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# SAWN TIMBER AND WOOD PROPERTIES OF 21-YEAR-OLD CUPRESSUS LUSITANICA, C. MACROCARPA, AND CHAMAECYPARIS NOOTKATENSIS × C. MACROCARPA HYBRIDS. PART 1: SAWN TIMBER PERFORMANCE

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## ABSTRACT

Demonstration plots of *Cupressus lusitanica* Mill., *C. macrocarpa* Gordon, and *Chamaecyparis nootkatensis* (D.Don) Spach × *C. macrocarpa* ("Leyland") in Rotorua, aged 21 years, were felled to compare lumber performance for appearance and structural uses. The trees had been planted at 1111 stems/ha, and later pruned in stages to height 5–8 m and thinned to 550 stems/ha.

Twenty trees of *C. lusitanica*, seven of *C. macrocarpa,* and 12 of Leyland were cut into 3-m sawlogs and sawn to 150 × 50-mm and 100 × 50-mm sizes, slowly air-dried, then kiln-dried and dressed. Lumber was graded visually as appearance and structural grades. All boards were tested for long-span bending stiffness using the E-grader, and a sample were tested for characteristic bending stiffness and strength.

Each taxon had some advantages and disadvantages in growth, form, and sawn timber characteristics. *Cupressus macrocarpa* had grown to the same diameter at breast height (dbh) as *C. lusitanica*, and both had grown much faster than Leyland. *Cupressus macrocarpa* was the tallest but was badly affected by canker. Leyland had straighter stems than the others, and a higher frequency of branching.

Sawn-timber recovery was 50–60% for all log height classes of each species, except for the butt logs of *C. macrocarpa* where it was approx. 40% owing to fluting and high taper. Leyland yielded more of the best appearance grades, with 46% Dressing, 35% Merchantable, and only 19% Box. *Cupressus lusitanica* averaged 26% Box, and *C. macrocarpa* 46%. Checks within knots were the worst defect for appearance grades in *C. lusitanica*, surface checks in *C. macrocarpa*, and pruned branch stub holes in Leyland.

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Long-span bending tests showed that *C. lusitanica* boards were much less stiff than those of the other species/hybrids. Bending stiffness of *C. lusitanica* was 4–6 GPa for both board sizes, and 6–8 GPa for *C. macrocarpa* and Leyland. Stiffness increased from the inner boards to the outer in *C. lusitanica* (4.3–7.2 GPa). Characteristic bending strength was lowest for *C. lusitanica* (21.3 MPa) and values for *C. macrocarpa* (31.4 MPa) and Leyland (28.0 MPa) were similar to global *Pinus radiata* D. Don values.

**Keywords**: sawn timber performance; appearance grades; structural grades; *Cupressus lusitanica; Cupressus macrocarpa*; *Chamaecyparis nootkatensis* × *Cupressus macrocarpa* Leyland.

## INTRODUCTION

*Cupressus macrocarpa* has been widely planted on New Zealand farms since 1860. It has eventually replaced totara (*Podocarpus totara* D.Don) as a durable timber for farm use, and kauri (*Agathis australis* (D.Don) Lindl.) as a stable timber for boat building. In recent years the development of portable sawmills has seen increased production of cypress timber and, because of its attractive appearance, it has been widely used in doors, joinery, and kitchens (Clifton 1990).

*Cupressus lusitanica* is not as well known in New Zealand as *C. macrocarpa*, but is now being planted more widely as it is less susceptible to the cypress canker fungi *Seiridium cardinale* (Wagener) Sutton & Gibson and *S. unicorne* (Cooke & Ellis) Sutton (Aimers-Halliday *et al*. 1994; Hood *et al*. 2001). It has a reputation for greater stability on drying than *C. macrocarpa* and, while not as strong, in other respects is considered very similar (Clifton 1990).

The inter-generic hybrid between yellow cedar *Chamaecyparis nootkatensis* and *C. macrocarpa* is known as Leyland cypress (*Cupressocyparis leylandii* or *Ch.* × *leylandii*), and several clones have been deployed widely by vegetative propagation. Four different Leyland clones were included in this study but, as the morphology and wood properties of each clone proved similar, they have been grouped under the generic term "Leyland". It is a healthy and well-formed cypress and has been widely planted in shelterbelts, but infrequently in plantations. The properties of New Zealand-grown Leyland cypress timber have been reported by Haslett (1986).

Utilisation of *Cupressus macrocarpa* and *C. lusitanica* has been investigated at Forest Research since the 1960s (J.A.Kininmonth, D.H.Williams & J.M.Mclaughlan unpubl. data; Haslett *et al*. 1985). These species were recognised by the New Zealand Forest Service as suitable for growing for "Special Purpose Timbers" (NZFS 1981), which prompted some further utilisation studies and publication of a summary of their properties and utilisation (Haslett 1986). The earlier studies had shown that kiln-dried *C. macrocarpa* timber from shelterbelts suffered extensive internal checking. Air-drying on its own, or in combination with kiln-drying, also resulted in surface- and end-checking. In contrast, *C. lusitanica* was successfully dried without internal checking or collapse using a low-temperature kiln schedule. However, checks developed within and around intergrown knots in this species, and both kiln- and air-dried boards showed end checking (A.N.Haslett unpubl. data). In some later studies, timber distortion was encountered — as crook in *C. macrocarpa* quarter-sawn boards (J.C.Park & A.G.Smith unpubl. data), as twist in boards that included pith (Haslett unpubl. data), and as crook and bow in two *C. lusitanica* studies on trees from Tairua Forest (G.Young unpubl. data). Boards from 27-year-old *C. macrocarpa*, which had been pruned in four lifts, were downgraded by large knots and large defect cores (Somerville 1993).

A 58-year-old *C. lusitanica* stand at Tairua Forest which had been grown from seed collected from a single tree, was suspected to be a *C. macrocarpa* hybrid. Its pruned butt logs yielded good appearance grades (J.C.Park & A.G.Mortimer unpubl. data). Timber from the upper unpruned logs, tested for bending stiffness (MoE) as a plank, showed that 57% of the stand volume would achieve structural grades, with strength similar to that of *Pinus radiata*.

Basic density has been assessed in several studies of *C. macrocarpa* and *C. lusitanica*, with trees ranging in age from 12 to 70 years for *C. macrocarpa* and 9 to 65 years for *C. lusitanica* (R.B.McKinley unpubl. data). Average basic density for *C. macrocarpa* from four sites, ranging in age from 19 to 22 years, was 350 kg/m$^3$. Trees of *C. lusitanica*, 20 years old and growing at Mangatu, had an average basic density of 365 kg/m$^3$, ranging from 308 to 450 kg/m$^3$.

Shrinkage of air- and oven-dried samples was assessed in seven studies of *C. macrocarpa* with a minimum age of 27 years (R.B.McKinley unpubl. data). Volumetric shrinkage varied from 4.2 to 6.6% for air-dried and 8.1 to 10.9% for oven-dried wood, with tangential shrinkage of 3.6% for air-dried and 6.3% for oven-dried material. There have been a similar number of studies for *C. lusitanica* but some did not include air-dried shrinkage. Average volumetric shrinkage of air-dried wood from *C. lusitanica* trees aged 13 and 40 years was 4.9% and 4.2% respectively (tangential shrinkage 3.4% and 2.5%). Volumetric shrinkage of oven-dried samples in a further five studies ranged from 8.1 to 13.2% (tangential 5.2 to 5.9%).

