

TOTARA – A GROWING RESOURCE!

Dave Cown and David Bergin

Totara (*Podocarpus totara*) regenerates prolifically in marginal pastoral hill country where there is a considerable resource with the potential to be managed as a future long-term supply of specialty timber (Figure 1). Totara is widely dispersed throughout New Zealand from sea level to over 500 metres, from well-drained flood plains to drought-prone hills, and from clay to volcanic soils. In Northland, young totara can grow rapidly and develop straight trunks of several metres in a decade, if conditions are suitable. The prospect of sawlogs with large diameters can be measured in decades, not centuries, as with old-growth. Under current law, timber can only be milled and sold from indigenous forests which are sustainably managed. However, in the case of regenerating totara, not enough is known about selection, management practices and sustainable logging options - and a market for the young timber must also be developed.

Open-grown totara usually develops a large crown with multiple leaders (Figure 2). However, an investigation of naturally-regenerating totara-dominant stands on farmland in Northland by the Northland Totara Working Group (NTWG) indicated that they develop into pole and semi-mature stands. These stands are relatively uniform in stem size and form as natural thinning occurs. While naturally regenerating stands may appear to grow slowly, research indicates that improved growth rates can be achieved by timely thinning. Naturally regenerating totara trees on farms could, therefore, have great potential as a sustainable wood resource. Under management for wood production, the saplings and poles with the best form and spacing could be selected and lower branches removed to make knot-free butt logs. Members of the NTWG believe that totara offers a unique opportunity for sustainable management on working farms, even in the presence of ongoing grazing!



Figure 1: Regenerating totara on farmland is a feature on many pastoral hill country landscapes throughout New Zealand. What is the potential for managing and utilising this resource?



Figure 2: Totara growing on farms are of varying stem size and form. Edge and open-grown trees form large round crowns with large diameter short stems; trees within stands can often have straight single trunks.

The NTWG was formally established in 2005 by a wide range of stakeholders including local landowners, agencies and trusts. It has established trials in Northland to evaluate a range of thinning and pruning options in naturally regenerating stands with different ages. The initiative has links with Scion's Diverse Forests programme within Future Forest Research.

The long term outcome of the project will benefit farmers throughout New Zealand through the utilisation of an existing resource that currently has low economic value associated with it. Naturally regenerated totara holds many environmental benefits such as the reduction of hill slope erosion, enhancement of water quality and increase of biodiversity. Regenerating totara often occurs on less productive steep hillslopes that continue to be grazed, or within riparian zones that are increasingly being fenced off. Consequently, management of the species as a long-term timber crop offers landowners opportunities to enhance their existing pastoral landscapes. Combined with the timber and carbon sequestration benefits, this approach has a unique

blend of productive, environmental and social sustainability outcomes.

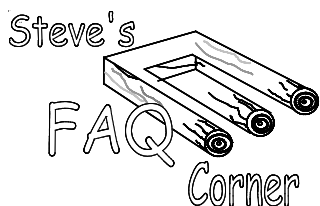
Totara was favoured by Maori due to its availability in large sizes, ease of splitting and natural durability and is still highly regarded for carving. Information from farmers and local handcraft workers indicates that young totara has a range of excellent qualities, but is rarely used as a specialty timber because of lack of a sustained resource. Rather, it is often regarded as weed and consigned to the firewood pile...

Amongst a number of initiatives by the NTWG, Scion is involved in the evaluation of the wood properties of naturally regenerated totara as a building block towards a sustainable market of high-value end-use applications. This will have economic, social and environmental sustainability benefits.

Indications to date are that the wood from regenerating stands of totara on farmland (Figure 3), while not as durable, has many of the properties of old-growth crops. There are likely to be high-value end-uses suited to the mixtures of sapwood and heartwood found in relatively fast-growing naturally regenerated totara.



Figure 3: Sawn timber from a recently felled open-grown totara tree that has regenerated on farmland in Northland.



Each issue we will delve into our files and give answers to frequently asked drying questions, trying to add to our general understanding of the technical issues behind the art of Wood Drying

WHAT IS THE EFFECT OF BLOCK STORAGE OF GREEN TIMBER ON KILN DRYING OF RADIATA?

Steve Rzley

It is well known that delays between sawing and drying should be avoided as final kiln-dried (KD) moisture content variability increases, as does the increased likelihood of surface checking. A previous reply to questions relating to ‘storage’ before kiln drying attributed increased surface checking to the drying out that occurs on the surface when the timber is stored in fillet (see the Scion Wood Processing Newsletter No 39: 2006). However, the matter of final moisture content (MC) variability and how the storage period of block-stacked green timber might contribute to this variability still needs to be addressed.

While examining the musty treasures lurking in the Scion vault, I came across a study that examined batches of 40 matched anti-sap-stain treated sapwood boards (around 130% MC) that were stored, block-stacked, for varying lengths of time. Using a 90/60°C Accelerated Conventional Temperature (ACT) drying schedule, the stacks were dried for 42 hours and checked for moisture content variability. Before drying, some boards from each stack were assessed by microscope.

Table 1 shows that the storage period of green block-stacked material appears to effect the drying and makes it less uniform. The wood also becomes progressively slower to dry (final MC is higher for the same drying time) and less uniform (both the MC gradient and the coefficient of variation (CV) of MC

increases) with increasing storage time. This indicates that green storage adversely influences the moisture content variability of the final KD and should be minimised. It is unlikely that surface drying effects are dominant during block-stacking and it is probable that other factors are present. This behaviour during storage of up to 10 weeks is correlated to the build-up of observable bacteria, seen in the right hand columns of Table 1. While every board was not sampled, it is evident that bacterial frequency increased within the storage times studied.

A look at the microscope photos provides a possible explanation. After storage, bacteria growths were observed on the bordered pit that connects cell lumens (Figure 1). A healthy bordered pit unaffected by bacteria looks very different (Figure 2). Technically the central torus, which is supported by the radial ‘spoke-like’ structure, controls fluid flow through the pit, and, as we discussed in a previous issue of the Scion Wood Processing Newsletter (No 42: 2008), if it becomes infected with bacteria it eventually becomes degraded by their growth. This pit membrane structure is known to be the main mechanism for the control of water transport between cells. In the short term, before degradation, the bacteria appear to block the opening thus limiting the passage of water. The more bacteria in the pits and in the lumens, the less chance there is of transporting moisture to the surface. This appears

Table 1: ACT drying of 40 matched boards of anti-sapstained material. Superscripts denote significant differences at 95% level.

