COMPARATIVE MOISTURE UPTAKE OF NEW ZEALAND GROWN DOUGLAS-FIR AND RADIATA-PINE STRUCTURAL TIMBER WHEN EXPOSED TO RAIN-WETTING

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DOUGLAS-FIR COOPERATIVE

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SUMMARY

Trials were undertaken to determine the relative resistance of radiata pine and Douglas-fir to wetting when exposed to the weather.

Douglas-fir samples were obtained from one Central North Island and three South Island sources and had a heartwood/sapwood mix typical for each resource. Radiata pine sapwood and heartwood samples were obtained from a Central North Island source. Material was exposed to the weather as horizontal studs in the first trial, and as horizontal and vertical studs in the second trial. The first trial ran over later winter from 29 July to 22 September 2003; the second, and more comprehensive investigation, from 22 October to 17 December 2003.

In the first trial, after seven days exposure, radiata pine reached a moisture content which would sustain decay (~27% mc), and remained well above that moisture content for the remaining 48 days of the trial. However, the maximum moisture content attained by Douglas-fir throughout the trial was only 21.8 % mc.

In the second trial, radiata pine sapwood rapidly attained a moisture content conducive to decay, and Douglas-fir did not. Because of the warmer and sunnier weather, fluctuations in moisture content were more pronounced than in the winter trial. Samples exposed horizontally attained higher moisture contents than those exposed vertically, irrespective of wood species or relative heartwood/sapwood content.

It is concluded that Douglas-fir timber shows significant positive differences from radiata pine in terms of susceptibility to moisture uptake. This trial confirmed the ‘refractory’ reputation of Douglas-fir, and the ‘absorbent’ reputation of radiata pine. At a practical level, Douglas-fir heartwood and sapwood can be regarded as equally impermeable, and independent of where in New Zealand it was grown.

INTRODUCTION

Untreated Douglas-fir and untreated radiata pine are assumed to be at similar risk of decay when used in the same structural situations (NZS 3602: 2004 "Timber and wood-based products for use in buildings" and the NZ Building Code). Neither is approved for use in the untreated state as framing for exterior walls except in buildings at a low risk of inadvertent moisture ingress.

Previous research has shown that a minimum wood moisture content of 27% is necessary for decay to be initiated in radiata pine sapwood when it is in contact with decaying wood (Page *et al.*, 2003). For the purposes of this report and conclusions, the conservative assumption is made that the minimum moisture for decay initiation is the same (27%) for Douglas-fir sapwood and heartwood and for radiata pine heartwood. However, once initiated, the rate of decay would be less in most examples of radiata pine heartwood and even less in Douglas-fir heartwood because of their comparative and greater natural durability than sapwood.

It is well known that Douglas-fir is a refractory species and its timber is difficult to impregnate with water, even under pressure. Radiata pine sapwood, on the other hand, is much more permeable to liquid water. Radiata pine heartwood has more variable permeability; some being as permeable as sapwood, some being almost as refractory as Douglas-fir.

It has been argued that although both timbers would differ little in susceptibility to decay if they attained the same moisture content (~ 27% MC), there would be significant differences in resistance to moisture uptake if both were exposed to the same wetting regimes, such as that represented by rainfall. Being the more permeable, radiata pine would be expected to attain a moisture content suitable for decay much more readily than Douglas-fir.

PRELIMINARY TRIAL

To test that hypothesis, ten 3.5 m lengths 90x45 mm of Douglas-fir and six 3.5 m lengths of radiata pine were selected from stock at Forest Research. Douglas-fir samples tended to be more "hearty" than radiata pine samples. A 10 mm thick section was taken approximately 1 metre from one end and initial moisture content determined by weighing the section, oven-drying and reweighing.

Residual 2.5 m lengths were weighed and lightly hosed with water. Samples were then laid out on bearers on an open asphalted area on Forest Research campus. Samples were sufficiently high off the ground to avoid additional wetting by rain splash. Samples were weighed at irregular intervals, although the frequency of weighing increased as the trial progressed. Moisture contents were calculated at each weighing from initial moisture content, initial sample weight and increase/decrease in weight from the previous weighing. The trial commenced on 29 July 2003 and was terminated 55 days later on 22 September 2003.

