Improved Methods for Achieving Traceability of Tree and Log Identities in Timber Processing Studies

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Abstract

We successfully tracked the identities of more than 550 selected 13-year-old trees from a *Eucalyptus nitens* (Deane & Maiden) progeny trial through tree felling, harvesting of butt logs, and sawmill processing to finished sawn boards using a two-stage approach. To track log identity from the standing tree to the log yard, we used a numbered under-bark wooden identification plug, glued into a hole drilled in the trunk prior to harvesting. To track tree identity for individual sawn boards, log-end templates with corresponding tree identification numbers were glued to the log ends before milling. Materials and methods used withstood harvesting and debarking, log transportation, milling, air and kiln drying, steam reconditioning, and final machining. A second study confirmed the success of the under-bark plug method to successfully track 548 selected standing trees through harvesting and transportation to the mill.

The ability to maintain unique tree identification of standing trees through the stages of log harvesting, transport, and timber processing is essential in research trials that compare silvicultural treatments or investigate genetic variation in wood product characteristics.

To maintain identities of selected standing trees through harvesting and transportation of logs to the sawmill, identity codes can be painted on the tree or log bark prior to harvesting, but in many types of modern mechanized harvesting operations, in-field debarking results in the loss of identity codes, and relabeling in the field during debarking operations is neither practical nor safe.

Certain types of log processing studies require individual log identities to be tracked through sawmilling systems to examine the effect of log traits on product recovery. For example, Ivkovic et al. (2006a, 2006b) investigated the effects of log diameter, stiffness, stem straightness, and knot size on sawn-board recovery and value in order to determine economic weights for these traits in genetic improvement programs of *Pinus radiata*. Washusen et al. (2009) compared the impacts of silvicultural regimes on sawn-board quality and recovery in *Eucalyptus nitens* (Deane & Maiden), and Blackburn et al. (2010) investigated genetic variation in checking traits of sawn boards of this species. Various methods have been developed to track sawn timber through production, but they are either labor-intensive, limit the number of individuals that can be tracked, or lack the high degree of fidelity required though the entire processing chain.

In earlier studies sawn boards were tracked through sawmills by numbering each board sawn from identified logs in a predetermined sequence (Park and Leman 1983). However, this method is labor-intensive and requires costly production stoppages while boards are marked with log identities.

The fingerprint traceability concept relies on the idea that every piece of wood or log can be individually identified if a sufficient number of unique features are measured accurately enough. In a veneer peeling study of Norway spruce (*Picea abies*) logs (Lemieux et al. 1997) the fingerprint method proved to have only limited value for research trial

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work because of the high levels of capital investment required and its inability to uniquely identify all logs. As a means of individually identifying all logs at sawmill before sorting, without the need for conventional marking, Chiorescu et al. (2003), developed the fingerprint method further by using data generated by two-dimensional log-scanning equipment at the log-sorting station. Log parameters and measurement accuracy lacked the precision to accomplish individual separation for more than 34 percent of logs. The fingerprint system, being free from marking and reading, is well suited to processing studies in high-speed sawmills (Chiorescu and Grönlund 2004). When logs of Scots pine (*Pinus sylvestris*) were batched according to different sorting criteria, the batch identity of individual logs was commonly lost between the sawmill log-sorting station and the saw intake. Chiorescu and Grönlund (2004) experimented with data from three-dimensional (3D) log scanning to generate a radio-frequency identification for the unique features of each individual log, but they found that only 57 percent of logs could be individually identified at the saw intake. Flodin et al. (2007) used X-ray log scanning to identify knot positions and size in 140 Scots pine logs that were sawn into boards in two cutting patterns. Data from the X-ray log scanner at the log-sorting station were combined with information from a 3D optical log scanner. A radio-frequency identification was then assigned to each log according to its unique features. Scanning system data from sawn-board yield at the green sorting station were compared with the log data, and results showed that over 90 percent of boards produced could be matched to the corresponding log. This approach of combining X-ray and 3D log-scanner fingerprint shows great potential for future development as a tool for use in process control, and it could be used for traceability in research trials if desired board information were captured at the green scanning stage before kiln drying. However, high capital costs would restrict research to sawmills that already have such equipment.

