Wood properties of 38-year-old Redwood from Mangatu Forest

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Executive summary

Thirteen randomly-selected stems were felled in a 38-year-old stand (Cpt. 11, Mangatu Forest) for an analysis of wood properties. Disc samples were collected from the ends of each 5m log and subjected to measurement of wood density, shrinkage and heartwood content.

The results confirmed that mature NZ grown redwood has a high heartwood content (>50%) and low and uniform density (stems averaging 323 kg/m^3). Shrinkage was also low and uniform. Between-tree variation was the largest component observed, suggesting that selective breeding may offer real opportunities for wood quality improvement.

Introduction

Redwood in the US is mostly used for building - decks, fences, outdoor furniture, weatherboards, window sashes, doors, blinds, interior trim - where durability, appearance and stability are major requirements. The supply of "old growth" lumber is now a small part of the market and the vast majority is from "second-growth" stands (less than 100 years old), where the wood characteristics are somewhat different. In particular, the heartwood is recognised as having only low to moderate decay resistance (USDA, 1999).

In New Zealand, redwoods have been a feature of the landscape since the 19th century, having been established as small plantations, shelterbelts and ornamentals throughout the country (Knowles and Miller, 1993). Some iconic remnants of the early plantings remain impressive, such as the Redwood Grove in Rotorua (Figure 1), proving that it can grow well when correctly sited. Many of the early Forest Service plantings throughout the country, however, were not successful, and the quality of the timber was disappointing compared to the US material (Brown, 2007).

Experience would suggest that well managed redwood should be an excellent choice for plantations in New Zealand Cornell, 2002; Vincent, 2001), and in fact renewed interest has been shown by some companies in planting redwoods (Webster, 2009). Studies have suggested that rotations of around 30 years may be feasible (Knowles and Miller, 1993; Rydelius, 2007).

The area of redwood plantations in New Zealand is currently very small - only a few thousand hectares - but the potential is high. It has been demonstrated to grow on a wide range of sites and outperforms radiata in many cases and there are established markets for the timber (Webster, 2009). The main uses are those to which US redwood has a good reputation - exterior and interior joinery and weatherboards.

Comparatively little work has been done on the wood properties and performance of New Zealand-grown redwood,

Figure 1: Redwood Grove in Rotorua (over 100 years old).

and the acknowledged gaps are around characteristics such as density, stability and durability (Cooke and Satchell, 2007; Poole, 2007) which could potentially affect export markets. Research to date has shown that basic wood properties are highly variable according to planting stock, siting, silviculture and rotation age (Cown, 1970, 2008; Colbert and McConchie, 1983; Cornell, 2007). Experience suggests that the low wood density, low hardness and low-to-moderate durability could restrict end uses. Clifton (1994) notes "it is brash, brittle, and altogether "punky". It is rated moderately durable". Cornell (2007) rightly cautioned that

market requirements, both domestic and export, should be considered before a long term commitment is made to fast growing clones.

Materials and Methods

The new research organisation, Future Forests Research (Diversified Species Theme), a partnership between the forest industry and Scion, identified redwood as a potentially valuable species for the future. As a priority it was decided to benchmark the wood characteristics of a mature, managed redwood stand. In conjunction with MAF (Ministry of Agriculture and Forestry) and FIDA (Forest Industries Development Agenda), a sawing study was conducted, in the course of which the wood properties were documented for comparison with existing data.

Material was made available from a 38-year-old pruned stand in Compartment 11 of Mangatu forest in Hawkes Bay. The stand was planted in 1970 at an initial stocking of 3086 spha. The silvicultural history is given in Table 1. The stand was pruned up to four times, up to a height of approximately 5.8 metres and thinned twice.