Daily rainfall was recorded at a weather station located approximately 1km NE of the trial. Although neither temperatures nor sunshine hours were recorded, the weather could be regarded as typical for late winter in Rotorua.

Results (Fig 1) showed that after the first six days exposure - during which time 11mm of rain fell - the moisture content of radiata pine reached the minimum required to initiate decay in that species (blue line in Fig 1). It remained above that minimum for the next 49 days after which the trial was terminated. In contrast, the moisture content of Douglas-fir samples never approached the required minimum moisture content throughout the whole period of the trial. In one 24-hour period in this test (Day 38), framing was subjected to 40mm rainfall. During that time the moisture content of Douglas-fir rose from 20.9% to 21.8%, well below the threshold moisture content of 27% required to initiate decay in radiata pine. During that same period, the moisture content of radiata pine rose from 39.7 to 43.1%.

Conclusions from the trial were that Douglas-fir is more difficult to wet than radiata pine and, under the conditions of the test, failed to reach a moisture content where there would be a risk of decay if it was in contact with decaying wood. Conversely, radiata pine reached this moisture content after 6 days exposure to rainfall and never went below that moisture content for the remainder of the trial.

Following this preliminary trial, the Douglas-fir Research Co-operative commissioned a more detailed investigation to assess moisture absorption characteristics of Douglas-fir from South Island sources and to compare this with that of Douglas-fir from the initial trial. Emphasis was also placed on determining if there were any significant differences in moisture absorption between Douglas-fir sapwood and heartwood in relation to that of radiata pine sapwood and heartwood.

MAIN TRIAL

Forty pieces of dried 90 x 45mm gauged radiata pine 2.4m in length were selected from central North Island sources, with 20 pieces consisting entirely of sapwood and 20 of heartwood.

Thirty pieces of 90 x 45mm gauged Douglas-fir, 2.4m in length were sourced from each of four locations: Rotorua, Canterbury, Tapanui and Naseby. Shipments contained samples which were 100% heartwood and up to 90 % sapwood. Samples were received either green or dried. Green samples were forced-air dried in the laboratory so that moisture contents of all samples at the commencement of the trial would be as similar as possible (Table 1). It was felt inappropriate to kiln dry all Douglas-fir shipments to a constant moisture content, since kiln drying this material is not common industrial practice.

Table 1: Initial mean moisture contents

Shipment/location	Initial mean moisture content (%) (range)
Douglas-fir Rotorua	13.4 (11.8 - 16.5)
Douglas-fir Tapanui	14.8 (13.1 - 16.8)
Douglas-fir Naseby	14.9 (13.2 - 16.9)
Douglas-fir Canterbury	13.4 (12.3 - 16.6)
Radiata pine sapwood CNI	12.1 (10.9 - 13.6)
Radiata pine heartwood CNI	13.9 (9.9 16.9)

The sapwood percentage of each piece of Douglas-fir timber was estimated, and the pieces from each separate source were divided into pairs with similar sapwood content. A nail was fixed at one end of one of each pair of samples so that it could be hung vertically from wire mesh, which formed the East wall of a building located on Forest Research campus. The roof of this building was sufficiently high so that it did not impede exposure to rainfall.

The other pair of each sample was exposed horizontally in the same manner as the preliminary trial.

All wood samples of Douglas-fir and radiata pine were weighed immediately before exposing the test material to the weather over a 56-day period from 22 October 2003. All samples were weighed at intervals and weight gains or losses recorded. Weight gains and losses were then converted into changes in moisture content of individual samples.

RESULTS

Changes in moisture content over the 55-day exposure period are shown in Fig 2 (horizontal exposure) and Fig 3 (vertical exposure). Included in each figure is a line drawn at 27% moisture content, which is the limiting moisture content of radiata pine for decay to be initiated if susceptible wood is in contact with decaying wood (Page *et al.*, 2003).