Green block stacking period	Moisture after drying		KD MC gradient	Number of boards with bacteria after each storage period			
	Mean	CV		Mean	Nil bacteria	Moderate bacteria	Abundant bacteria
None	6.4 ^a	15	1.1 ^a	15	3	0	18
2 weeks	6.7 ^a	18	2.2 ^{a,b}	12	6	0	18
6 weeks	7.7 ^a	19	3.7 ^c	0	11	4	15
10 weeks	11.0 ^b	29	6.7 ^d	5	11	2	18

to be a possible cause for more variable drying and increased moisture gradients resulting from storage of block stacked green timber.

Since bacterial growth is very temperature dependant and the season in which this study was undertaken is unknown, it is hard to know exactly what this means

in practice in terms of recommending storage times. It does indicate, however, that storage times of greater than 2 weeks before drying, particularly in warmer temperatures which accelerate bacterial growth, should be avoided.

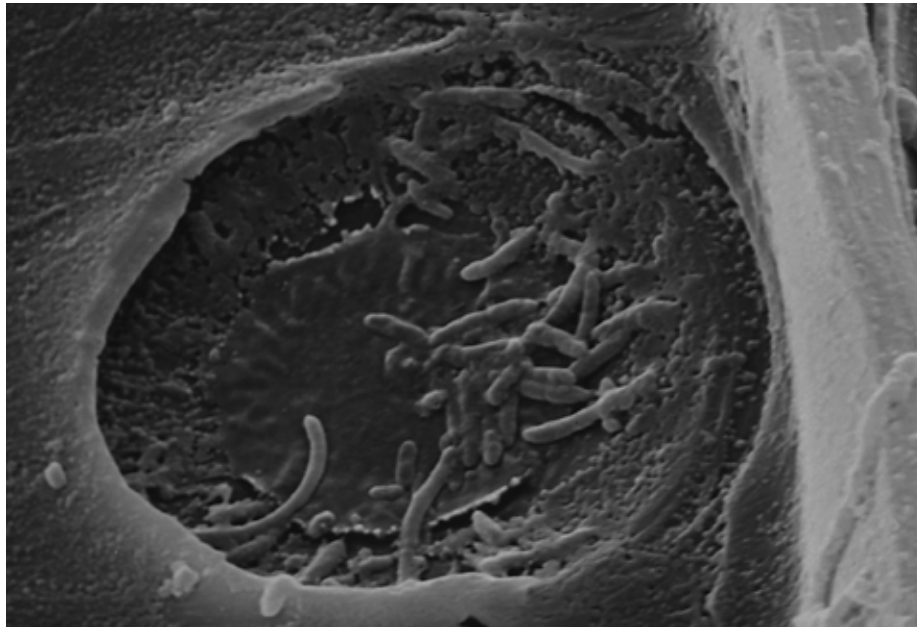


Figure 1: Bordered pit from radiata pine affected by bacteria during green storage.

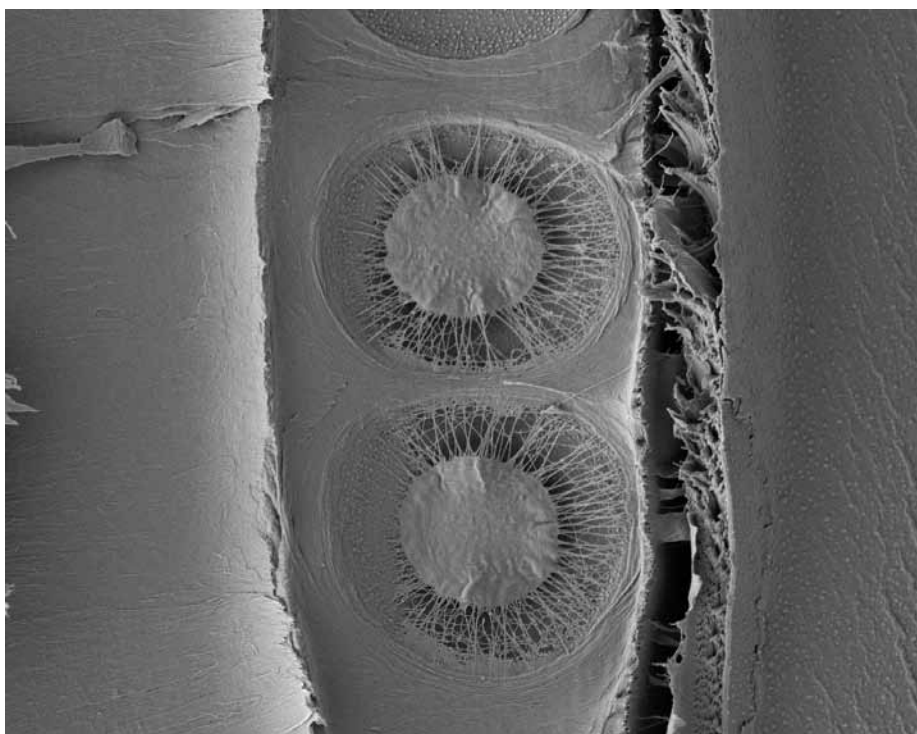


Figure 2: Bordered pit, torus and margo not affected by bacteria.

ASSESSMENT OF THE END GRAIN OF LOG ENDS AND LOG DISCS

John Lee and Rod Brownlie

Log ends and wood discs have traditionally been used to visually assess various aspects of wood quality – distribution of growth, heartwood extent, intra-ring checking, resin blemishes, compression wood, etc. With improved photography and image analysis, the surface quality becomes critical. Surfaces assessed visually have previously been created using a sharp well-maintained chainsaw, but with the move to newer technologies like RGB imagery (colour), Near Infrared (NIR) and Sonics (USV), the quality of the saw cut and the quality of the photographic images have become critical.

Two new developments have been introduced at Scion to improve the surface cut-face of stem sample discs and also to improve the consistency of digital photographic imaging of the surfaces for assessment of wood properties.