In *C. lusitanica*, provenance variation in density, heartwood percentage, and shrinkage, evaluated in single discs of 12-year-old trees, showed that the trees with higher density were less variable from pith to bark and were faster growing, and that heartwood formation was extremely variable (D.L.McConchie & G.D.Young unpubl. data).

Stiffness of small clear specimens of *C. lusitanica* increased linearly with age of tree (Bier & Britton 1999). Lowest values of bending strength (MoR 60.9 MPa) and stiffness (MoE 4.5 GPa), both at 12% m.c., were from material cut from 13-year-old trees from Mangatu, and the highest values (MoR 84.1 MPa and MoE 8.9 GPa, both at 12% m.c.) were from the 47-year-old material from Tairua Forest referred to above.

Brailsford (1999) asserted that cypresses, grown on relatively short rotations of 20 to 25 years, could yield well-formed logs containing high proportions of naturally durable timber with favourable properties and appearance. The study reported here was designed to test Brailsford's assertions. The principal objective of the first part of this study was to determine the appearance and structural quality of lumber from young pruned trees of three cypress species/hybrids, when harvested at age 21 years. The objective of the second part (Low *et al.* in prep.) was to investigate the individual-tree relationships between wood properties (determined from discs and increment cores) and the performance of appearance and structural lumber. These relationships are important in the selective improvement of product performance by tree breeding and in the construction of breeding objectives.

## MATERIALS AND METHODS

### Material

Small demonstration row plots of *C. lusitanica*, *C. macrocarpa*, and Leyland hybrids were selected for the study. These were located in the Forest Research Long Mile area in Rotorua. The Leyland hybrids were grown from cuttings of four clones — Haggerston Grey, Clone#3, Green Spire, and Old Alice. *Cupressus macrocarpa* (seedlot WN77/7) and *C. lusitanica* (seedlot AK77/23) were grown from seed. All stock were planted at 3 × 3-m spacing (1111 stems/ha) in 1981, were pruned to between 5 and 8 m, and thinned to approx. 550 stems/ha. The site was reasonably fertile, but was subject to many frosts in winter. The *C. macrocarpa* grew well, but was badly affected by canker, while the *C. lusitanica* grew more slowly than on warmer Bay of Plenty and Northland sites.

### Standing Tree Measurements

Twenty-four trees of *C. lusitanica*, 17 of *C. macrocarpa*, and 21 of Leyland in the stand were assessed while still standing for tree height, height of first unpruned branch, diameter at breast height (dbh), stem straightness score (1 = very sinuous to 9 = very straight), branch diameter score (1 = average branch diameter of 1 cm to 5 = 5 cm diameter), branch angle score (1 = steep to 5 = flat branch angle), branch frequency score (1 = few branches to 5 = many branches), malformation score (1 = repeated forking to 9 = no forks or ramicorns), and bark thickness at breast height (measured by bark gauge).

A 10-mm pith-to-bark increment core was extracted at breast height for possible SilviScan microfibril angle, density, and stiffness (MoE) measurement (Evans

2003) and a 5-mm pith-to-bark core was also extracted from breast height for densitometry.

## Felled Tree Assessments and Measurements

Trees for processing were >30 cm in diameter, free from stem canker, and not badly forked. Ten out of 17 *C. macrocarpa* trees available were rejected for the processing study because of stem canker which often causes bad stem fluting, and nine of 21 Leyland trees were too small. Thus only 20 trees of *C. lusitanica*, seven of *C. macrocarpa,* and 12 of Leyland could be selected for the study, and these were felled and cross-cut into 3-m logs up to a small-end diameter (s.e.d.) of 150 mm. Discs of 50 mm were removed between logs.

Each log was assessed for sweep by measuring (in millimetres) the maximum deviation of the log surface from a straight line. The branch index (BIX) was calculated as the mean diameter (in millimetres) of the largest branches in each of four quadrants. Small-end diameter and large-end diameter (l.e.d.) were measured on the discs corresponding to the log ends.

Two discs were taken at the bottom of the first log, three discs at height 3 m, and two discs between all 3-m sawlogs, plus the top of the top log. Disc 1 was used for density determination, disc 2 for internal checking, and disc 3 (at height 3 m only) for shrinkage. Further discs for density determination were taken above the top log, at 5-m intervals to 100 mm s.e.d. Results of wood-property determinations from discs and cores, and their relationships with sawn timber properties, will be reported in Part 2.

## Sawing and Timber Processing

A Woodmizer mill was used to saw all 3-m logs in a cant sawing pattern, maximising 150 × 50-mm and 100 × 50-mm dimensions, to enable the timber to be tested by the E-grader. The sawing pattern was recorded for each log, with tree/board number marked on each piece of timber produced.

The boards were filleted in stacks, and kept under cover in a pole barn. Air-drying was completed in 10 months to a moisture content of 13–21%. The timber was then kiln dried to 13% m.c. The 50-mm-thick timber was gauged (knife angle 22º) to 145 × 45 mm and 95 × 45 mm to provide uniform dimensions for testing. The 25-mm timber was also minimally dressed, in order to reveal defects.

## Grading

The 45-mm-thick material was visually graded as structural grades F1, F2, and Box (NZS 3631: 1988). Appearance grades normally apply to 25-mm timber, but most of the boards were gauged to 45-mm thickness. Therefore, defects present in the 45-mm boards were recorded by assigning appearance grades to each side of the board as Dressing, Merchantable, and Box, based on NZS 3631: 1988. It was not possible to determine the true grade, because of the hidden face.

The appearance grading criteria were as follows:

(a) When pith and wane were encountered, the piece could be classed as Merchantable at best, as it is not permissible to have Box on the reverse side of Dressing grade.

(b) All other grading, for knots, checking, holes, and so on, was based on each visible face on the assumption that it was the best face. This would lead to some pieces being assessed as a lower grade than they actually would be if ripped into two boards, as the hidden face could be one grade better. For example, it was apparent from the depth of the pruned stub holes that some boards may have been clear on the unexposed face.

The timber was also graded as “Market” grade or Box. Market grade, an amalgam of some of the grading practices in the market, was equivalent to Dressing grade except that pruned stub holes up to 15 mm diameter, tight encased knots up to 15 mm diameter, and checks and chips in knots up to 5 mm were also allowed. Various in-house grades similar to this are used by industry to market cypresses, instead of using Dressing grade (J.C.P.Turner pers. comm.).

## Stiffness and Strength Testing

All the 45-mm-thick timber was tested for long-span bending stiffness as a joist ($LMoE_J$) using the E-grader. A sample was also selected for bending-strength testing; this sample comprised thirty 145 × 45-mm boards of each species, covering the range of long-span stiffness. For the 95 × 45-mm boards, only *C. lusitanica* was tested, because there were insufficient pieces in the two other species. This timber was tested for bending strength and stiffness as a joist (in accordance with AS/NZS4063:1992) in a Grade 1 Baldwin Universal test machine over third point spans of 1710 mm for the 95 × 45-mm boards and 2610 mm for 145 × 45-mm boards.

## Internal Checking Assessment of Boards

For *C. lusitanica* only, a preliminary assessment of internal checking was made on at least two destructively strength-tested boards per tree from the butt log by cutting 30 cm from the bottom end of each board and recording the number of internal checks. One board was selected from the core at this height, near or including pith, and the other board was selected to include mainly outerwood. The remaining boards of *C. lusitanica* and boards of the other species will be assessed for internal checking and reported in Part 2.