Table 1: Silvicultural History

Activity	Age (Year)	Description
Pruning	9 (1979)	Fixed lift pruning to 2.2 metres
Thinning	9 (1979)	Thinned to waste down to 800 sph
Pruned	10(1980)	Fixed lift pruning to 4.0 metres
Pruned	12(1982)	Fixed lift pruning to 5.8 metres
Thinning	12(1982)	Thinned to waste down to 512 sph
Pruned	15(1985)	Variable lift pruning to 5.8 metres

Thirteen stems were selected from the study stand to represent a cross section of the diameter range and aimed to cover a sample of live green branches to the pruned height, small dead branches and large dead branches. From each stem, BH increment core samples were collected for analysis of the outerwood density distribution prior to log making (5.5 m). At the time of felling, logs were assessed with the HM200 and discs (50mm thick) were taken from the butt end and the top of each log recovered. In the laboratory the discs were assessed as follows:

- Diameters over and inside bark (DOB and DIB)
- Age (total growth rings) and heartwood rings - to estimate heartwood %
- Wood Density:
  - Radial trends by 5-ring and 10 ring groups.
- Shrinkage (green to air-dry):
  - Longitudinal, radial, and tangential shrinkage by 5-ring and 10 ring groups .

For the butt disc, density/shrinkage blocks were removed in 5-ring groups and all remaining discs were sectioned into 10-ring groups.

Results

Standing Tree and HM200 Log and Stem Measures

The standing tree properties are given in Table 2 are for the thirteen felled trees. A wide range in properties was observed. DBHOB ranged from 380 to 842mm (average 590mm) and tree height ranged from 29.4m to 41.1m

Table 2: Standing tree properties

Tree No	DBH OB (mm)	Tree height (m)	Pruned height (m)	Outerwood density (kg/m^3)
2	511	29.4	5.2	274
4	400	35.2	6.0	385
5	380	31.4	6.5	420
6	385	31.0	6.0	360
7	583	31.8	6.6	405
8	770	41.1	6.1	335
9	602	40.4	6.8	345
10	680	32.6	5.2	305
11	603	38.0	6.5	347
12	810	35.5	7.1	341
14	565	32.7	6.5	333
16	540	40.0	6.1	382
17	842			299
Mean	**590**	**34.9**	**6.2**	**348**
Min.	380	29.4	5.2	274
Max.	842	41.1	7.1	420

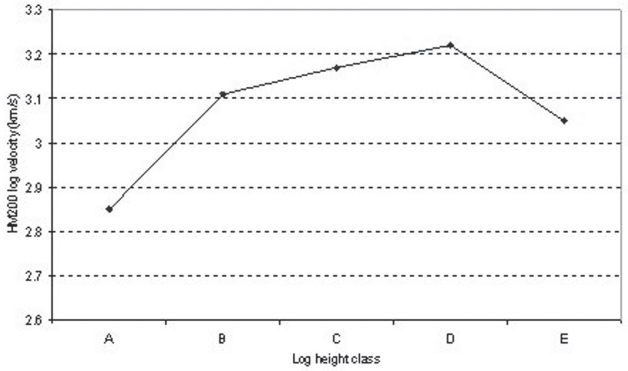

Figure 2: Average HM200 trends by log height class

averaging 34.9m. Outerwood density values in the sample stems ranged from 274 kg/m^3 to 420 kg/m^3 (average 348 kg/m^3). The outerwood values from the Mangatu site covered most of the range observed in other studies of NZ redwood (Cown, 2008).

After stem felling, log acoustic stiffness was measured with the HM200.The overall trends are shown in Figure 2.

As has been observed in radiata pine, acoustic values tend to increase upwards in the stem. It is considered that this is due to the decreasing moisture content due to reducing heartwood content, and may not reflect actual differences in lumber stiffness.