A workshop radial arm saw gives an excellent surface but is limited in its application to discs from small logs (100 mm). During 2008, a surfacing saw was developed which can ensure high quality surfaces meeting the needs of the new technologies. To match the cut quality of the radial arm saw we modified a Peterson “Skill Mill” portable sawmill by altering the type and size of the saw blade. We constructed a housing in

which the height of the disc can be adjusted so that the saw skims horizontally over the surface removing 2-5 mm of wood (Figure 1). This process uses fresh sawn discs and leaves a very smooth surface free of any tear outs or saw marks (Figure 2). Further modifications are underway to enable the saw to handle larger discs (up to 800 mm).

The skimmed discs offer much greater detail of the growth rings and wood features.

To create a permanent record and allow automatic analyses of visible features, tight control of the disc photography is necessary. Photos had previously been taken by a photographer either in the forest or using adjustable floodlights in an improvised studio environment. Latterly a fixed camera booth was constructed with controlled (fluorescent) lighting and a high quality digital camera (22 megapixels) installed in a fixed position above the samples. The conditions ensure constant lighting over the disc surface so no hotspots or shadows influence computerised analysis. The digital camera is operated remotely using proprietary software on a dedicated computer allowing instant viewing, facilitates storage and transfer to client servers for image analyses (Figure 3).



Figure 1: Discs are placed on an adjustable height table and inserted into the housing. The saw then passes over the samples.

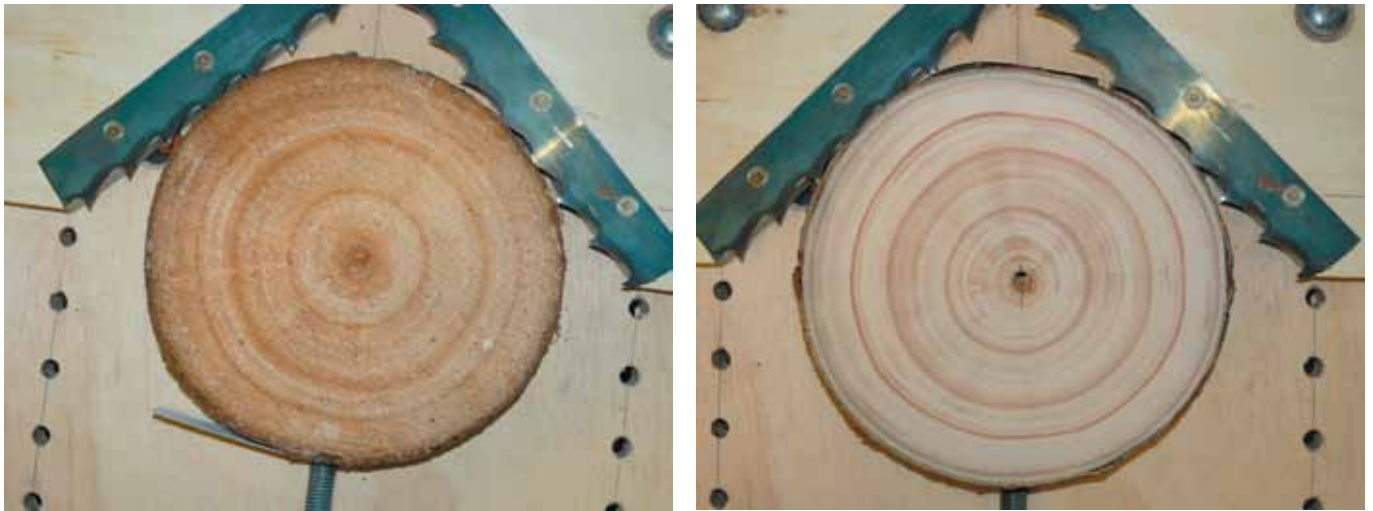


Figure 2: Disc before and after skimming.

This new system has greatly enhanced the potential for undertaking research on within-tree incidence of visible wood features such as compression wood

and resin blemishes. It also allows investigation of external factors influencing cambial growth and distribution.

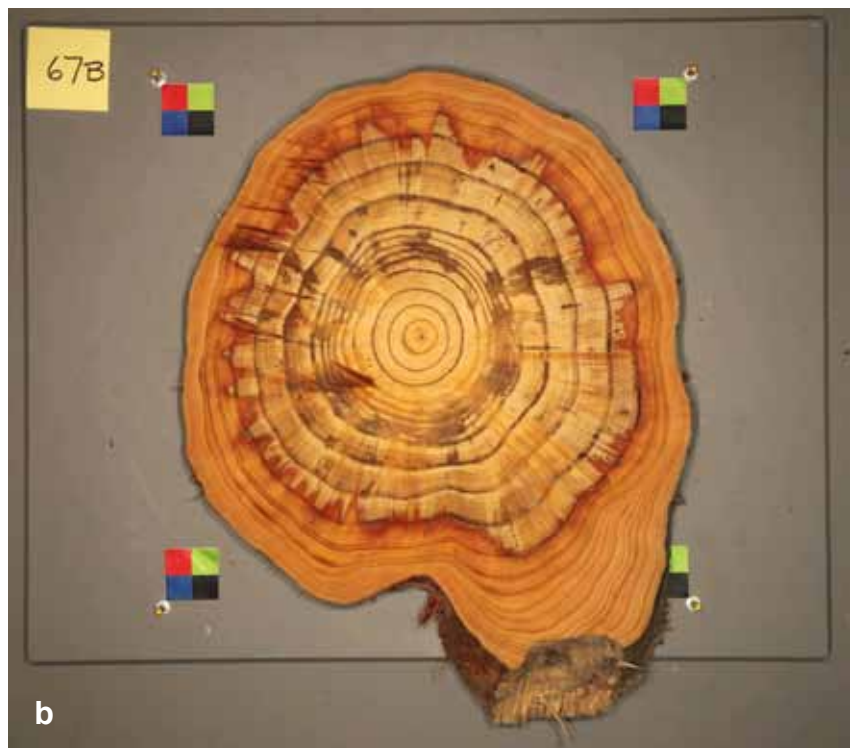


Figure 3: (a) Photo Booth with controlled light and camera function.
(b) Photo Image illustrating fine detail of growth rings and pathological heartwood.

WOOD FUELS TRADING SITE

George Estcourt

Trading

The Wood Fuels Trading Site opened in May 2009. It is an online marketplace for sellers and buyers of various forms of wood fuels. It has been developed by EECA to increase the wood energy market.

