15 years or so. Site 14 was thinned at age 26, and the canopy had still not closed completely 15 years later. Ring widths show a definite increase over the unthinned crops but it is clear that even under optimum conditions radial growth rates will be slow compared with radiata pine. However, Corsican pine can compensate for this to some extent by maintaining very high stockings and consequently high volumes per acre up until at least the age of the oldest crops in the Rotorua region, i.e.,*ca.* 60 years.

The figures in Table 5b indicate that the initial growth rates are very similar between sites, independent of seedlot or site factors.

Effect of Radial Growth Rates on Wood Density

The effect of radial growth rate *per se* on wood density can be examined by determining the relationships between the width of the outer 10 growth layers at breast height (the length of the sample core) and the basic density of the same 10-ring sample both within and between sites. Table 6 presents the results of such a study. The Dumgree seedlots and the imported seedlots have been separated in this analysis because of the large difference in age between the groups.

From Tables 6a and 6b it is obvious that although statistically significant relationships can be found for some sites, the variation between sites is such that the overall regression is not significant. Thus it must be concluded that in general no significance can be attached to the correlation between density and growth rate *per se,* and that crops can be grown as fast as is otherwise desirable without adversely affecting the intrinsic timber strength.

When the basic density figures in Table 5a are correlated with the ring width values in Table 5b, a highly significant negative regression is found, indicating that ring width as a whole (as distinct from radial growth rate in the outer rings) is a reasonable guide to density class. This relationship is largely fortuitous owing to the presence of low-density, wide-ringed corewood, and is applicable to most conifers prior to the onset of heartwood formation.

Latewood

Percentage latewood values as measured by the blunt probe method (cited by Harris, 1965) are summarised in Table 5c for the North Island sample sites. Between-seedlot variation is minimal among the Kaingaroa compartments, but significant differences are

TABLE 6—Effect of growth rate on wood density of the outer 10 growth layers at breast height

Site No.	Mean *D	Mean L†	No. of trees	Regression	Correlation coefficient, r
(a) Dumgree seedlots (mean age, 20 yr)					
1	509	43	50	D = 572 — 1.449 L	—0.496
5	530	37	50	D = 623 — 2.169 L	—0.599
7	531	44	50	D = 483 + 1.166 L	0.199
18	434	45	30	D = 470 — 0.878 L	—0.360
19	386	30	30	D = 438 — 1.686 L	—0.410
22	407	53	30	D = 427 — 0.372 L	—0.186
23	455	41	30	D = 423 + 0.780 L	0.167
24	412	44	30	D = 466 — 1.215 L	—0.444
26	455	38	30	D = 487 — 1.003 L	—0.186
27	404	64	30	D = 372 + 0.037 L	0.191
31	429	37	30	D = 459 — 0.797 L	—0.216
34	447	34	30	D = 449 + 0.054 L	—0.015
38	386	21	30	D = 372 + 0.271 L	0.065
39	383	56	50	D = 414 + 0.370 L	—0.200
All sites	441	42	480	D = 454 — 0.338 L	—0.072
(b) Corsican seedlots (mean age, 40 yr)					
3	592	17	50	D = 504 + 3.619 L	0.504
6	604	13	50	D = 591 + 0.473 L	0.053
14	498	30	50	D = 505 — 1.500 L	—0.240
15	455	19	50	D = 459 — 0.130 L	—0.024
21	422	18	30	D = 449 — 1.192 L	—0.410
28	383	18	30	D = 406 — 1.261 L	—0.210
29	488	20	30	D = 512 — 1.189 L	—0.250
30	436	18	30	D = 429 + 0.416 L	0.074
37	480	51	30	D = 492 — 0.739 L	—0.170
40	459	21	30	D = 494 — 1.624 L	—0.368
41	465	21	30	D = 506 — 1.930 L	—0.375
All sites	480	22	410	D = 494 — 0.593 L	—0.093

* D = Basic density of outer 10 growth layers at breast height (kg/m^3)

† L = Radial width of outer 10 growth layers at breast height (mm)

apparent between the two Dumgree seedlots. This indicates that some unidentified environmental factor could be important in influencing latewood production.

Since no sample trees were felled in the South Island, comparable figures are not available. However, crops from which 10-mm cores were taken can be assessed for 'latewood ratio"; a concept developed by Harris (1969) for describing density variation within growth rings from densitometer data. Table 5d contains latewood ratio values for the five North Island sites and three South Island sites. Thus sites 7, 24, 27, and 39 represent crops of similar genetic constitution, as do sites 14 and 37. As with wood density, site 7 tends to have higher latewood readings than the other areas.

Very little variation is found in latewood ratio values among the crops thus sampled, and this is interpreted as being indicative of a fairly uniform production of latewood between sites. However, the densitometer charts for the Dumgree seedlots (Figs. 5e, 5f, 5g and 5h), and show a decrease in latewood density with increasing latitude, which is not accounted for in the measurement of latewood percentage or latewood ratio.

Table 5h demonstrates highly significant correlations between wood density and both latewood percentage and latewood ratio, although the relationships are of limited value for predictive purposes ($R^2 = 54\%$ and 35% respectively).

Heartwood

The heartwood content of Corsican pine stems is much less than that of most other commercial exotic conifers. Initiation of heartwood development does not occur until the trees are 25 to 30 years old, and by 40 years, less than 10% of the timber can be classified as heartwood (Table 4). According to Saliceti (1926), it takes about 360 years to develop 65% heartwood in Corsica.

No major differences can be detected between seedlots in heartwood percentage, although it is not possible to estimate the rate of heartwood formation in the Dumgree seedlots since none of the crops sampled is at a sufficiently advanced age.