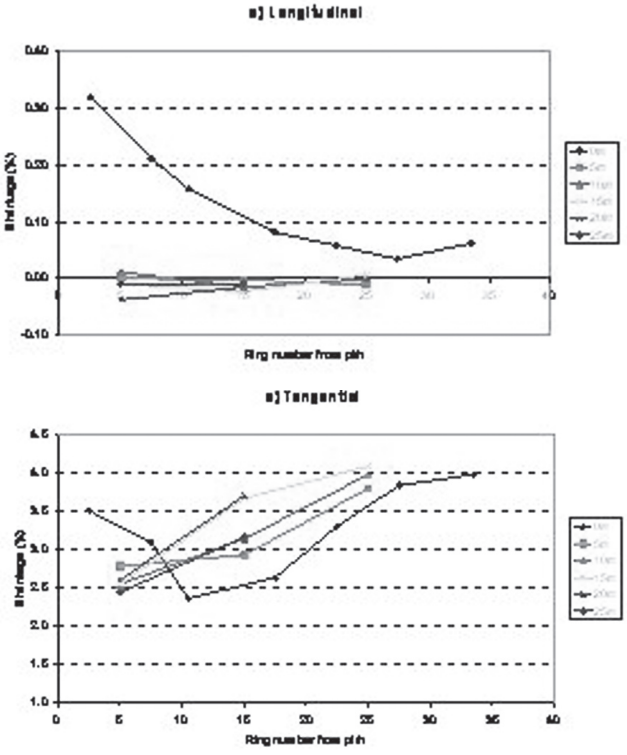

Figure 4: Shrinkage by ring groups and disc heights

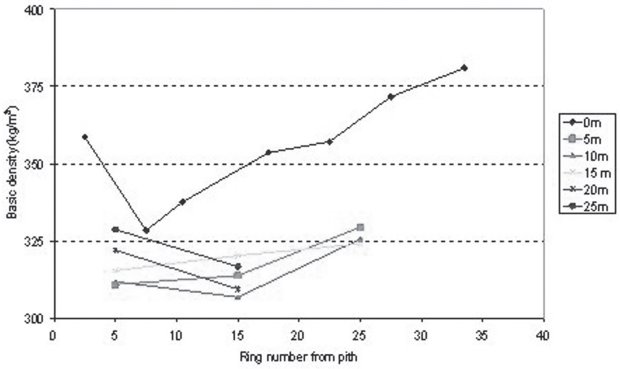

Figure 3: Radial wood density trends at 5 heights (ring groups were combined in some samples due to narrow rings).

Wood Property Measures

Basic Density Trends

The density values were summarised by pith-to-bark trends according to disc height (Figure 3). With the exception of the butt disc, there was little variation in average values from pith to bark. This confirms the low density and within-tree uniformity observed in other redwood studies (Cown, 2008). Heartwood and sapwood were virtually identical in wood density above the butt level.

Shrinkage Trends

Redwood is renowned for low shrinkage and good dimensional stability (USDA, 1999). Previous studies (Young, 1983; Colbert and McConchie, 1983) confirmed this.

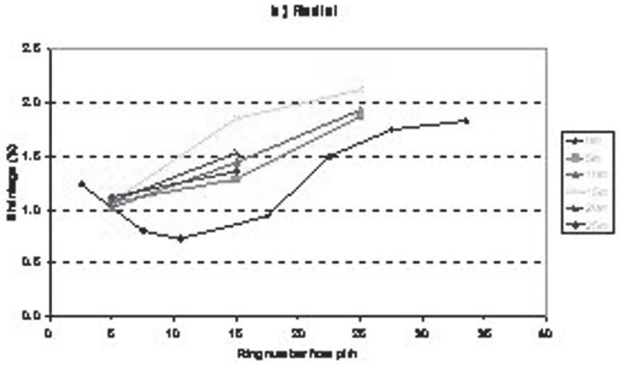

Table 3: Average wood properties by disc height

Disc ht. (m)	DOB (mm)	DIB (mm)	Bark (mm)	Heartwood (%)	Heart rings	Total rings	Air-dry shrinkage (12% MC)*			Basic density (kg/m³)	N
							Long.	Rad.	Tan.		
0.2	687	576	56	57	21	36	0.14	1.2	3.2	349	13
5.3	-	403	-	57	16	30	0.01	1.4	3.1	314	13
10.2	382	351	16	52	13	26	0.00	1.4	3.1	310	13
15.0	292	289	13	47	10	22	0.01	1.5	3.2	316	12
19.6	270	263	12	35	8	17	0.03	1.3	3.2	317	8
25.2	247	194	26	27	6	15	0.01	1.2	2.8	323	3

* Long. = Longitudinal shrinkage
Rad. = Radial shrinkage
Tan. = Tangential shrinkage

Average values for dimensional shrinkage are summarised in Figure 4. Overall, values are considerably lower and more uniform than for radiata pine (Cown *et al.* 1991).