The Wood Fuels Trading Site is part of the Bioenergy Knowledge Centre (BKC) which was featured in the Scion Wood Processing Newsletter No. 39: 2006. The BKC website has since been upgraded and can be found at www.bkc.co.nz. The Wood Fuels Trading Site can be reached at www.woodfueltrading.co.nz. Figure 1 shows the Wood Fuels Trading Site.

Wood fuels – good for the environment

Wood fuels are carbon-neutral and renewable. As concerns grow over both climate change and the

reserves of fossil fuels, wood fuels have a prominent role to play in the provision of clean burning fuels. The New Zealand wood processing industry is in a good position to utilise processing residue for wood fuel production.

Wood fuels – good for your pocket

In addition to environmental benefits are the economic benefits of using wood fuels. Wood fuels are cost competitive with other fuel types. Using wood processing residue as a wood fuel minimises the need to landfill the residue, thus saving landfilling costs. Wood fuels create energy self-sufficiency so processing mills are not exposed to external fuel price fluctuations.

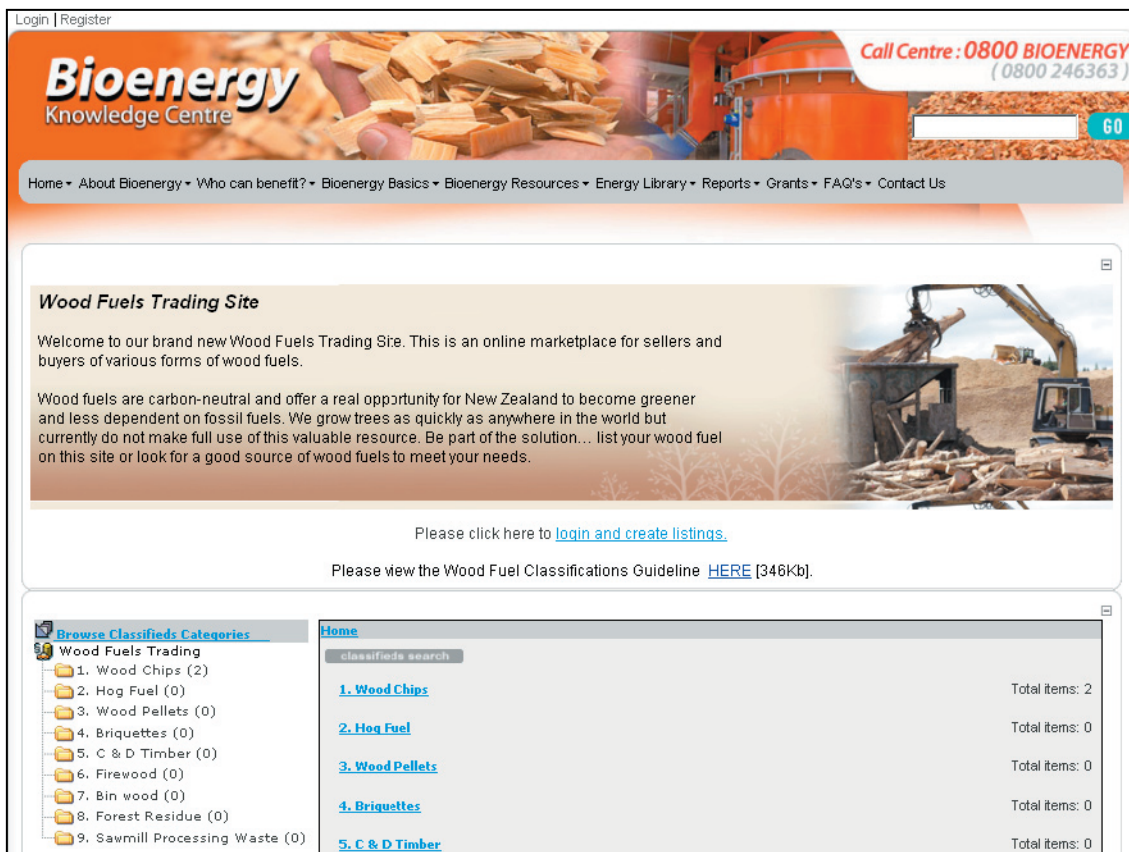


Figure 1: Wood Fuels Trading Site web-page.

Category ID: 0
 Category Path:
 Change Category: Category: 1, Wood Chips

Title:
 Message: Enter your message here.

Pricing Option: Willing to negotiate Fixed Price
 Additional Details: Free Shipping Buyer Pickup Cash Only
 Price:
 Image File: Upload photo to database (will overwrite existing photo)
 Maximum image size is 800kb
 Browse...

File Attachment: Upload Attachment file to database (will overwrite existing file)
 Browse...

Name:
 Group:
 Email:
 Phone:
 Expires: 19/08/2009

submit cancel

Figure 2: Information required to “Post new Listing”.

In order to post a listing you are required to register. This is very straight forward requiring only basic contact details such as name and e-mail address.

Once registered and logged in you can post a listing of the wood fuel you wish to trade. The information required is given in Figure 2.

An example of a listing is given in Figure 3. It describes the wood fuel being traded and gives contact details of the seller. All negotiations take place directly between seller and buyer via initial e-mail contact.

Wood fuels are categorised as wood chips, hog fuel, wood pellets, briquettes, c & d timber, firewood, bin wood, forest residue, and sawmill processing waste. These categories are defined by the Wood Fuel Classification Guidelines prepared for the Energy Efficiency Conservation Authority (EECA).

The Wood Fuels Trading Site will facilitate the use of wood fuels across New Zealand by putting suppliers and customers in contact with each other.

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Item Information
 itemID: 25
 Title: Wood chips from whole chipped trees and branches
 Message: Wood chips made from whole chipped trees and branches, mostly pine but some other trees in there too. By-product of land clearing work, chip is clean but unsorted, produced from 10 inch chipper. Basically unlimited supply. Price is negotiable as it delivery. Unsure of what exact price should be at this early stage, please call to discuss. Located about 10km East of the Bombay hills.
 Attachment: [Download Attachment](#)
 Price(\$): \$20/cubic metre or \$100/Tonne plus GST and deliver

Pricing Option: Willing to negotiate
 Additional Details: Free Shipping Buyer Pickup Cash Only
 Date Created: 5/15/2009 6:00:04 PM

Contact Information
 Name: Glenn Mackenzie
 Email: glennmackenzie@adra.co.nz

Product Review
 No average for the specified item
 No reviews for the specified item
[Post Review](#)

[Return to the previous page](#) [Return to user's home page](#)

Page Options:
[Print this page](#)
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[Email this page](#)
[Make an Inquiry](#)

Figure 3: “Example of a new Listing”.