### Statistical Analysis

The demonstration plots were planted in rows, which could be separated into three groups or replications. However, no replication effect was observed, so this classification was omitted. Similarly, the trees on the north edge of the block had noticeably larger branches and thicker stems, but omitting these did not change the results of any analyses.

The growth and form data collected on standing trees were classified by species and tree. Data collected on logs had the further classification of log height within each tree and data collected on boards had the extra classification of board number within each log. The position of individual boards within each log was charted and used to compare a group of boards from close to the tree centre with groups selected from closer to the outside of the tree.

Analysis of variance was carried out using PROC GLM of the SAS® software package (SAS Institute 1989) and means were compared using the Tukey multiple range test option. Analyses were carried out for each species separately and for all species combined. PROC MEANS of the SAS® software package (SAS Institute 1988) was used to group boards by defect type and provide the mean, and the standard deviation maximum and minimum for each defect type within board categories.

## RESULTS AND DISCUSSION

### Tree Characteristics

Leyland cypress trees were notably straighter than *C. macrocarpa*, which did not differ appreciably from *C. lusitanica* (Table 1). *Cupressus lusitanica* had a higher branch thickness score (larger diameter branches) than *C. macrocarpa*, but had the fewest branches. The branch angle score was lower (thus steeper-angled branching) in *C. macrocarpa* than in the other species. The mean values for the reduced sample of sawn trees were similar to those of the whole stand, except for a higher incidence of forking in the sawn *C. macrocarpa* trees.

Although mean breast height diameters of *C. lusitanica* and *C. macrocarpa* were similar and larger than for the Leyland hybrids, the *C. macrocarpa* were taller than the other species (Table 2). *Cupressus macrocarpa* was pruned to 6.4 m, *C. lusitanica* to 5.8 m, and Leyland to 5.1 m which reflected its slower height growth. Bark thickness of the study trees was 6–8 mm for all species.

TABLE 1–Species mean tree form and branching scores* for stand and study trees.

| | Number of trees | Tree form | | Branching | | |
|---|---|---|---|---|---|---|
| | | Straightness 1–9 | Malformation (1–9) | Angle (1–5) | Diameter (1–5) | Frequency (1–5) |
| Stand | | | | | | |
| *C. lusitanica* | 24 | 6.79 ab† | 8.25 | 4.08 a | 3.46 b | 2.21 a |
| *C. macrocarpa* | 18 | 6.56 b | 7.39 | 2.44 b | 2.61 a | 4.28 b |
| Leyland | 22 | 7.68 a | 8.18 | 4.00 a | 2.91 ab | 4.56 b |
| Study trees‡ | | | | | | |
| *C. lusitanica* | 20 | 6.95 | 8.10 a | 4.15 a | 3.50 | 2.20 a |
| *C. macrocarpa* | 7 | 6.86 | 5.43 b | 2.57 b | 2.57 | 3.86 b |
| Leyland | 12 | 7.67 | 8.25 a | 3.92 a | 2.83 | 4.67 c |

* A straight, non-malformed tree with flat-angled, small-diameter, and few branches would score resp. 9, 9, 5, 1, 1.

† Tukey multiple range test: Means with no letters in common are significantly different at p<0.05

‡ Only trees >30 cm dbh and free of canker-caused malformation were sawn.

TABLE 2–Species mean height, diameter, and pruned height for stand and study trees.

| Trees | No. of trees | Height (m) | Height of pruning (m) | Diameter at breast height (mm) | Bark thickness (mm) |
|---|---|---|---|---|---|
| Stand | | | | | |
| *C. lusitanica* | 24 | 18.9 b* | 5.7 b | 373 ab | 7.8 b |
| *C. macrocarpa* | 18 | 21.7 a | 6.4 a | 378 a | 7.0 ab |
| Leyland | 22 | 18.3 b | 5.1 b | 332 b | 6.7 a |
| Study | | | | | |
| *C. lusitanica* | 20 | 19.3 b | 5.8 a | 385 a | 8.0 |
| *C. macrocarpa* | 7 | 22.5 a | 6.4 a | 369 ab | 7.3 |
| Leyland | 12 | 18.4 b | 5.1 b | 331 b | 6.7 |

* Tukey multiple range test: Means with no letters in common are significantly different at P<0.05

## Log Quality and Sawn Timber Recovery

The butt logs (A logs) of the *C. macrocarpa* and Leyland had the most sweep, but in the upper logs sweep was generally small (Table 3). Branch index in unpruned logs (mean diameter of four largest branches per log) was 7.6 cm in log C (height 6.2–9.2 m) for *C. macrocarpa*, 6.6 cm for *C. lusitanica,* and 6.4 cm for Leyland. These branch indexes are high and may reflect development of ramicorn branches that compete with the leader. They do not agree with the branch thickness score

TABLE 3–Species means by log height class for sweep and branch index (BIX) of sawing study trees.

| Log | *C. lusitanica* | | | *C. macrocarpa* | | | Leyland | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of logs | Sweep (mm) | BIX (mm) | No. of logs | Sweep (mm) | BIX (mm) | No. of logs | Sweep (mm) | BIX (mm) |
| A (0–3 m) | 19 | 6.2 | | 7 | 14.8 | | 12 | 14.8 | |
| B (3.1–6.1 m) | 20 | 3.9 | | 7 | 0 | | 12 | 8.3 | |
| C (6.2–9.2 m) | 18 | 7.3 | 66.3 | 7 | 0.6 | 75.5 | 12 | 5.4 | 63.6 |
| D (9.3–12.3 m) | 4 | 0 | 61.9 | 4 | 0 | 69.3 | | | |
| Least significant difference | 17 | | | 21 | | | 19 | | |

given to the standing tree, where *C. macrocarpa* was lowest of the three taxa. Todoroki *et al.* (2001) reported 51 mm BIX for *P. radiata* in a study of 26-year-old trees at 400 stems/ha.

The taller *C. macrocarpa* trees produced four or five logs, *C. lusitanica* produced four logs, and Leyland three (Table 3). Mean volumes per tree were respectively 0.49, 0.40, and 0.29 $m^3$ (Table 4).

TABLE 4–Species mean sawn volume outturns by log height class

| Species | Log | Logs (No.) | s.e.d. (mm) | Boards (No.) | Vol/log ($m^3$) | Log taper (cm/m) | Recovery (%) |
|---|---|---|---|---|---|---|---|
| *C. lusitanica* | A | 19 | 323 | 173 | 0.185 | 4.06 | 51 |
| | B | 20 | 284 | 132 | 0.132 | 1.31 | 57 |
| | C | 18 | 232 | 83 | 0.085 | 1.77 | 51 |
| | D | 4 | 216 | 18 | 0.073 | 1.71 | 49 |
| Mean vol./tree | | | | | 0.399* | | |
| *C. macrocarpa* | A | 7 | 309 | 50 | 0.147 | 4.76 | 42 |
| | B | 7 | 283 | 47 | 0.127 | 0.86 | 61 |
| | C | 7 | 241 | 32 | 0.089 | 1.38 | 54 |
| | D | 4 | 203 | 16 | 0.071 | 2.42 | 52 |
| | E | 1 | 190 | 4 | 0.060 | 1.33 | 57 |
| Mean vol./tree | | | | | 0.493 | | |
| Leyland | A | 12 | 288 | 82 | 0.132 | 1.92 | 55 |
| | B | 12 | 246 | 61 | 0.102 | 1.42 | 60 |
| | C | 12 | 186 | 40 | 0.059 | 2.00 | 51 |
| Mean vol./tree | | | | | 0.293 | | |
| Total | | 123 | | | | | |