The values in this study indicated that longitudinal shrinkage can be similar to radiata only in the inner rings at the extreme base of the stem where values can reach 0.3% on average. Elsewhere longitudinal shrinkage is

Table 4: Average stem wood properties

Tree	Volume (m³)	Bark depth (mm)	Heartwood (%)	Heart rings	Total rings	Air-dry shrinkage (Air-dry)				Basic density (kg/m³)
						Long. (%)	Rad. (%)	Tan. (%)	Comb. (%)	
2	1.22	26	52	13	28	0.17	1.0	2.8	3.9 -	275
4	1.41	23	52	15	31	0.10	1.3	3.1	4.5	337
5	1.00	21	46	10 -	27	0.01	1.9	3.4	5.3	380 +
6	0.84 -	15	46	12	26	0.00	1.3	2.9	4.2	340
7	2.54	24	52	14	30	0.01	1.6	3.3	4.8	370
8	4.01 +	25	60	18	29	0.04	1.5	4.0	5.5 +	302
9	2.80	12	44 -	15	30	-0.01	1.5	3.6	5.1	304
10	2.07	25	60	23 +	32	0.02	1.0	2.8	3.9 -	320
11	2.52	23	61	17	29	0.01	1.3	2.8	4.2	315
12	3.94	27	58	18	30	0.00	1.3	3.5	4.8	304
14	1.80	27	46	12	29	0.14	1.3	2.7	4.1	331
16	2.90	28	56	19	30	0.05	1.1	2.9	4.0	361
17	2.45	22	66 +	21	31	0.02	1.2	3.0	4.2	262 -
Mean	2.27	23	54	16	30	0.04	1.3	3.1	4.5	323

- Minimum
- Maximum

inconsequential. For radial and tangential values, trends are similar to those outlined in Colbert and McConchie (1983):

Disc properties

Average disc values by height are provided in Table 3 and selected wood properties summarised in Fig 4.