APPLICATION OF BORACOL 200RH (FRAMESAVER) TO CONTROL DECAY ON PRE-DECAYED MODEL FRAME UNITS

Mick Hedley, Dave Page, Jackie van der Waals

Small, simulated wall units have been used to test the durability of treated and untreated radiata pine (*Pinus radiata*) framing at Scion since 2001. Most trials have been established to determine the effectiveness of commercial formulations in preventing decay in framing subjected to intermittent wetting. Results of these tests have been used to develop suitable preservative formulations and retentions for Hazard Class H1.2 for inclusion in NZS 3640:2003, the New Zealand standard for chemical preservation for round and sawn timber.

A trial was established to determine the effectiveness of Boracol 200RH, marketed as FrameSaver by Osmose New Zealand. It is a boron/glycol formulation intended for remedial *in-situ* applications. To simulate typical house remediation situations the product was applied to untreated framing which had already developed significant decay.

Frame units were constructed from untreated 90 x 45 mm planer-gauged, kiln-dried, untreated radiata pine. These units consisted of 500 mm studs, top and bottom plates and a central dwang. The units were pre-wetted to approximately 40% moisture content. They were inoculated with two decay fungi *Coniophora puteana* and *Oligoporus placenta*, the latter being a brown rot fungus often isolated from decaying radiata pine framing in New Zealand. Each frame was inoculated at four locations: interface of dwang and studs, interface of bottom plate and studs.

Black polythene was attached to the back face to retain moisture. Wet fibreglass insulation was then packed in the wall cavity before a fibre-cement sheet was attached to the front face with building paper underneath to simulate monolithic cladding construction. Frames were stored in a controlled environment room, maintained at a temperature of 25 °C and 95% relative humidity, and periodically wetted using a hose. Six units were exposed to decay for 7 weeks, 5 units exposed for 10 weeks and 5 units exposed as untreated controls.

After this time, units to be treated were stripped, cleaned and superficially dried. Units exposed for 10 weeks were more severely decayed than those exposed for 7 weeks and some decay mycelium remained on the surface of the former even after cleaning. FrameSaver was then applied by brush to all surfaces of these units. Units which had been exposed for 7 weeks received a single coat at an application rate of 8.9 kg/m³ (determined by weighing the unit). Units exposed for 10 weeks received two coats of Framesaver at a total application rate of 15.3 kg/m³.

After the Framesaver application, units were re-inoculated with fresh feeder strips of the decay fungi, the cleaned polythene backing replaced and clean wet fibre glass batts placed in the wall cavity. New building paper and the original fibre cement sheet were placed on the front face and the units returned to the controlled environment room. Periodic wetting of units by hose continued to maintain a high moisture content and to simulate severe rain leak events.



Figure 1: Frame unit with inoculation strips attached left and right on dwangs and bottom plates, before enclosure with building paper and fibre-cement cover.

Table 1: Average decay ratings (Index of Condition) at each assessment.

Untreated Controls					
Weeks	0	26	52	78	104
Decay	10	4.5	4.1	1.9	0

Exposed to decay for 7 weeks before treatment ¹										
Weeks*	0	26	52	78	104	130	157	177	210	239
Decay	7.6	7.9	7.2	7.4	7.7	7.2	7.5	7.1	7.1	6.9

Exposed to decay for 10 weeks before treatment ²											
Weeks*	0	16	42	68	94	120	146	174	203	226	255
Decay	7.5	6.7	7.1	6.4	6.3	6.5	6.4	6.2	6.4	6.4	6.0

¹ Exposed to decay for 7 weeks before treatment followed by one coat of Framesaver (application rate of 8.9 kg/m³).

² Exposed to decay for 10 weeks before treatment followed by two coats of Framesaver (total application rate of 15.3 kg/m³).

*FrameSaver applied week 0.

Table 2: Retention of borate preservative in various framing components under different treatment scenarios (% borate acid equivalent, BAE) at trial termination.

Treatment	Analysis Zone	Framing Component				
		Bottom Plate	Dwang	Left Stud	Right Stud	Top Plate
1 ¹	Cross-section	0.17	0.37	0.39	0.34	0.25
1 ¹	Core	0.07	0.30	0.32	0.32	0.11
2 ²	Cross-section	0.66	0.37	0.64	0.36	0.55
2 ²	Core	0.59	0.35	0.46	0.26	0.19

¹ Exposed to decay for 7 weeks before treatment followed by one coat of Framesaver (application rate of 8.9 kg/m³). Initial cross-section retention of preservative = 0.45% BAE m/m

² Exposed to decay for 10 weeks before treatment followed by two coats of Framesaver (total application rate of 15.3 kg/m³). Initial cross-section retention of preservative = 0.76% BAE m/m

This trial simulates a worse case leaky-house repair scenario where building repairs have been unsuccessful and the wood remains exposed to a warm and wet environment containing active decay fungi.

Units were assessed non-destructively at periodic intervals up to 255 weeks to determine any further development of the initial decay.

Decay ratings at each assessment are shown in Table 1. The average decay rating is recorded for all of the 5 components in a set of units, where 10 represents no decay, 7 moderate decay, 4 severe decay and 0 failure through decay, with intermediate ratings between these points.

The results show that during the exposure period after FrameSaver application there was very little progression of decay in units on which FrameSaver

was applied. Untreated units had all failed at 104 weeks exposure. Clearly, since assessments were non-destructive, the decay rating can only apply to exterior appearance plus any decay detected by probing the wood surface. Most decay was associated with areas immediately below the points of inoculation. These areas are where decay would have been concentrated during the pre-decay phase. The decay rating reflects these localised pockets of decay, rather than a total surface decay rating. In other words, the detected pockets of decay have not extended/deepened following FrameSaver application.

At 239 weeks exposure (7 weeks pre-decay period) and 255 weeks exposure (10 week pre-decay period) one unit of each was disassembled and samples taken from each component for preservative analysis. The results are shown in Table 2.

The concentration of borates needed to inhibit brown rot fungi is in the order of 0.15-0.25% boric acid equivalent. It can be seen in Table 2 that core retentions indicate that, in most components, the inhibitory concentration of borates against brown rot fungi is above this range. This indicates that the preservative diffused into the wood in sufficient amounts to inhibit or even kill any residual decay fungi from the original infection. This would explain why pockets of decay initiated in units before they were treated had not extended during the remainder of the trial.