In many sawmilling studies that evaluate processing performance of individual trees and logs, individual logs are color coded, with color combinations painted onto the large and small ends of each log, which are then assigned a sequence number so boards can be traced to the log of origin (Washusen et al. 2009). While this has proved successful, it is time-consuming and labor-intensive, and the number of logs assessed is limited to the range of color combinations that can be distinguished. The method can also result in incorrect identification through errors in painting or color selection. Furthermore, errors in log and board numbering and hence allocation of sawn boards to the wrong log may occur when many people are involved at different sawmill work locations. Smith et al. (2003) therefore developed a tracking method that would enable the reconstruction of logs from data obtained from the sawn timber. Identity templates were glued to the log ends so that a portion of the template remained on each board, thereby maintaining log identity for all sawn boards. A pattern of lines on the template referencing the log cross-sectional area enabled the position of each individual board within the log to be determined, facilitating studies of radial and circumferential variation in sawn-board properties.

Microdot technology uses small tags (dots) less than 1 mm in diameter etched with a unique identification number, which are suspended in an adhesive medium for spray or paint on attachment to the objects to be identified (Wright et al. 2005). The technology has been used successfully by law enforcement agencies to trace vehicles after theft or hijacking and could potentially provide traceability in log processing trials. Marketed in Australia as DataDotDNA (Club-Marine 2009), it is only available in large batch volumes of many thousands per individual number and requires national database registration. The current (2010) price is approximately AU$350 per registered number, presently making it too expensive for tracking large numbers of trees.

We developed the methods described here to track log identity from 560 standing trees in a progeny trial of *E. nitens* through the stages of harvesting, debarking, log transport, and processing in a high-speed linear sawmill (R200 HewSaw) to final machined board products. We used under-bark identification tags and purpose-designed log-end templates to track identities so that the individual tree origins of all sawn, dried, and dressed boards could be maintained. The analysis of wood properties of sawn-board traits and their relationships to standing-tree traits in this study, based on the retained genetic identities of the individual trees, is reported by Blackburn et al. (2010). A subsequent rotary peeled-veneer trial, testing a similar number of trees from the same progeny trial, provided an independent test of the tree identity tracking procedures.

Methods

Maintaining tree identity of harvested logs

Tree selections for a sawing study were made by assessing a large progeny trial of *E. nitens* managed by Forestry Tasmania, where more than 6,000 trees of 415 individual families were to be harvested at age 14 years. All trees were assessed for diameter at breast height and stem straightness, and 560 trees from 129 families that met sawmill size and stem straightness requirements were selected for sawing (Blackburn et al. 2010). Unique three-digit codes numbered 001 to 560 were cross-referenced to the preexisting tree identification system used in the progeny trial and used to maintain traceability throughout the study by being clearly identified on the standing trees, log identification markers, and log-end templates.

Selected trees were first marked with a fluorescent pink spray paint (Dy-Mark) patch, and the identification number was marked therein using a large nib permanent black ink marker. The patch was large enough to clearly identify neighboring selections from any single selection in the trial (Fig. 1), which assisted the harvester operator to choose and fell trial selections prior to the main harvest.

The same numbering system was used in a follow-up study to identify the trees selected for a rotary peeled-veneer trial, where 548 trees were selected from adjacent replicates in the same progeny trial.

While selected trees were being processed into sawn boards, it was a sawmill requirement that, should an identification plug not be removed prior to sawing, the plug material should be capable of being sawn or wood chipped for pulpwood, without damaging saws or chippers or leading to rejection of wood chips. This ruled out the use of plastic, metal tags, or recently available micro radio-frequency devices, which would introduce a risk of contaminating processed wood chips, a by-product of any sawn timber process. If a small residue of undesirable material is found, the whole wood-chip batch is rejected; therefore, a 35-mm-diameter dowel of commonly available

Figure 1.—The standing-tree identification method with a white band indicating identification-plug position.

hardwood (*Eucalyptus obliqua*) was cross-cut sawn to produce identification plugs 8 mm in thickness.

To facilitate drilling holes that could accommodate the plugs, a 50-mm wood chisel was used to open a bark window to expose the cambium, which made speed-bore drilling into the wood much easier. A motorized gas drill (Tanaka Pro Force, TEO262R) with a 38-mm speed-bore drill bit (Irwin Speedbor, 98838) was used to drill a flat-bottomed hole with a central indent. The indent improved glue bonding, and the hole size gave sufficient clearance for installing the plug. A drill depth of approximately 40 mm enabled location of the wooden identity plug at a depth well below the cambium surface, where it would not be in contact with debarking machinery. The drill was readily transportable and had adequate torque for this size of hole, without the need to drill a pilot hole. To enable alignment of sawn-board positions with standing-tree orientation, holes were drilled on the south side of trees, and the hole position was later used to visually align the log-end template.