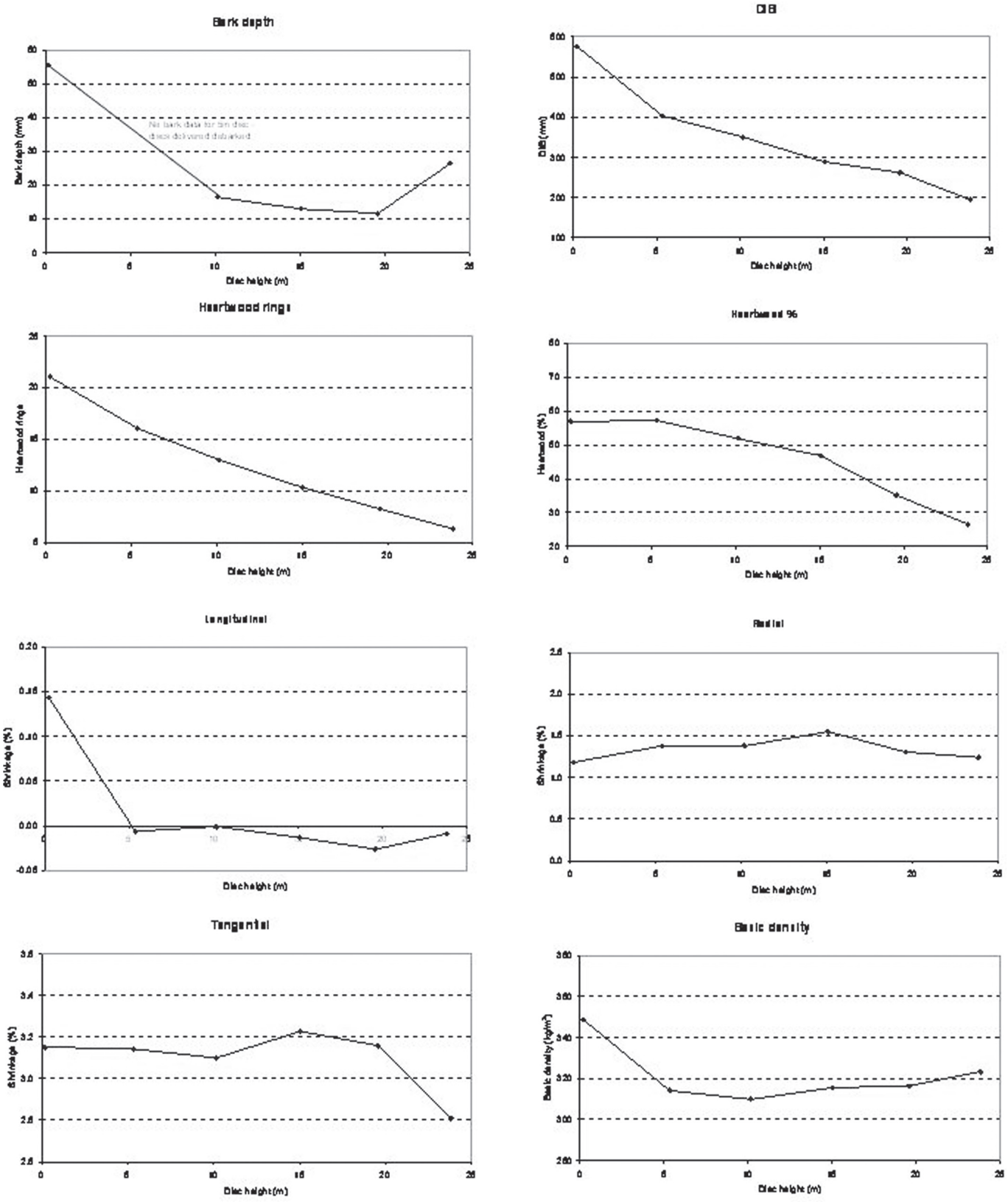

Figure 5: Selected wood properties by disc height

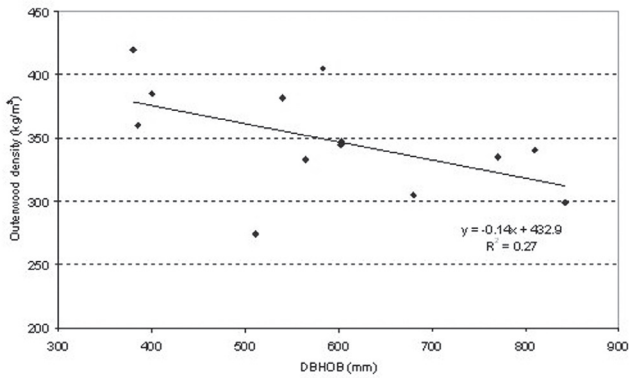

Figure 6: Relationship between DBH and outerwood density

Heartwood decreases progressively with stem height from an average of 21 growth rings at the base (46 - 67% area) to 6 growth rings at 25m (30 - 35% area). The averages of other wood properties are shown in Figure 5, where is can be seen that most wood properties remain remarkably constant above the butt level, in contrast to radiata pine (Cown *et al.*, 1991).

Log and Tree properties

The wood characteristics measured on the discs were used to calculate weighted values for individual logs and stems, and hence average stem values (Table 4).

Volume of the sample trees ranged from 0.84 to 4.01 m^3 and heartwood % from 44 to 66%. Wood density varied from a low of 262 kg/m^3 to a high of 380 kg/m^3. Shrinkage values remained fairly uniform throughout and the ratio of tangential: radial averaged 2.4 - indicating stable wood.

Relationships

The sample trees were selected to cover the range in DBH values, and within the stems there was a weak correlation between DBH and outerwood density (Figure 6).

The The correlation between outerwood increment core values and the weighted tree values was excellent % (Figure 7).

Conclusion

This is the most comprehensive study of NZ redwood to date, comprising 13 stems from a single site.