The conclusion drawn is that application of Frame-Saver to partially decayed model framing units arrested further development of decay even though exposure conditions were ideal for fungal growth. Preservative analysis showed that boron penetrated into the core of most components in a sufficient amount to control decay.

The two photographs below illustrate the extent of borate impregnation. Two samples were assessed from each component. All components tested positive for boron through the whole of the cross section.

Unit A had been exposed to decay for 10 weeks prior to preservative application (Figure 1). There is significant brown rot decay visible in the bottom plate and dwang plus small patches on one corner of the right stud and the top plate. This decay had been present when the units were treated.

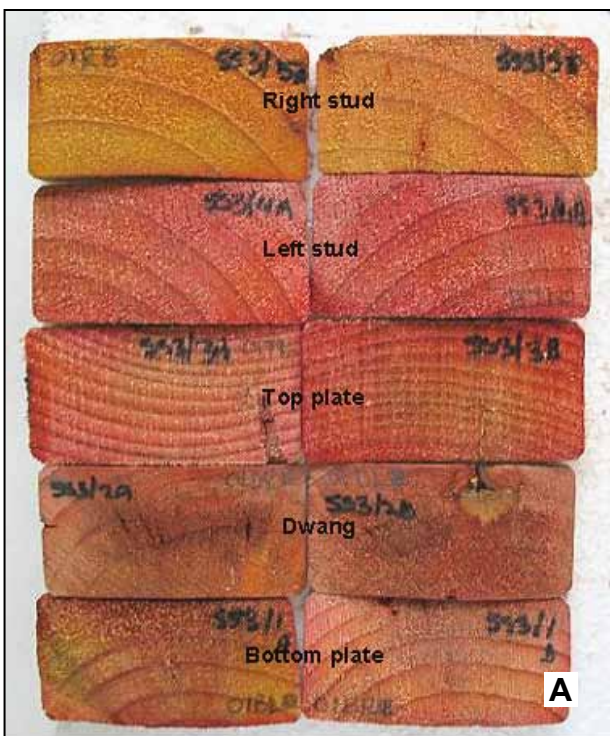


Figure 1: Cross sectional tumeric reagent tests for boron in components from a wall unit after 236 weeks exposure after 2 applications of FrameSaver.

Unit B had been exposed to decay for 7 weeks prior to preservative treatment (Figure 2).

In unit B there is significant brown rot decay visible in the centre of the dwang section on the right and a smaller pocket in the top corner of the dwang section on the left. This decay had been present when the units were treated.

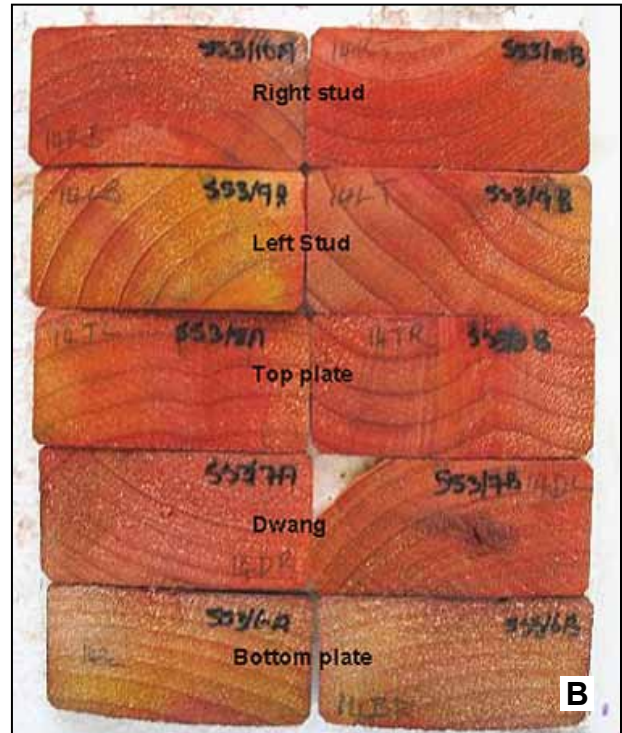


Figure 2: Cross sectional tumeric reagent tests for boron in components from a wall unit after 236 weeks exposure after 1 application of FrameSaver.

CHITOSAN FOR WOOD PROTECTION; ADVANCES IN IMAGING CHITOSAN IN WOOD CELLS

Adya Singh, Tripti Singh, Kourosb Nasheri and Catherine Rickard

Articles published previously in the Scion Wood Processing Newsletter (Nos. 38, 39 and 42) on the biactives area of Scion's work discussed results of preliminary studies. These results suggest that, if the process is optimised, chitosan treatment can potentially be employed as an effective environmentally compatible wood protection system.

Since the antifungal activity of chitosan is correlated with its concentration, formulation and loading in wood, it is important to understand the distribution of impregnated chitosan within wood tissues. In this article we describe a novel technique we developed for micro-imaging chitosan within chitosan-treated wood. This technique provided evidence that chitosan impregnated the lumens of wood tissues and indicated that it may also infiltrate into cell walls, which may enhance chitosan retention within wood tissues.

The microscopy method developed is simple, rapid and effective in readily locating chitosan within wood elements. The microscopy work was undertaken on radiata pine wood that had been impregnated with chitosan. Chitosan formulations and processes used have been substantially improved since the initial trials (process confidential), yielding greater loading of chitosan and a more uniform impregnation, judging by microscopic analysis.

The distribution of chitosan within wood tissues was assessed by imaging methods involving combined light (LM) and scanning electron (SEM) microscopic examination of sections obtained from impregnated wood blocks. The impregnated blocks were harder than unimpregnated control blocks and sectioning with a microtome resulted in damage to wood tissues. Sectioning by hand using single edge razor blades

minimized cell distortions. Combined LM and SEM involved the following preparation. All sections examined were cut transversely, i.e. perpendicular to the wood grain.

The sections examined with LM were initially unstained. The contrast differentiation between impregnated chitosan and wood cell walls was sufficient to locate the cells containing chitosan.

The sections were then examined with LM after staining with a blue dye (aqueous toluidine blue). This stains the cell wall but not the chitosan. The staining enabled assessment of whether chitosan had penetrated cell walls, in addition to filling cell lumens.