Statistical Analysis

The moisture content measurements were analysed as effects of the following independent variables: location (timber source), position (horizontal or vertical exposure), sapwood percentage, and species using analyses of variance (PROC GLM of SAS 8.2). The effects of the independent variables were grouped using Fisher's Least Significant Difference (95% significance-level). The effect of sapwood percentage was modelled for Douglas-fir using a linear regression.

The effects of location of the timber for Douglas-fir are presented in Table 2. The effect of position for both species is presented in Table 3. The effect of sapwood percentage on moisture content for radiata pine is presented in Table 4, while the results for Douglas-fir are presented in Figure 4. The linear regression for moisture content as a function of sapwood percentage for Douglas-fir was significant with a slope of 0.018 (R^2 = 0.03).

A total of 19 different pieces of radiata pine had at some measurement time higher moisture content than the critical 27%, and on average those 19 pieces were above the threshold for 10 measurement times. For Douglas-fir only one piece at one measurements time was above the threshold.

Site	Mean	Standard deviation	Group
Canterbury	17.87	2.60	A
Naseby	17.48	2.22	B
Rotorua	17.75	2.73	A
Tapanui	17.37	2.36	B

Table 2 – ANOVA summary for moisture content of Douglas-fir as an effect of location. Combined effects of location and sapwood, and location and position were not statistically significant.

Position	Mean	Standard deviation	Group
Horizontal – Douglas-fir	18.26	2.75	A
Vertical – Douglas-fir	16.85	1.88	B
Horizontal – radiata pine	25.72	9.22	C
Vertical – radiata pine	18.58	4.70	A

Table 3 – ANOVA summary for moisture content of Douglas-fir and radiata pine as an effect of position. Combined effects of location and position, and sapwood and position were not statistically significant.

Wood	Mean	Standard deviation	Group
Sapwood	24.89	9.73	A
Heartwood	19.73	5.25	B

Table 4 – ANOVA summary for moisture content of radiata pine as an effect of sapwood/heartwood percentage. A combined effect of sapwood and position was not statistically significant.

DISCUSSION

From Table 2 it is evident that there were statistically significant differences between Douglas-fir from some of the locations. However, the absolute differences were very small, for example the wood with the highest average moisture content was that from Canterbury, and it contained on average 0.48 percent more moisture than the driest wood from Naseby. There were no combined effects between location and position, or location and sapwood percentage. In other words, wood from different sources does not react differently to position (vertical or horizontal) nor sapwood percentage (range 0-90%). Hence, it is concluded that all NZ grown Douglas-fir timber can be similarly classified with respect to moisture uptake, regardless of its origin.

From Table 3, it is evident that it was important how the wood was positioned, with marked differences between species. Horizontally positioned radiata pine had an average moisture content 7.1% higher than if positioned vertically. The difference for Douglas-fir was only 1.4%. Douglas-fir positioned horizontally did not differ significantly from vertically positioned radiata pine.

The amount of sapwood has only a small effect on the moisture uptake for Douglas-fir (Figure 4). The modelled difference between pieces which are entirely sapwood and are entirely heartwood is only 1.8%. For radiata pine, the difference in moisture content between all-sapwood pieces and all-heartwood pieces was 5.2 percent. Furthermore, pieces of Douglas-fir sapwood on average contained less moisture than pieces of radiata pine heartwood.

We conclude that Douglas-fir timber shows significant positive differences from radiata pine in terms of susceptibility to moisture uptake. This trial confirmed the ‘refractory’ reputation of Douglas-fir, and the ‘absorbent’ reputation of radiata pine. At a practical level, Douglas-fir heartwood and sapwood can be regarded as equally impermeable, and independent of where in New Zealand it was grown.

REFERENCE

Dave Page, Mick Hedley, Betty Patterson and Jackie van der Waals. 2003. The effect of wood moisture content and timber treatment on initiation and development of decay in radiata pine framing. Report prepared for the Weathertight Buildings Steering Group, February 2003.