* Least significant difference 0.144

Sawn timber recovery (conversion) was generally lower in the butt logs than the second logs. *Cupressus macrocarpa* butt logs were affected by fluting and were occasionally elliptical, which resulted in poorest butt-log recovery of all taxa (Table 4). Fluting in these young trees had not developed to the extent seen in older *C. macrocarpa*, and so was not assessed as a trait in its own right. Taper was defined as the difference between large- and small-end log diameters, as centimetre/metre of log length. Taper was less and sawn timber recovery was greater in the second logs than in the butt logs in all species (Table 4). Taper was high in butt logs of *C. lusitanica* and *C. macrocarpa* and showed wide variation among trees — e.g., from 1.7 to 7.7cm/m for *C. lusitanica* (Table 5). There was a strong and significant negative correlation between taper and conversion percentage of butt logs for *C. macrocarpa* (–0.80; the higher the taper, the lower the conversion percentage) where the commencement of fluting at the base of the trees added significantly to the taper measurement. The same correlations for *C. lusitanica* and Leyland were weaker and not significant ($p \leq 0.05$). Todoroki *et al.* (2001) found considerably less taper (9 mm/m) in 26-year-old *P. radiata.*

TABLE 5–Taper variation within log height classes for each species

| Species | Log | No. of logs | Log taper (cm/m) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | s.d. | Min. | Max. |
| *C. lusitanica* | A | 19 | 4.06 | 1.81 | 1.67 | 7.67 |
| | B | 20 | 1.31 | 0.60 | 0.00 | 2.67 |
| | C | 18 | 1.77 | 0.82 | 0.50 | 3.67 |
| | D | 4 | 1.71 | 0.48 | 1.00 | 2.00 |
| *C. macrocarpa* | A | 7 | 4.76 | 1.30 | 3.33 | 6.67 |
| | B | 7 | 0.86 | 0.38 | 0.67 | 1.67 |
| | C | 7 | 1.38 | 0.62 | 0.33 | 2.33 |
| | D | 4 | 2.42 | 1.45 | 1.00 | 3.67 |
| Leyland | A | 12 | 1.92 | 0.64 | 1.00 | 3.33 |
| | B | 12 | 1.42 | 0.57 | 0.33 | 2.33 |
| | C | 12 | 2.00 | 0.57 | 1.33 | 3.00 |

## Grading of Sawn Lumber for Appearance

*Cupresssus lusitanica*

This species yielded 39% of its sawn timber out-turn of 150 × 50 as Dressing grade, the best appearance grade, as against 46% for Leyland and 30% for *C. macrocarpa* (Table 6). Outturns of 100 × 50 were respectively 8.8%, 4.4%, and 3.5%. Leyland showed the highest proportion of Merchantable grade, and *C. macrocarpa* had the highest proportion of Box grade.

TABLE 6–Species mean timber volume per tree by grade and dimension

| Species | Dimension* | Dressing | | Merchantable | | Box | |
|---|---|---|---|---|---|---|---|
| | (mm) | m³/tree | Tree volume (%) | m³/tree | Tree volume (%) | m³/tree | Tree volume (%) |
| *C. lusitanica* | 150 × 25 | 0.151 | 39.2 | 0.074 | 19.2 | 0.092 | 23.7 |
| | 100 × 25 | 0.034 | 8.8 | 0.017 | 4.5 | 0.018 | 4.6 |
| *C. macrocarpa* | 150 × 25 | 0.121 | 30.0 | 0.072 | 18.0 | 0.156 | 38.9 |
| | 100 × 25 | 0.014 | 3.5 | 0.012 | 2.9 | 0.027 | 6.7 |
| Leyland | 150 × 25 | 0.095 | 33.1 | 0.102 | 35.7 | 0.043 | 15.1 |
| | 100 × 25 | 0.013 | 4.4 | 0.023 | 7.9 | 0.011 | 3.9 |

* Assuming that 50-mm boards are two pieces.

Defects that caused down-grade have been grouped by type and analysed on the basis of proportion of total number of pieces (including Dressing grade) downgraded by that defect (Table 7). All knot-size-related defects have been grouped together. The most serious defects for *C. lusitanica* were knot checks, which affected up to 64% of boards of one tree (mean 24%). But for this defect, there would have been twice as many Dressing grade boards. Knots tended to check in all species and, when some wood chipped out during dressing, this check was often enlarged to exceed the size allowed for Dressing grade (Fig. 1). This defect might be alleviated

TABLE 7–*Cupressus lusitanica*: proportional sources of degrade of 25-mm boards (with standard deviation and range)

| Defect type | Boards per tree (%)* | | Merchantable and Box boards | | | |
|---|---|---|---|---|---|---|
| | Merchantable† | Box | Boards/tree (%) | s.d. | Min. | Max. |
| Knots | 13.2 | 3.0 | 16.2 | 7.6 | 0 | 29.4 |
| Surface checks | 0 | 2.5 | 2.5 | 3.0 | 0 | 10.8 |
| Knot checks | 23.3 | 0.7 | 24.1 | 15.2 | 2.0 | 63.6 |
| End splits | 0 | 0.3 | 0.3 | 1.0 | 0 | 4.0 |
| Twist | 0 | 3.2 | 3.2 | 7.0 | 0 | 29.6 |
| Crook | 0 | 5.7 | 5.7 | 7.9 | 0 | 28.6 |
| Wane | 5.6 | 3.2 | 8.8 | 6.0 | 0 | 19.5 |
| Health | 0 | 2.7 | 2.7 | 6.6 | 0 | 27.6 |
| Pruned stub hole | 7.5 | 4.0 | 11.5 | 5.7 | 2.6 | 25.0 |
| No defect | 0.3 | 0.3 | 0.5 | 1.6 | 0 | 6.9 |
| | 49.9 | 26.0 | 76.0 | | | |

* Assuming that 50-mm boards are two 25-mm pieces.
† The remaining 24% of boards are Dressing, i.e, no downgrading defect.

FIG. 1–*Cupressus lusitanica*: Knot check caused by chipping out during dressing.

by improved machining, such as by a change in knife angles. The impact of knots could be much reduced by pruning, creating a smaller diameter over stubs (DOS), and by harvesting older trees.

Twist, crook, and pruned stub holes were other more frequent defects encountered in *C. lusitanica.* Twist and crook reduced the grade to Box, affecting an average of 9% of boards overall, ranging up to 30% for the worst tree. This is a serious problem, as reported in an earlier study (Young unpubl. data). Knot size and pruned branch stub holes accounted for a total of 28% of degrade to Merchantable and Box grades in this species.

*Cupressus macrocarpa*

The most serious defect for this species was surface or face checking, degrading on average 29% of boards (per tree) to Box, ranging from 11% to 58% (Table 8). Slow air-drying to 18% did not reduce this defect to acceptable levels. Knot checks downgraded a further 14% of boards from Dressing grade to Merchantable. However, trees varied widely in how much they were affected. It is not clear what are the causes of knot checking, and whether they are related to internal checking. Twist and crook were minor defects for this species, degrading only 6% of Merchantable boards to Box.