The sections were also examined with a high resolution SEM after appropriate sample preparation. This involved soaking with aqueous osmium tetroxide, rinsing in water, air drying and finally coating with chromium in a vacuum coater. The SEM used two modes, the secondary electron imaging mode (SEI), which is the usual operational mode, and backscattered imaging (BEI), examining the images in the same areas of the impregnated wood tissues.

The advances achieved in the micro-imaging technique for visualising chitosan through developing new sample preparation techniques and combining LM with SEM yielded valuable information enhancing our understanding of the distribution of impregnated chitosan in radiata wood tissues. Visibly, the chitosan impregnated wood (Figure 1) appeared yellowish (compare with the unimpregnated control wood Figure 2). Collectively, the micrographs illustrated in Figures 3-6 provide evidence that chitosan was present in cell lumens (cell wall lined empty spaces)



Figure 1: Chitosan impregnated radiata pine wood.



Figure 2: Non-impregnated (control) radiata pine wood.

and had also impregnated cell walls. It was possible to detect the presence of chitosan in cell lumens in the light micrographs taken from unstained sections, as the deep orange coloured chitosan was distinguishable from the light orange coloured cell walls (Figure 3, arrows).

The staining of sections with toluidine blue, a stain widely used to contrast lignified plant tissues, greatly enhanced the differentiation between orangish coloured chitosan and bluish coloured cell walls, making it possible to readily examine the pattern of chitosan within wood tissues. It became apparent that chitosan had not only filled cell lumens (Figure 4, arrows) but had also impregnated cell walls (Figure 4, arrowheads), evidenced by the light orange appearance of the walls of those cells that contained chitosan also in their lumens.

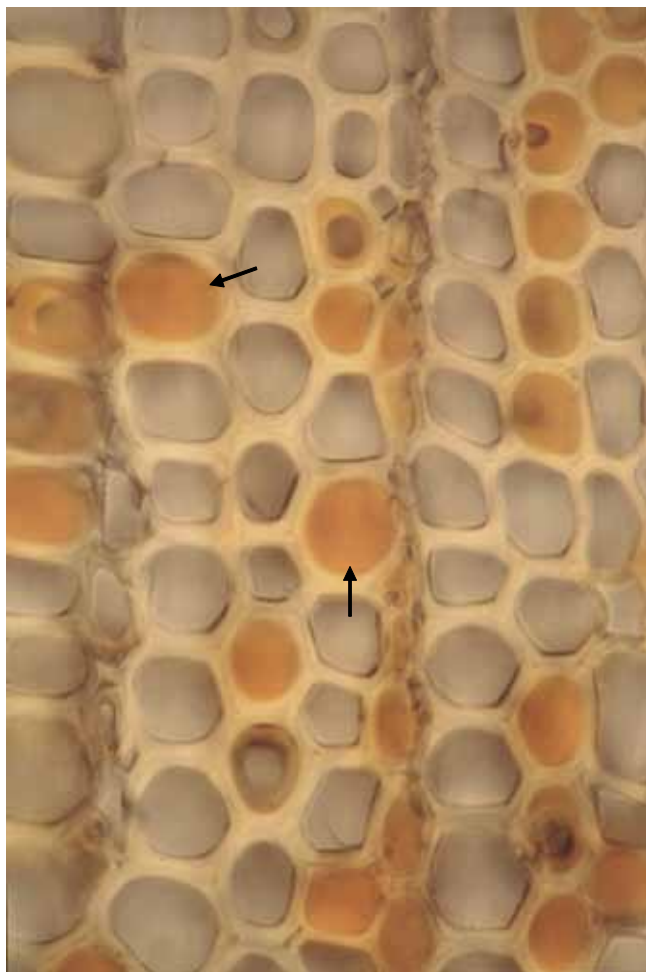


Figure 3: Light micrograph of a section that was not contrasted with a dye. Deep orange coloured chitosan (arrows) is distinguishable from the light orange coloured wood cell walls.

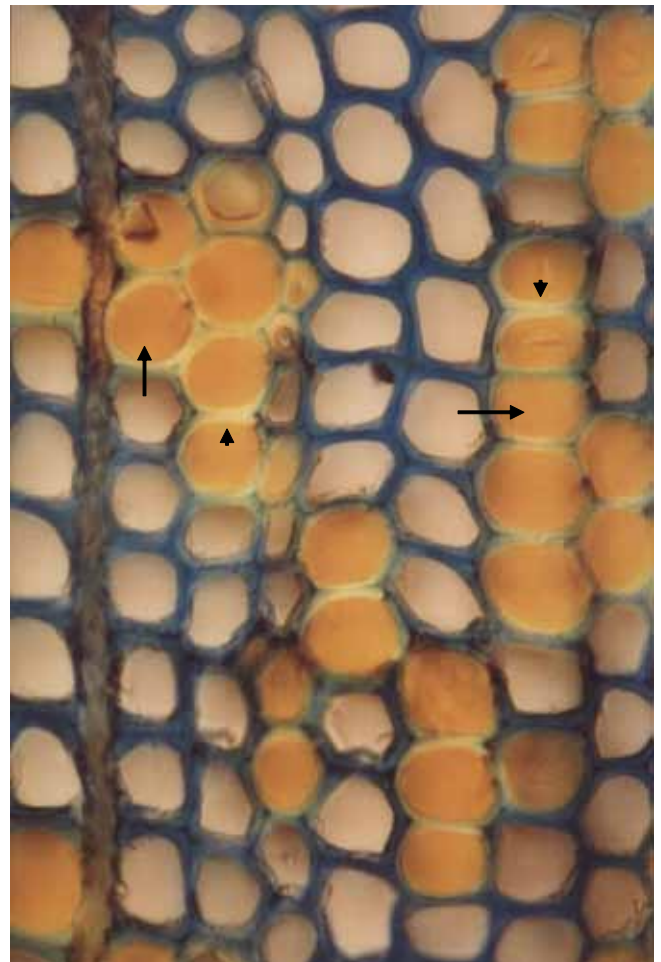


Figure 4: Light micrograph of a section that was contrasted with the dye toluidine blue, shows excellent colour differentiation between chitosan (orange colour) and wood cell walls (blue colour). Chitosan has filled cell lumens (arrows) and also impregnated cell walls (arrowheads).