Fig 1 Moisture content of 90 x 45 x 2500 mm radiata pine and Douglas fir exposed to natural rain wetting after initial artificial wetting on Day 0

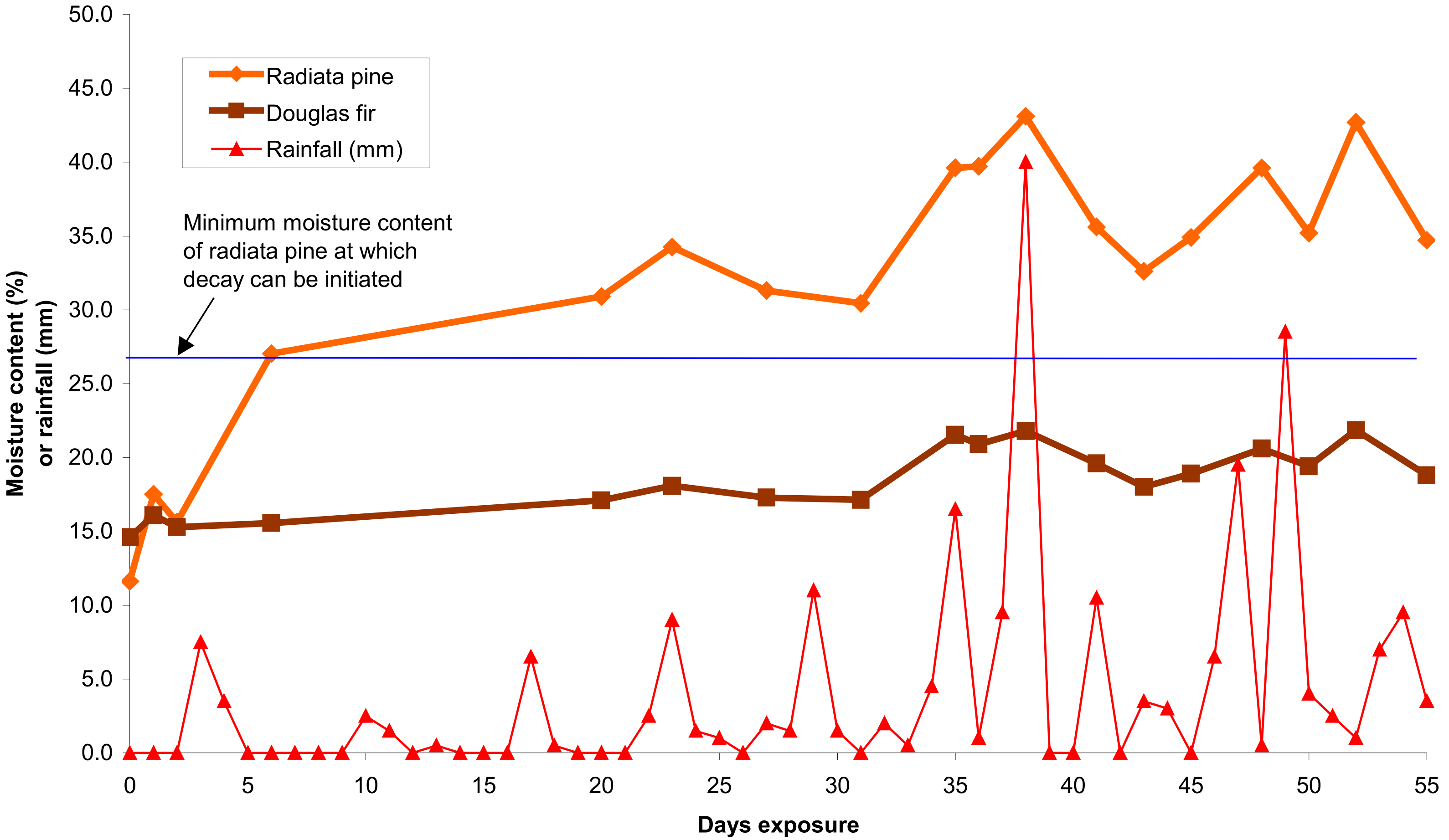


Fig 2 Main trial