Resin Content

Table 7 gives the mean resin content of heartwood and sapwood samples from the felled trees. Variability occurred within sites, and the small differences in mean values between crops of similar age (Nos. 12, 14, 17, and Nos. 7 and 24) cannot be considered as being significant.

TABLE 7—Percentage resin content (methanol extractives)

Site No.	Resin content %		
	Heartwood	Sapwood	Mean
12	16.1	4.6	5.6
14	16.6	5.0	5.5
17	19.7	4.3	5.4
7		3.3	3.3
24		3.5	3.5

Heartwood resin contents are extremely high compared with figures obtained for radiata pine (J. M. Harris, pers. comm.) and lodgepole pine (*Pinus contorta* Dougl.) (Harris, 1973), but the very small percentage of heartwood present in the sample trees results in mean figures little higher than the sapwood values. The two Dumgree crops (sites 7 and 24) show significantly lower sapwood resin contents, but this could very likely be an effect of age rather than inherent difference. These crops are 4° apart in latitude and exhibit large differences in wood density (Table 4) but are practically identical in resin content.

The results suggest that resin content is not genetically variable between the seedlots sampled, and is not influenced by site to any great degree.

The exceptionally high resin content of the heartwood will result in increasingly high mean values as the trees grow older, but heartwood formation starts late and is very slow.

Moisture Content

The average moisture contents for the trees felled are presented in Table 4. Sites 12, 14, and 17 are very similar in this respect and the small differences are closely related to differences in basic density. Of the two Dumgree seedlots, site 24 has high mean moisture content because of the low wood density and the absence of heartwood. Site 7 has noticeably low moisture content values, but when they are expressed in terms of percentage saturation, the figures for the two sites are very close (81% and 84% respectively).

Because of the very small amounts of heartwood occurring in the sample discs it was found impracticable to determine a mean value for the heartwood moisture content. The indications were that at the breast height level, the values ranged from 40% to 60%.

Shrinkage

Mean values for volumetric and dimensional shrinkages are given in Table 4, and Tables 5e, 5f, and 5g show the radial variations in volumetric, tangential and radial shrinkages. Neither the ratio of tangential/radial shrinkages nor the radial gradients would indicate any particular drying problems from these causes. However, the occasional high values recorded for longitudinal shrinkage, e.g., site 14, suggest that the timber from certain crops may be prone to dimensional changes on drying.

The figures derived for Corsican pine are similar to those determined for lodgepole pine (Harris, 1973), and slightly greater than those for radiata pine (Hinds and Reid, 1957).

Tracheid Length

Tracheid length is widely recognised as being an important property in coniferous woods, though the technological significance of small changes in mean length is not fully understood at present. Table 8a shows the mean breast height values for the sites on which sample trees were felled and two additional South Island sites. The figures

TABLE 8a—Mean tracheid lengths (mm) at breast height

Site No.	Ring number from pith 2			10			25		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
12	1.1	1.2	1.3	2.5	2.8	3.0	3.3	3.8	3.9
14	1.1	1.3	1.5	2.2	2.6	2.8	3.3	3.8	4.1
17	1.1	1.2	1.4	2.0	2.3	2.5	2.6	3.3	3.7
7	1.2	1.4	1.7	2.4	3.2	3.4			
24	1.3	1.3	1.4	2.4	2.7	2.9			
27	1.2	1.4	1.6	2.0	2.4	2.5			
39	1.2	1.3	1.5	2.0	2.1	2.3			

Table 8b—Within-tree variation in tracheid length (Site 12)

Internode	Ring No. from pith 2	10	25
B.H.	1.2	2.8	3.8
15th	1.4	2.0	4.1
25th	1.5	2.9	3.7

confirm the general trend found in conifers, i.e., a rapid increase in the corewood region followed by a lesser increase out to the bark.

Sites 7, 24, 27, and 39 (seedlot No. NM 47/451) show a distinct decrease in mean tracheid length in ring No. 10 with increasing latitude, irrespective of altitude.

In comparison with other conifer species grown in New Zealand, the mean tracheid lengths for Corsican pine appear to be slightly less than those for radiata pine (Harris, 1965) and greater than those for lodgepole pine (Harris, 1973). It is not likely that tracheid lengths will have any influence on the marketing prospects of Corsican pine.

DISCUSSION

The primary object of the survey was to determine the extent of the variation in the intrinsic wood properties of the Corsican pine crops at present growing in New Zealand. The greatest concentration of this species is in central North Island, where nearly 50% of the total area of Corsican pine was planted and the vast majority of the stands are in the pre-1940 age group (imported and Rotorua seedlots). Of the later, more widely dispersed plantings, the Dumgree seedlots were the most commonly used.

Genotypic variation in wood properties is minimal in the seedlots sampled and no one stands out as being superior in any particular trait. Thus, if at some time in the future a tree breeding programme were considered worthwhile, the first and most important level of selection would be for stem form. Of the wood properties which could affect utilisation, perhaps resin content is in most need of adjustment. As there is no evidence of much variation in this property between the seedlots sampled, any selection for low resin content would have to be at the individual tree level.

The bulk of the produce from current stands, at least in central North Island, will probably be pulped by the kraft process, in which the high resin content of the heartwood may cause problems in delignification. Preliminary studies on the pulping of Corsican pine have shown that a relatively high proportion of screenings is in fact produced (J. M. Uprichard, pers. comm.).

At present, it appears that Corsican pine will have only an extremely limited future in New Zealand forestry, with the possibility of being planted commercially only in some very dry areas of the Canterbury Plains where radiata pine has establishment problems. However, it fares comparatively well at high altitudes, e.g., in Tongariro Forest, and if more such areas were to be developed for forestry it could still find a place as a useful alternative to lodgepole pine where needle blight is absent.

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