*Leyland cypress*

Leyland timber graded better for appearance than the other species but grew appreciably more slowly. Its worst defect was pruned branch-stub holes (Table 9, Fig. 2), with on average 15% of boards degraded. Knot checks down-graded 11% of Dressing to Merchantable and 7% to Box. Leyland had the lowest proportion of

TABLE 8–*Cupressus macrocarpa*: Proportional sources of degrade of 25-mm boards (with standard deviation and range)

| Defect type | Boards per tree (%)* | | Merchantable and Box boards | | | |
|---|---|---|---|---|---|---|
| | Merchantable† | Box | Boards/tree (%) | s.d. | Min. | Max. |
| Knots | 6.8 | 0.9 | 7.7 | 6.3 | 0 | 17.2 |
| Surface checks | 0 | 29.2 | 29.2 | 16.8 | 10.9 | 57.5 |
| Knot checks | 13.2 | 0.5 | 13.7 | 7.4 | 0 | 23.4 |
| End splits | 0 | 6.0 | 6.0 | 5.3 | 0 | 15.0 |
| Twist | 0 | 2.2 | 2.2 | 3.8 | 0 | 8.0 |
| Crook | 0 | 1.4 | 1.4 | 2.6 | 0 | 6.3 |
| Wane | 4.9 | 4.4 | 9.3 | 9.2 | 0 | 19.2 |
| Health | 0 | 1.1 | 1.1 | 2.9 | 0 | 7.7 |
| Pr. stub hole | 7.6 | 0.8 | 8.3 | 5.4 | 3.7 | 19.2 |
| No defect | 0.2 | 0 | 0.2 | 0.6 | 0 | 1.6 |
| | 32.7 | 46.4 | 79.2 | | | |

* Assuming that 50-mm boards are two 25-mm pieces.
† The remaining 21% of boards are Dressing, i.e, no downgrading defect.

TABLE 9–Leyland cypress: proportional sources of degrade of 25-mm boards (with standard deviation and range)

| Defect type | Boards per tree (%)* | | Merchantable and Box boards | | | |
|---|---|---|---|---|---|---|
| | Merchantable† | Box | Boards/tree (%) | s.d. | Min. | Max. |
| Knots | 4.2 | 0.5 | 4.7 | 3.1 | 0 | 9.7 |
| Surface checks | 0.3 | 6.7 | 6.9 | 6.3 | 0 | 17.9 |
| Knot checks | 10.9 | 0 | 10.9 | 4.4 | 5.0 | 21.1 |
| End splits | 0.4 | 2.9 | 3.3 | 3.6 | 0 | 10.5 |
| Twist | 0 | 0 | 0 | 0 | 0 | 0 |
| Crook | 0 | 0.5 | 0.5 | 1.7 | 0 | 5.9 |
| Wane | 5.2 | 2.6 | 7.8 | 4.5 | 0 | 17.2 |
| Health | 0.6 | 2.0 | 2.6 | 3.0 | 0 | 7.7 |
| Pr. stub hole | 13.1 | 2.0 | 15.1 | 8.2 | 3.8 | 29.0 |
| No defect | 0.3 | 2.2 | 2.5 | 4.6 | 0 | 15.4 |
| | 35.0 | 19.4 | 54.3 | | | |

* Assuming that 50-mm boards are two 25-mm pieces.
† The remaining 46% of boards are Dressing, i.e, no downgrading defect.

Box grade, e.g., 15% of 150 × 50-mm stock (39% for *C. macrocarpa* and 24% for *C. lusitanica*).

Pruned stub holes occurred in all species, affecting on average 12%, 8%, and 15% of boards for *C. lusitanica*, *C. macrocarpa,* and Leyland trees respectively. When

FIG. 2–Leyland cypress. *Left*: Pruned branch stub, showing absence of intergrowth around dead branch wood (appearing as a dark line). *Right*: The "stub hole" that results from branch death after pruning and lack of connection to the surrounding wood. The dark resinous material is the dark line in the photo at left.

a branch stub dies back, the occluding wood often does not attach to the outer few millimetres of the stub. When a board is cut through the last few millimetres of the branch stub, the stub drops out leaving a large hole (Fig. 2). Knot size that exceeded the allowance for Dressing grade was the reason for degrading 16.2% of *C. lusitanica* boards compared with 7.7% of *C. macrocarpa* and 4.7% of Leyland. This was reflected in the high branch index of *C. lusitanica.*

The identification of the more important sources of appearance degrade in each taxon is hindered by the varying and small number of trees sawn, especially of *C. macrocarpa*, and the different amounts of variation in each defect (as the standard error) shown by each taxon.

### Market Grade

The timber was also assessed for an appearance grade called "Market grade", similar to that being used by industry to market cypress timber, instead of Dressing grade (Table 10). The volume of boards that did not meet Market grade (i.e., downgraded to Box) was higher than when using NZS 3631:1988 for Dressing and Merchantable grades. This was because pruned stub holes, knots, and checked knots, acceptable for Merchantable grade, were not acceptable for Market grade. *Cupressus macrocarpa* had the largest proportion of volume downgraded in this way.

### Visual Grading for Structural Use

All 50-mm-thick lumber was visually graded for structural use, according to NZS 3631:1988. Leyland showed appreciably better grades than the other two species, with 78% No. 1 Framing and minor proportions of No. 2 Framing and Box (Table 11). *Cupressus lusitanica* had a lower proportion of No. 1 Framing as 150

TABLE 10–Species mean volume per tree of Market grade and Box, by dimension

| Species | Dimension* | Market | | Box | |
|---|---|---|---|---|---|
| | | $m^3$/tree | Tree volume (%) | $m^3$/tree | Tree volume (%) |
| *C. lusitanica* | 150 | 0.202 | 52.3 | 0.117 | 30.3 |
| | 100 | 0.043 | 11.1 | 0.024 | 6.3 |
| *C. macrocarpa* | 150 | 0.188 | 46.8 | 0.161 | 40.1 |
| | 100 | 0.027 | 6.7 | 0.025 | 6.2 |
| Leyland | 150 | 0.190 | 66.2 | 0.050 | 17.4 |
| | 100 | 0.035 | 12.2 | 0.012 | 4.2 |

* Assuming that 50-mm boards are two pieces.

TABLE 11–Species mean volumes and proportions of structural grades per tree, by dimension.

| Species | Dimension | No. 1 Framing | | No. 2 Framing | | Box | |
|---|---|---|---|---|---|---|---|
| | | $m^3$/tree | %/tree | $m^3$/tree | %/tree | $m^3$/tree | %/tree |
| *C. lusitanica* | 150 × 50 | 0.213 | 58.5 | 0.027 | 7.4 | 0.063 | 17.3 |
| | 100 × 50 | 0.044 | 12.0 | 0.008 | 2.1 | 0.010 | 2.7 |
| *C. macrocarpa* | 150 × 50 | 0.257 | 71.2 | 0.003 | 0.9 | 0.058 | 16.0 |
| | 100 × 50 | 0.026 | 7.1 | 0.006 | 1.8 | 0.011 | 3.0 |
| Leyland | 150 × 50 | 0.203 | 77.7 | 0.011 | 4.3 | 0.013 | 5.0 |
| | 100 × 50 | 0.029 | 11.0 | 0.003 | 1.0 | 0.003 | 1.0 |

× 100-mm stock than *C. macrocarpa* (59% *versus* 71%), owing largely to twist and crook, which were major causes of degrade in this species (Table 12). Decay or insect attack ("health") was also a significant cause of degrade. The higher levels of Box grade in *C. macrocarpa* were due mainly to end-splits (Table 13). Most of the Leyland was No. 1 Framing, with some downgrade due to knot size, end-splits, and insect damage (Tables 11, 14).