Heartwood % in the 38-year-old stand ranged from 44% to 66% confirming that redwood is a "heartwood" species. In this case stem values averaged 54%

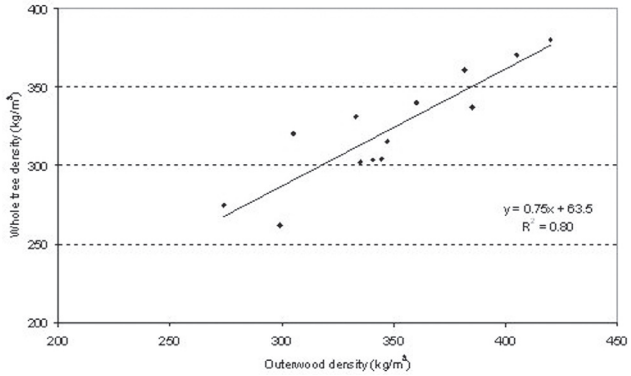

Figure 7: Outerwood density prediction of stem density

The wood density has again been shown to be relatively uniform within stems but highly variable between individual stems. In general (as with other species), there is a slight negative relationship between growth and wood density. Much of the variation in density is most likely genetic in origin, and stem differences of up to 120 kg/m^3 have been observed in this study (Table 5). Fortunately, there is a very good relationship between BH outerwood density and whole stem, which means that if low density wood is considered undesirable, stems can be screened non-destructively and poor individuals identified. Improvement in redwood quality is most likely to come from the selection of clones with average or above wood density, and with improved durability.

Shrinkage values also confirmed the low overall shrinkage of redwood.

Compared to other NZ data (Table 5) the mean values for this study sit pretty well around the average. Overall, regional variation seems to be minimal and reaffirms the uniform nature of the average characteristics of the NZ redwood. Indicative US data are included for comparison where available (USDA, 1999).

Acknowledgements

The authors are indebted to Paul Silcock (NZ Forestry Ltd. - formerly Scion) and Hamish Marshall (Interpine Forestry) for carrying out the sawing study and providing the wood samples for this study. Thanks are due to the FFR redwood industry members, MAF and FIDA for funding the sawing study, and to the Foundation for Research Science and Technology (Diverse Forests CO4X0805) for funding this publication.

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Table 5: Comparison of Redwood study results

Location	No. of trees	Age (years)	Basic density (kg/m3)	Heartwood (%)	Air-dry shrinkage (adjusted to 12% MC)			Comments
					Long.	Rad.	Tan.	
					(%)			
NZ Data								
Auckland region	1	20 est.	311		0.05	0.9	2.8	1 board sample
Rotoehu	57	22	320	47	-	-	-	1.4m discs
Taumarunui	2	28	232		-	-	-	2 board sample
Taumarunui	2	29	348		0.19	1.1	2.9	6 board sample
Gisborne	2	40	365		-	-	-	
Tauranga	5	45	353	52	0.01	1.4	2.9	
East Cape	2	49	367		0.06	1.4	3.1	
Whaka Cpt 2	7	50	289		0.02	1.5	3.5	
FRI Arboretum	1	50 est.	397		0.02	1.6	2.8	
Mangatu	**13**	**54**	**323**	**54**	**0.04**	**1.3**	**3.1**	**Current study**
Helensville	1	60 est.	380		-	-	-	2 board sample
Waitapu Cpt 2	2	63	460		-	-	-	
Hokitika	1	64	225	75	-	-	-	
Whaka Cpt 2	7	69	327	65	-	-	-	
Mangakino	4	-	336		-	-	-	
Mean (107 trees)		46	336	59	0.06	1.3	3.0	
US Data								
Old Growth	**?**	**>100**	**400**	*****	**N/A**	**2.6**	**4.4**	
Young Growth	**?**	**60-80**	**350**	**“**	**N/A**	**2.2**	**4.9**	

* US values are for heartwood. According to Piirto (1986) the heartwood of both old growth and young growth has appreciably lower shrinkage than sapwood.

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