The scanning electron micrographs in Figures 5 and 6 were taken, from the same area of a section, in the secondary electron (SEI) and backscattered electron (BEI) imaging modes respectively. A comparison of Figures 5 and 6 illustrates the usefulness of the technique developed in relation to backscattered electron imaging for enhancing visualisation of chitosan, and thereby more accurately assessing the pattern of chitosan distribution within the impregnated wood tissues. In the images obtained using the SEI mode, chitosan was poorly differentiated from cell walls as they had a similar contrast (Figure 5). In the images produced in the BEI mode, chitosan was

readily detected as it appeared very bright compared to the grey coloured cell walls (Figure 6). Thus, in the BEI image shown in Figure 6 the presence of chitosan is readily detectable in the spaces within tissues

(arrows), including the very small size cavities as intercellular spaces and in the tip regions of tracheids (arrowheads).

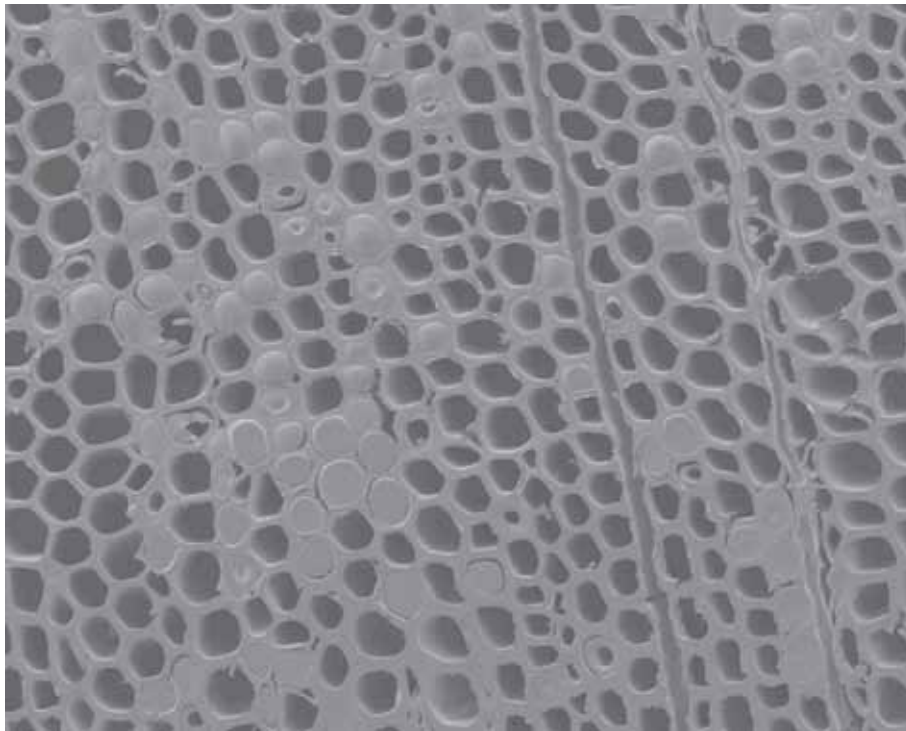


Figure 5: Scanning electron micrograph of a section taken in the secondary electron imaging mode. Chitosan is poorly differentiated from wood cell walls.

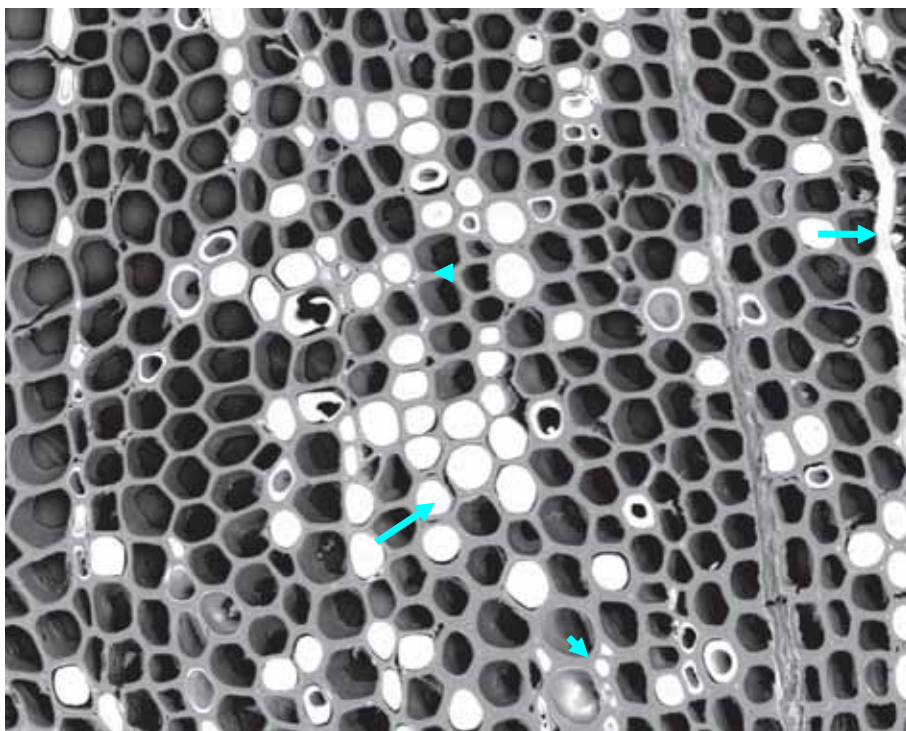


Figure 6: Scanning electron micrograph of the same section that appears in Figure 5 was taken in the backscattered electron imaging mode. Chitosan (bright material), which is readily detectable, has filled spaces of all sizes present within wood tissues (arrows and arrowheads).

In conclusion, the novel sample preparation techniques developed and the combined use of light and scanning electron microscopy to examine chitosan impregnated radiata pine wood enabled us to acquire images that suggest that the refinements made in chitosan formulations and impregnation technology achieved excellent chitosan uptake and impregnation of wood tissues. For optimal protection of wood, it is important that bioactive agents in use not only fill cell lumens and cavities but also impregnate

cell walls. Impregnated cell walls can enhance the adhesion of the chitosan present in the cell lumen with establishing a tight seal against the invading microorganisms. The images illustrated suggest that important advances have been made in achieving this objective through developing process refinements. Currently, leachability and durability tests are underway to determine the extent of chitosan retention within the impregnated wood and the effectiveness of the chitosan present in controlling wood decay.