## Long-span Bending Tests

All boards, both 145 × 45-mm and 95 × 45-mm, were tested for long-span stiffness and strength, using the E-grader (Table 15). The numbers of trees per taxon varied from seven for *C. macrocarpa*, to 12 for Leyland, to 20 for *C. lusitanica,* and numbers of boards tested per tree were 13, 10, and 14 respectively. *Cupressus lusitanica* showed much lower mean stiffness as a joist than *C. macrocarpa* and the

TABLE 12–*Cupressus lusitanica*: proportional sources of degrade of 150 × 50-mm and 100 × 50-mm Framing grade boards per tree (with standard deviation and range)

| Defect | Boards per tree* (%) | | No. 2 Framing + Box boards (% per tree) | | | |
|---|---|---|---|---|---|---|
| | No. 2 Framing | Box | Tree mean | s.d. | Min. | Max. |
| Knots | 8.0 | 1.0 | 9.0 | 11.4 | 0 | 37.5 |
| End Splits | 0 | 0.1 | 0.1 | 0.6 | 0 | 2.9 |
| Twist | 0 | 3.6 | 3.6 | 7.9 | 0 | 33.3 |
| Crook | 0 | 7.1 | 7.1 | 8.8 | 0 | 30.0 |
| Bark | 0.4 | 1.8 | 2.2 | 3.2 | 0 | 8.3 |
| Health | 0 | 3.7 | 3.7 | 8.0 | 0 | 33.3 |
| No defect | 0 | 0.3 | 0.3 | 1.3 | 0 | 5.9 |
| | 8.4 | 17.6 | 25.9 | | | |

* The remaining 74% of boards are No. 1 Framing, i.e., no downgrading defect.

TABLE 13–*Cupressus macrocarpa*: proportional sources of degrade of 150 × 50-mm and 100 × 50-mm Framing grade boards per tree (with standard deviation and range)

| Defect | Boards per tree* (%) | | No. 2 Framing + Box boards (% per tree) | | | |
|---|---|---|---|---|---|---|
| | No. 2 Framing | Box | Tree mean | s.d. | Min. | Max. |
| Knots | 1.7 | 1.2 | 2.9 | 3.7 | 0 | 8.3 |
| End Splits | 0 | 7.3 | 7.3 | 8.3 | 0 | 19.1 |
| Twist | 0 | 2.8 | 2.8 | 4.8 | 0 | 10.0 |
| Crook | 0 | 0.9 | 0.9 | 2.5 | 0 | 6.7 |
| Bark | 0 | 4.5 | 4.5 | 4.6 | 0 | 10.0 |
| Health | 0 | 2.4 | 2.4 | 6.3 | 0 | 16.7 |
| No Defect | 0.5 | 0 | 0.5 | 1.3 | 0 | 3.3 |
| | 2.1 | 19.1 | 21.2 | | | |

* The remaining 79% of boards are No. 1 Framing, i.e., no downgrading defect.

Leyland cypress hybrids, e.g., 5.29 GPa for 145 × 45-mm boards, *versus* 7.77 and 7.64 GPa, respectively (Table 15, Fig. 3 and 4). Comparisons of the 95 × 45-mm boards of *C. macrocarpa* and Leyland were based on too few boards to be reliable.

The cumulative frequency distributions for the AS/NZS4063 bending strength and stiffness testing (Fig. 5 and 6) demonstrate similar results; for the 145 × 45-mm timber (from 21-year-old trees), *C. lusitanica* had the lowest stiffness, followed by *C. macrocarpa* and Leyland cypress which had similar stiffness properties to New Zealand-wide *P. radiata* from forest sites (though these were from appreciably

TABLE 14–Leyland: proportional sources of degrade of 150 × 50-mm and 100 × 50-mm Framing grade boards per tree (with standard deviation and range)

| Defect | Boards per tree* (%) | | No. 2 Framing + Box boards (% per tree) | | | |
|---|---|---|---|---|---|---|
| | No. 2 Framing | Box | Tree mean | s.d. | Min. | Max. |
| Knots | 5.3 | 1.3 | 6.6 | 6.6 | 0 | 16.7 |
| End Splits | 0 | 4.6 | 4.6 | 10.7 | 0 | 36.4 |
| Twist | 0 | 0 | 0 | 0 | 0 | 0 |
| Crook | 0 | 0 | 0 | 0 | 0 | 0 |
| Bark | 0 | 0 | 0 | 0 | 0 | 0 |
| Health | 0 | 0.6 | 0.6 | 2.1 | 0 | 7.1 |
| No Defect | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5.3 | 6.5 | 11.8 | | | |

* The remaining 88% of boards are No. 1 Framing, i.e., no downgrading defect.

TABLE 15–Species means, standard deviations, and ranges for long span stiffness by board size

| | Board size 145 × 45 mm | | | Board size 95 × 45 mm | | |
|---|---|---|---|---|---|---|
| | *C. lusitanica* | *C. macrocarpa* | Leyland | *C. lusitanica* | *C. macrocarpa* | Leyland |
| Mean MoE (GPa) | 5.3 | 7.8 | 7.6 | 6.1 | 7.8 | 7.9 |
| Standard deviation | 1.6 | 1.7 | 1.2 | 1.6 | 1.9 | 1.6 |
| Range | 8.4 | 7.2 | 5.7 | 6.7 | 6.8 | 4.7 |
| Minimum | 3.0 | 4.6 | 4.7 | 3.7 | 4.5 | 6.1 |
| Maximum | 11.4 | 11.8 | 10.4 | 10.4 | 11.3 | 10.9 |
| No. boards | 255 | 101 | 115 | 79 | 14 | 23 |
| CV% | 29.6 | 21.6 | 16.2 | 25.7 | 24.9 | 20.6 |

older and larger-diameter trees). Stiffness of the 95 × 45-mm boards of *C. lusitanica* was intermediate between Leyland and *C. macrocarpa*, probably because this size was cut from outerwood slabs.

*Cupressus lusitanica* also had the lowest bending strength in 145 × 45-mm boards, followed by *C. macrocarpa* and Leyland cypress. The 145 × 45-mm *C. macrocarpa* and Leyland cypress had similar bending strength properties to the 145 × 45-mm "New Zealand-wide" *P. radiata*. The 95 × 45-mm boards of *C. lusitanica* had lower strength properties than comparable "New Zealand-wide" *P. radiata*, though the 95 × 45-mm boards of *P. radiata* had higher stiffness than all cypress boards. The low stiffness values are consistent with previous findings for *C. lusitanica* of this age.