horizontal samples

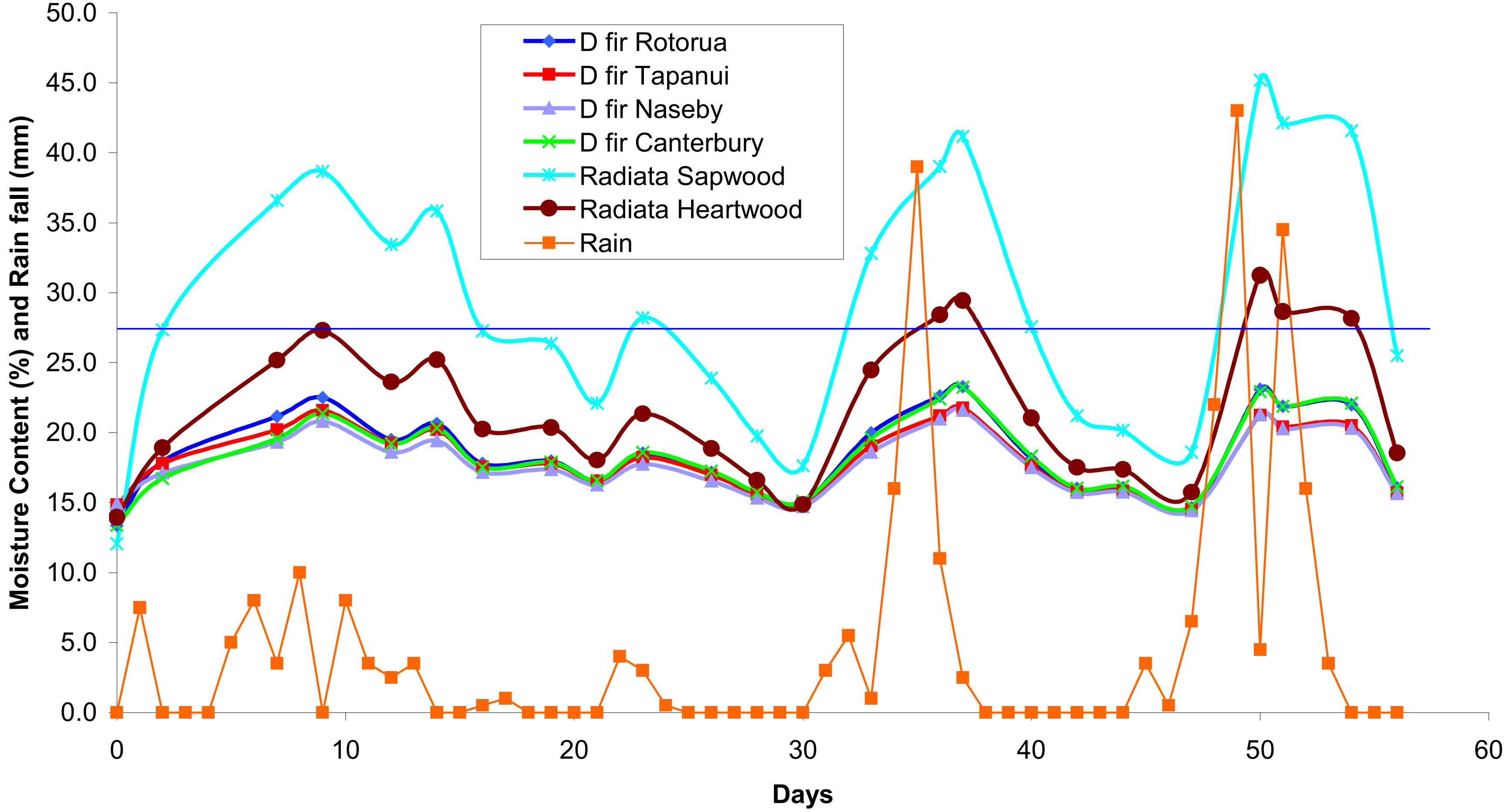
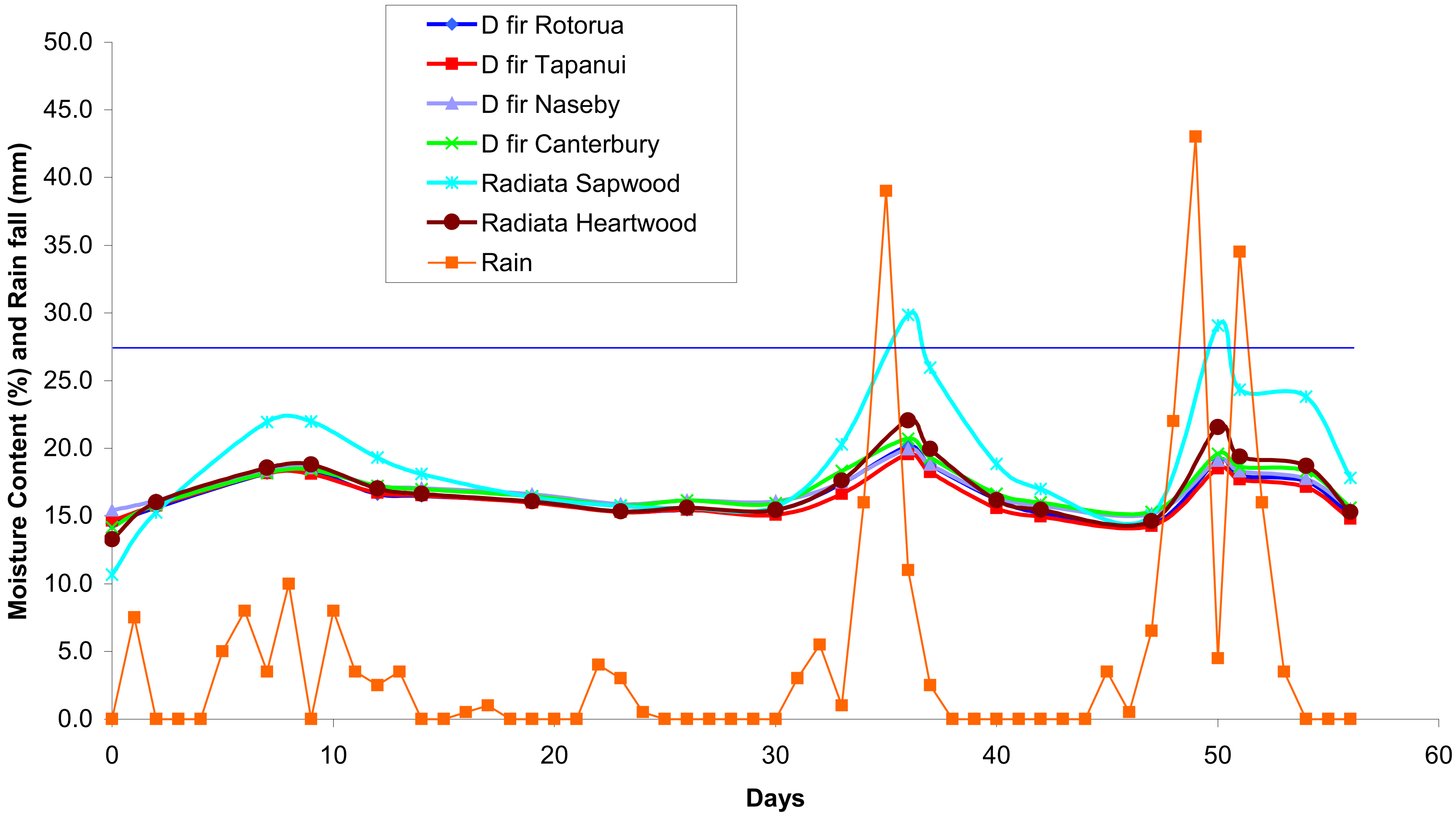