Before drilling, discussions with harvesting contractors and plantation owners ensured holes were positioned at a height that would be above the harvesting head saw path, yet close enough to the ground to minimize the amount of stump left for postharvest ground preparation. The requirement that the plug hole did not reduce the later recovery of sawn boards meant that locating the hole farther up the stem, for example at breast height, was not an option. To help the harvester operator locate the cutting head, a white band was painted around each tree's circumference approximately 25 mm below the plug hole. This enabled harvesters to minimize the length of log between the identification-plug hole and the harvest cutting height. Because the terrain was rocky and variable, the actual cut height at the trial site was approximately 25 cm. Plugs were later removed in the sawmill yard by cutting a disk 50 to 75 mm in thickness from the lower log end, which was required for wood quality assessment.

To improve the adhesive bond between the wood fiber and identification plug, holes were left to dry for approximately 2 weeks in the first study, prior to gluing the plugs in place. However, in the subsequent study, identity plugs were successfully held in the tree when glued into holes immediately after drilling, resulting in a major cost savings because an additional site visit for the gluing operation was unnecessary. Black permanent ink markers were used for plug tree number identification.

To secure identification plugs in position, Selleys Liquid Nails High Strength was found to be the most suitable adhesive we tested. There are stronger adhesives, but they require a mechanical grip while the glue sets. Liquid Nails had sufficient bond-peel strength; adhered well to dry and wet timber, as proved in both studies; had an extended tack time that facilitated handling; and did not require a mechanical force to secure while drying. These features meant individual plugs could be quickly glued in place, moving on to the next tree without the need to return. Care was taken not to apply excessive glue. We found the easiest method of installation was to apply adhesive to the plug's rear face before insertion and then bed the plug to the bottom of the hole.

After a 7-day cure period, a coat of Selleys Aquadhere, a polyvinyl-acetate (PVA) glue, was applied to seal the surface (Fig. 2) and to protect numbered faces from the weather and from forest debris that might be embedded in the hole during felling, debarking, and forwarding to the plantation landing. In the second study, plug surfaces were

Figure 2.—Identification plug installed.

not sealed in this way, and numbers on the plug still remained legible after two wet winter months. Provided trees were previously identified and easily visible, two people could drill and install about 150 plugs per day using this method.

After felling selections in the first trial, a 5.6-m butt log was extracted, debarked, and forwarded to a log landing designated for trial selections. All selections were accounted for, and only one identification plug was lost due to harvester operator error. This loss was noticed by the operator, who stamped the tree number into the log-end surface before debarking. No harvested logs were misplaced, but three selections with plugs were missed by the harvest operator.

To reduce incidence of log-end splitting, log ends were coated in Dussek-Campbell–Technimul log grease and gang nailed at the harvest landing. On larger diameter logs, two gang nails were used.

Log identification at the sawmill

At the sawmill, to facilitate log handling and location of identification plugs, logs were laid on ground bearers. Many identification-plug holes were found to be blocked with dirt, and all plug faces were soiled and difficult to read. A hand-pumped water pressure sprayer and brush removed excess dirt and cleaned plug faces so numbers were clearly visible. After disk removal from log ends, the plug-identification number was transferred to the log with a black permanent marker. Both disks and logs were then marked with an L to indicate the lower log end and U to indicate the upper log end.

For the sawmill study it was necessary to maintain tree identity, identify upper and lower sawn-board ends, and determine the diametric position of the outer boards in the log. A template meeting these requirements is show in Figure 3. The tricolor design and consistent positioning of the template in relationship to the identification plug meant, if required, a sawn board's azimuth position in the log could be determined. Character spacing and bold type (Arial 16 point) were selected for number definition and readability. Having proved successful in previous studies by Smith et al. (2003), laser printer paper of 80 g/m was chosen for the template print medium, and Bondall Bondcrete, a high-quality PVA bonding and sealing agent, was used to fix templates to log ends.

After disk removal, log-end surfaces were exposed to the weather. To help reduce any further log-end splitting, templates were glued to log ends within 2 days. A generous coating of Bondcrete adhesive was first applied to the log and the template's back surface, and care was taken to position the template central to the log end. Once wet with adhesive, the paper was flexible enough to cover any surface irregularities without tearing. To prevent ripping and tearing away from the log end, template papers overhanging log ends were firmly stuck down to the outer longitudinal log surface (Fig. 3). For weather protection, another coat of Bondcrete was applied to the template's front face.