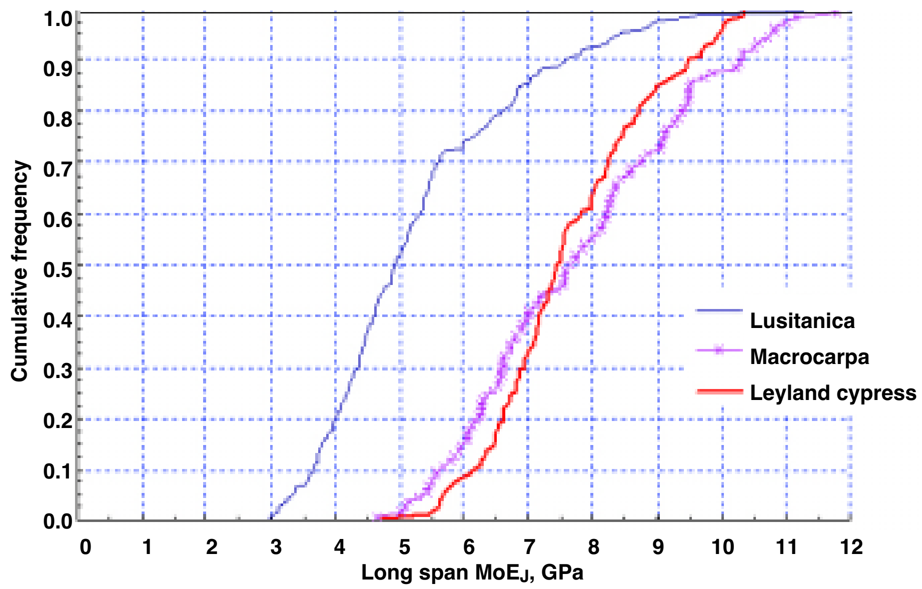


FIG. 3–Cumulative frequency distributions of bending stiffness by species for 145 × 45-mm boards by AS/NZS4063.

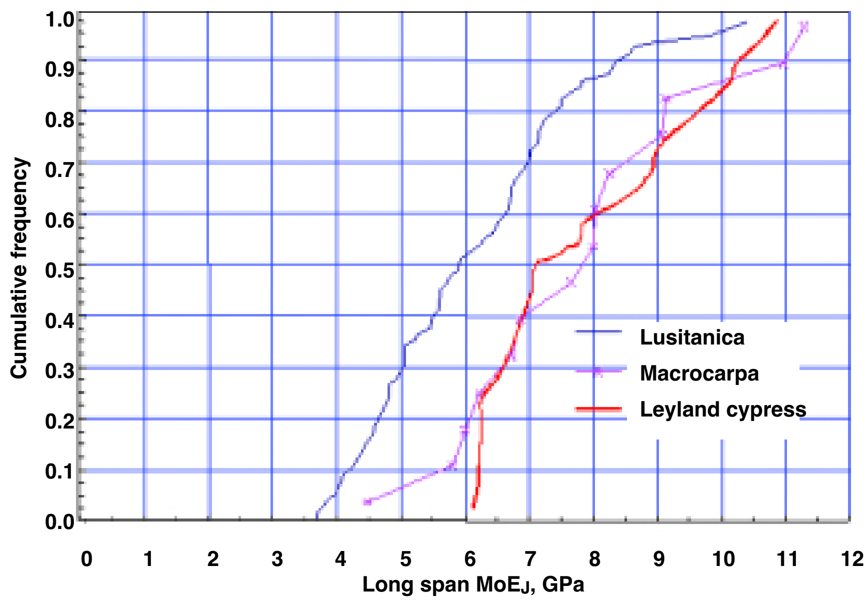


FIG. 4–Cumulative frequency distributions of bending stiffness by species of 95 × 45-mm boards by AS/NZS4063.

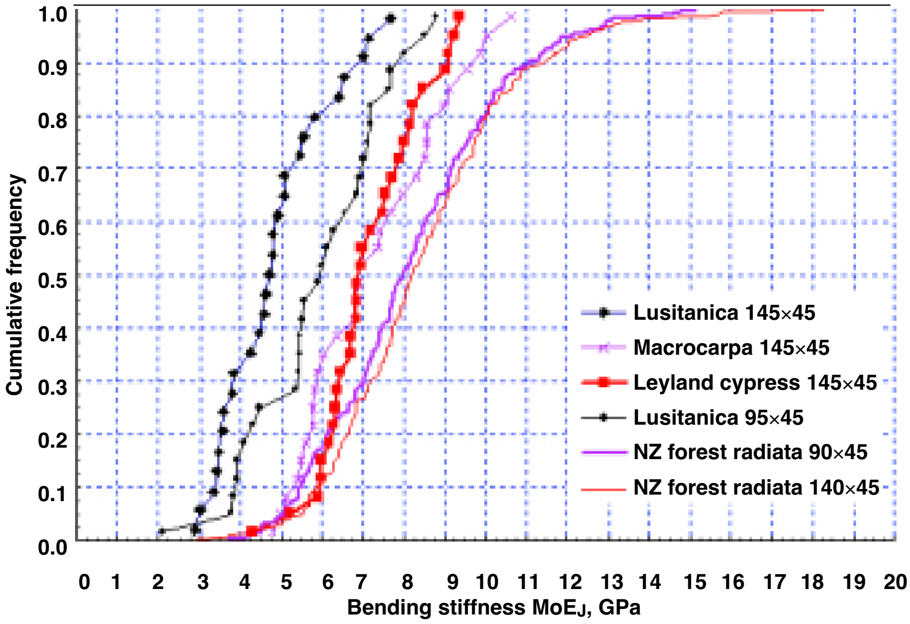


FIG. 5–Comparison of cumulative frequency distributions of AS/NZS4063 bending stiffness of *P. radiata* global values with cypress species, for 145 × 45-mm and 95 × 45-mm boards.

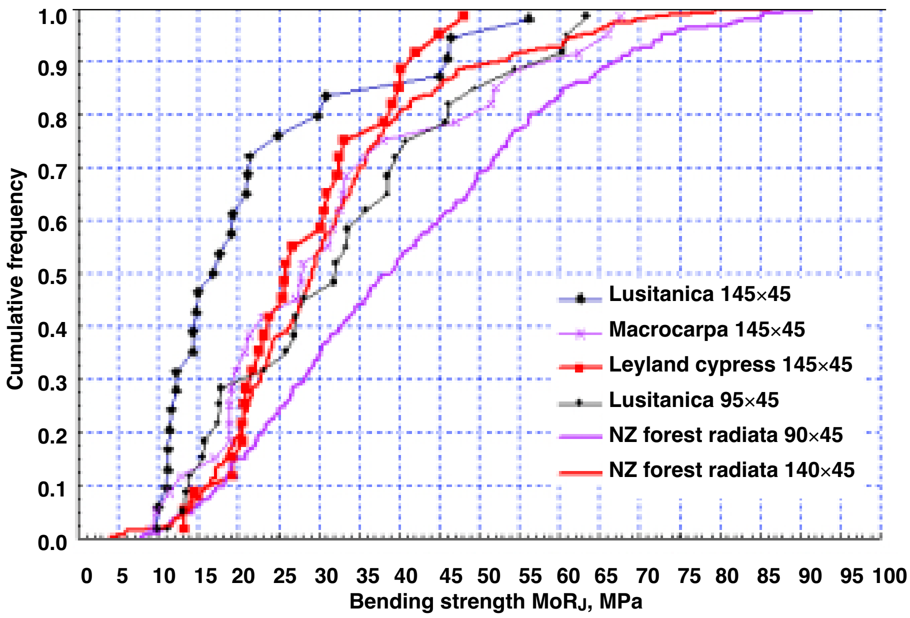


FIG. 6–Comparison of cumulative frequency distributions of AS/NZS4063 bending strength of *P. radiata* global values with cypress species, for 145 × 45-mm and 95 × 45-mm boards.