Fig 3 Main trial vertical samples



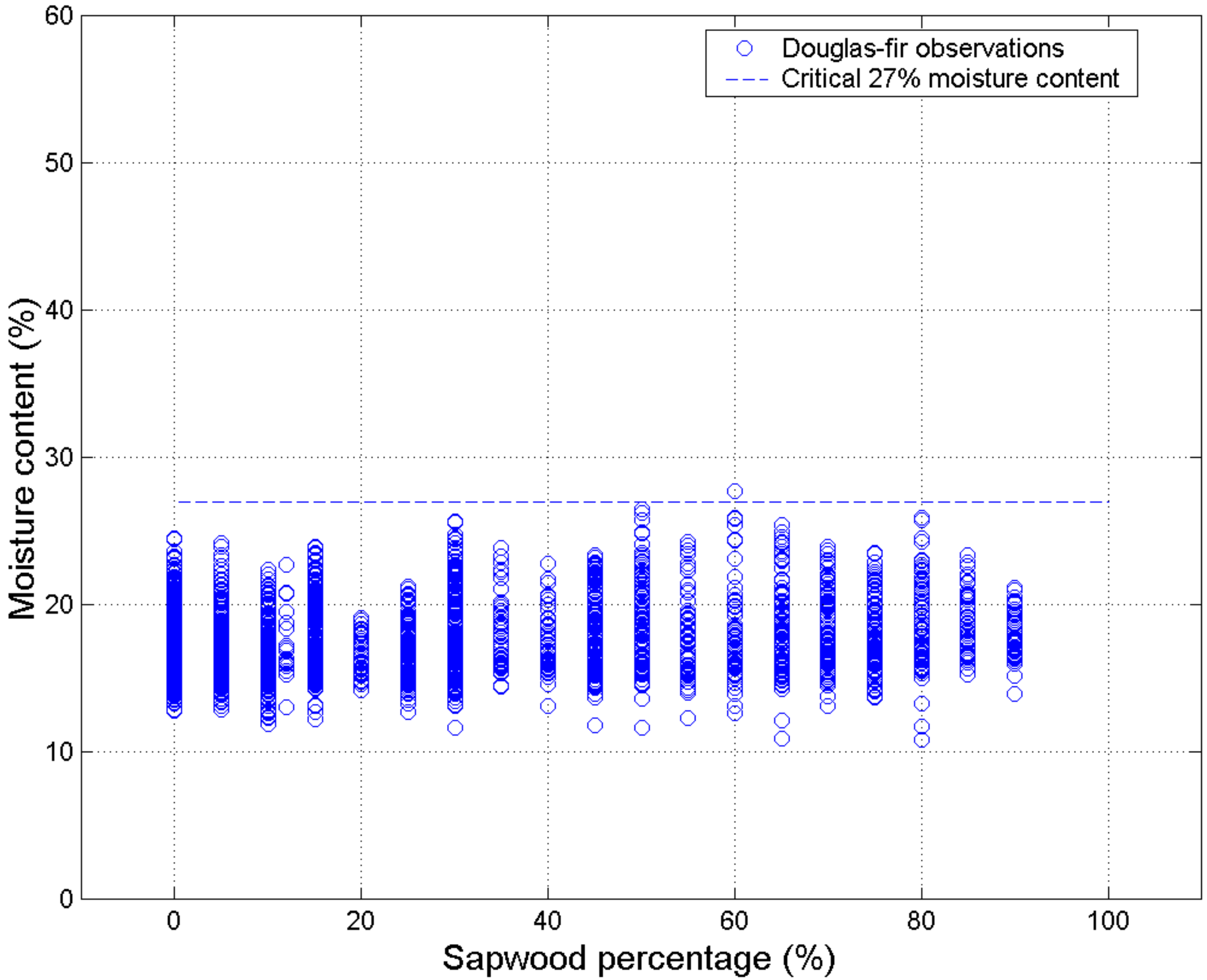


Figure 4. Observations of moisture content versus sapwood percentage for Douglas-fir and the critical 27% moisture content threshold