A pilot study was undertaken to test the chosen materials with a worst-case scenario involving roughly sawn log ends, steam reconditioning of sawn boards (saturated steam at 98°C), and elevated (66°C) dry-bulb drying kiln temperatures. After gluing templates to a number of test logs, an additional coat of Bondcrete was applied to the template's outer surface. These logs were subsequently sawn by standard mill processing operations. The test proved successful; all templates remained in place and were legible after kiln drying with no bleeding of printed characters. The same materials and methods were therefore used in the main study. For this trial A4 size (210 by 297 mm) laser copier paper was an adequate size for logs, which had small-end diameters of at least 150 mm and large-end diameters up to a maximum of 340 mm.

The trial logs were batched into five different cutting patterns depending on log small-end diameter. Board numbers per log and board dimensions varied according to the pattern. The R200 HewSaw used to mill the logs is a single-pass linear flow multisaw and chipper system that produces a single cant of boards (Washusen and Innes 2008). After kiln drying, outer boards nearest the cambium were planed to a final dimension of 90 by 35 mm and selected for further studies. For boards of these dimensions, part of the template identification would remain on all trial study boards, and therefore tree identification would be maintained from the field trial to the final sawn-board product (Fig. 4).

Figure 3.—Attached log-end templates.

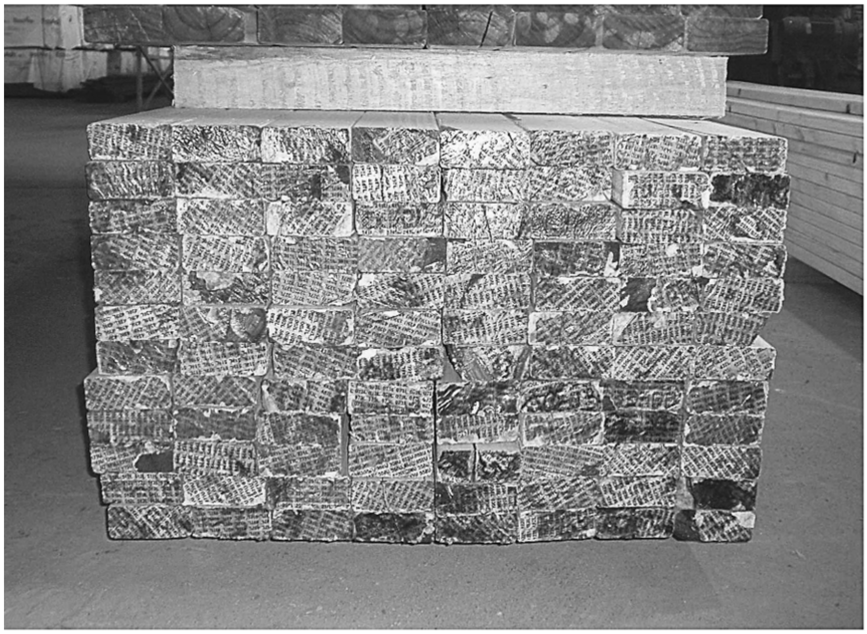

Figure 4.—Template sections remaining on boards after final machining.

Sawn-board identification

Logs were processed through standard mill operations, with no special or additional production operations or mill stoppages required for the trial. All outer boards, identified through their green-sawn dimensions of 106 by 45 mm, were separated from the remainder and stacked in the sawmill yard for air drying, which took over 6 months. Halfway through the air-drying period, a second coat of Bondcrete was applied to board ends to provide some additional weather protection to the templates. Most boards retained the full board portion of template. A few templates had been subject to minor tearing in sawing, and approximately 3 percent of boards had no template remaining on one end. In these cases, the board's other end was used to identify missing templates, enabling all boards to be matched to original tree identities. During air drying there was no visible degradation of the templates except for some minor discoloration, which did not affect readability.

To further assess the robustness of materials chosen, a number of surplus trial boards were tested through the remaining production processes of steam reconditioning, kiln drying, and final machining. Templates remained intact, and while there was some further discoloration of templates in kiln drying, the heavy density of print characters meant all numbers could be clearly identified and additional marking was unnecessary.