The "characteristic" stiffness (MoE) and strength (MoR) properties were tested of a sub-sample of 27–30 boards per taxon-board size category, using the Baldwin machine (Table 16). This sub-sample was based on a sample chosen from the E-grader stiffness data to span the range within that category. Leyland cypress and *C. macrocarpa* barely achieved the bending strength and stiffness requirements of the MGP6 grade, whereas *C. lusitanica* failed to reach the lowest structural grade, for bending strength or for stiffness.

TABLE 16–Species means, standard deviations, and ranges for characteristic bending stiffness and strength properties, by board size

| | Bending stiffness $MoE_J$ (GPa) | | | | Bending strength $MoR_J$ (MPa) | | | |
|---|---|---|---|---|---|---|---|---|
| | *C. lusitanica* 145 × 45 | *C. lusitanica* 95 × 45 | *C. macrocarpa* 145 × 45 | Leyland 145 × 45 | *C. lusitanica* 145 × 45 | *C. lusitanica* 95 × 45 | *C. macrocarpa* 145 × 45 | Leyland 145 × 45 |
| Mean | 4.8 | 5.9 | 7.2 | 7.2 | 21.3 | 32.5 | 31.4 | 28.0 |
| s.d. | 1.3 | 1.6 | 1.7 | 1.2 | 12.9 | 15.4 | 16.8 | 9.5 |
| Range | 4.8 | 6.7 | 5.8 | 5.1 | 46.4 | 52.2 | 58.6 | 35.0 |
| Minimum | 2.9 | 2.1 | 4.8 | 4.3 | 9.8 | 11.3 | 9.1 | 13.2 |
| Maximum | 7.7 | 8.8 | 10.60 | 9.4 | 56.2 | 63.5 | 67.6 | 48.2 |
| No. boards | 27 | 30 | 30 | 30 | 27 | 30 | 30 | 30 |
| CV% | 27.1 | 27.2 | 22.9 | 17.0 | 60.7 | 47.4 | 53.5 | 33.9 |
| Rk,norm, MPa | | | | | 8.9 | 10.2 | 7.3 | 12.7 |
| Ek, GPa. | 4.0 | 4.8 | 6.9 | 6.9 | | | | |

In order to determine the effect of the age of wood on board stiffness, the sawing diagrams were used to select a sample of *C. lusitanica* boards in three categories, predominantly from the outer, intermediate, or inner growth rings (Table 17). The boards from the outer rings had a stiffness of 7.22 GPa, compared with 5.40 GPa

TABLE 17–Mean stiffness of inner, intermediate, and outer *C. lusitanica* butt log boards, and their basic density, based on density of 5-ring groups from discs taken at the top of the butt logs

| Position | Stiffness | | Density | |
|---|---|---|---|---|
| | No. of boards | Mean | No. of 5-ring samples | Mean |
| Outer | 78 | 7.22 a* | 40 | 359 a |
| Intermediate | 39 | 5.42 b | 40 | 334 b |
| Inner | 36 | 4.30 c | 40 | 340 b |
| Least Significant Difference | 0.57 | | 7.54 | |

* Tukey multiple range test: Means with no letters in common are significantly different at $p<0.05$

for intermediate boards and 4.30 GPa for the inner boards. This compared with a density (determined from 5-ring groups at height 3 m for *C. lusitanica* only) of 359 $kg/m^3$ for rings 11 plus, 334 $kg/m^3$ for rings 6–10, and 340 $kg/m^3$ for the inner five rings ($F_{2, 60}$ $p<0.0001$). This showed that the wood stiffness, unlike density, is far from being even across the stem, as suggested by Brailsford (1999), and is strongly affected by distance from the pith.

There is also a gradient of decreasing stiffness with height in the tree for all three species (Table 18) — e.g., for *C. lusitanica*, stiffness of boards from the basal 3-m log was 5.61 GPa *versus* 4.85 GPa for the fourth 3-m log. There were significant differences between trees ($F_{19, 231}$ $p<0.0001$) and between log heights within trees ($F_{3, 231}$ $p<0.0001$). These differences are likely to reflect the increasing proportion of corewood with height up the stem, probably accompanied by higher microfibril angles.

TABLE 18–Species mean board stiffness by log height class

| Log | *C. lusitanica* | | | *C. macrocarpa* | | | Leyland | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. logs | No. boards | Stiffness | No. logs | No. boards | Stiffness | No. logs | No. boards | Stiffness |
| A | 19 | 111 | 5.61 a* | 7 | 40 | 8.24 | 12 | 50 | 8.32 a |
| B | 20 | 91 | 5.25 ab | 7 | 28 | 7.59 | 12 | 44 | 7.23 b |
| C | 18 | 44 | 4.60 b | 7 | 23 | 7.59 | 12 | 21 | 6.87 b |
| D | 4 | 8 | 4.85 ab | 4 | 9 | 6.81 | | | |
| LS difference | | | 0.97 | | | 1.53 | | | 0.57 |

* Tukey multiple range test: Means with no letters in common are significantly different at $p<0.05$

## CONCLUSIONS

This study was based on cypress trees that were only 21 years old, about half “normal” rotation age. The deficiencies of cypress appearance and structural lumber would be greatly alleviated by a longer rotation, with the addition of more rings of outerwood. Despite known uniformity of wood density, wood stiffness increases strongly from pith to bark, and so cypresses do have a corewood problem, like most conifers. Trees of 300 to 500 mm dbh yielded only 0.2 to 0.6 $m^3$ sawn timber at age 21 years, and harvesting and milling at this age would be barely viable economically. Growing cypresses on a short rotation of 21 years negates some of the advantages of cypress timber from older trees over *P. radiata* but could still be done provided appropriate early thinning and pruning were undertaken.

The principal objective of the first part of this pilot study was to determine whether appearance and structural performance of lumber from young (21-year-old) pruned trees of *C. macrocarpa, C. lusitanica,* and the “Leyland” hybrids was acceptable. *Cupressus macrocarpa* grew to the same diameter on this site as *C. lusitanica*, but was badly affected by canker. Both grew much faster than Leyland which had straighter stems than *C. lusitanica* and *C. macrocarpa*, and had a higher frequency of branching. Branching was quite heavy in the upper unpruned logs for all three taxa.

Sawn timber recovery was acceptable, but there was a lot of tree-to-tree variation in checking in each species. Knot checks were an important defect in all species, which may have technological solutions in the dressing process. In Leyland the most common defects were pruned branch stub holes caused by lack of intergrowth around dead branch wood. Possibly pruning practice changes could help here.

Long-span bending tests showed that *C. lusitanica* boards were much less stiff than the Leyland hybrids and *C. macrocarpa*, and all were less stiff than *P.radiata*. Stiffness increases substantially from the inner boards to the outer in *C. lusitanica* and increased age will undoubtedly result in improved stiffness in *C. lusitanica* and the other species relative to global *P. radiata* values.

Internal and face checking of *C. macrocarpa* appears to be a real problem, at least in this study of young trees. Warp on drying and lower stiffness are serious disadvantages of *C. lusitanica*. The good performance of the appearance and structural products of the four *Chamaecyparis nootkatensis* × *C. macrocarpa* hybrid clones (Leyland) may be a pointer towards the development of faster-grown hybrids involving southern Oregon provenances of *Ch. nootkatensis*. The "ovensii" hybrid clone of *Ch. nootkatensis* × *C. lusitanica* is reputed to grow fast and be resistant to canker.

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