Before final processing and machining, photographs were taken of the individual air-dried stacks using a digital camera with 8-megapixel image quality. Photographs had adequate resolution to determine and record a board's identity and stack position, which could, if required, be used later to spatially analyze the effect of a board's stack position on final product characteristics. Air-dried boards were then steam reconditioned, kiln dried, and planed to the final merchantable product: 90 by 35-mm framing stud, used extensively in the construction industry. No further loss of identity template or discoloration occurred. For added security of identification, the board's log-end template identity numbers were written onto the board face using black permanent ink marker pens.

Discussion

The method described enabled individual tree selections in a field trial to be tracked through harvesting, transportation to sawmill, and manufacturing of final sawn products. This study was made on harvested butt logs and boards that were processed through HewSaw machinery with a multi-blade saw-head and cant chipper. If multiple logs from the same tree are to be studied, this would require additional holes drilled and securing identification plugs on the felled stem before or after bucking to the required log length. This would require access to felled logs, which would not be practical in large-scale studies for operational and safety reasons. The identification template sections on board ends remained intact through processing, and therefore the method is considered robust. These end-template methods can only be applied to sawn-board studies provided the common mill procedure of board end docking is omitted or postponed until identity is transferred from the end template to the board face.

Although in this study only one wooden plug was damaged by the harvester operator, lack of care when locating the felling head could have resulted in more being lost. Discussion with the harvesting contractors ensured that they appreciated the significance of the identification plug and had an understanding of the study objectives. Three selections were missed by the harvester operator. This could have been avoided if the tree identification patch area was large enough to span the tree's circumference, so the operator could clearly identify all selections from all angles when working through the trial. If time permits, an inspection of the trial area and/or audit of harvested selections to account for all identified trees is recommended.

In the second processing study on trees from the same trial, the plug-identity method again proved successful, tracking 548 trees through harvesting and debarking to billeting of harvested logs for rotary veneer peeling, with no loss of identity in any of the selected trees.

In the log yard, forest debris and dirt had accumulated in the identification-plug hole, and it was difficult to identify black ink marked wooden plugs without time-consuming water spraying and scrubbing. If electric power and water are available, a hand-held power water blaster could be used to assist cleaning and improve number identification. In the rotary peeled-veneer trial, workers attempted to engrave tree identifications in the wooden plug with a hand-held rotary engraver, which did not impart a sufficient level of definition to the numerals. An alternative would be to rout identification numbers in wooden plugs, which would improve readability of the plug after harvesting and transportation.

To locate plug holes in the log yard, remove wood sample disks by chainsaw, and complete log-end preparation with correct template orientation, it was necessary to lay logs on ground bearers. This necessitated a large layout area in the log yard to accommodate log rolling. Discussion and agreement on the area and number of ground bearers required should be made with sawmill staff prior to log transportation to the mill in this type of study. In the rotary peeled-veneer study, log-end discs were removed in the field between log debarking and forwarding operations, which provided the room to roll the logs as needed without using valuable log-yard space. After disk removal, the tree identification number was spray painted on both ends and the side of the log to aid segregation at the log landing.

The extent of detail on a log-end template depends on the study being undertaken. Smith et al. (2003) found template marking density must be sufficient to allow for board identification after sawing. Although the gluing system and print material recommended by these authors proved successful, they encountered difficulties with too much fine detail and insufficient density of markings, resulting in difficultly reading template details, particularly after kiln drying. Running a test batch of logs through all relevant mill processes is highly recommended, particularly before sawing and machining of the main study material.

If end disks are removed for further studies, logs can sit idle while other logs are being prepared, which can exacerbate log-end splitting, particularly in warm dry weather. Ideally, applying a coat of Bondcrete to log ends as soon as the protective log-grease coating has been removed at disk sawing would reduce the loss of log moisture. In the machining of trial logs a number of board template edges were torn and ragged, or a percentage of the template was missing. Investigation showed this occurred when saw blades became blunt. This happens more frequently in warmer times of the year when wood fiber is drier. To reduce this effect and the loss of log moisture content, nighttime water sprinklers could be installed.

The methods reported here require no costly mill stoppages, cost relatively little, require no unique equipment or specialized knowledge, and can be used by personnel with a minimum of training. These methods have proved robust and reliable enough to maintain tree identification from a standing-tree progeny trial, through harvesting, debarking, and normal sawmill operations, to final sawn-board product.

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