Selecting hybrid pine clone/s for deployment – the pointy end of breeding for wood quality.

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ABSTRACT

A clonal forestry research program on slash × Caribbean pine hybrids commenced in Queensland in 1986. Each cycle of clonal tests covers about five calendar years from field planting and studies of wood quality variation have so far been used in selecting superior clones from the first three series of tests for commercial plantation deployment. Experience from the series III clonal selection round is used to highlight the difficulties of ranking elite clones given a large number of growth, form and wood property traits. Ranking and performance of clones for productivity, relative to the other clones in the tests, can change significantly between early age assessments (e.g. annually at 3, 4 and 5 years). Additionally, the weights applied to various wood properties to influence structural sawn wood recovery are not well understood.

Three to six ramets were felled from 32 clones at age 6.8 years and a three metre butt log was sawn into 70×35mm structural boards. The clones sawn were ranked as the best 12 in the Series III trials for deployment using available growth, form and wood trait assessments and then 20 of the next best available were also studied. All recovered boards were assessed for distortion and tested for MoE and MoR. A range of non-destructive wood evaluation methods were used to estimate wood stiffness in these trees. Standing tree acoustic velocity assessed with an ST300 tool was slightly less strongly correlated with the average MoE of the recovered scantling boards (r=0.88) than with predictions of MoE from resonance vibration test samples and SilviScan estimates (both r= 0.89). Moderate relationships were found between average twist of the sawn boards and the average spiral grain angle of growth rings 2, 3 and 4 (r= 0.70) assessed in a breast height 12mm increment core, and between average bow in the

boards and average microfibril angle (r= 0.64) from SilviScan assessments of core samples.

Key Words

Pine hybrids, clones, selection, stiffness, wood quality, non-destructive sampling

INTRODUCTION

Wood quality assessments are an essential part of genotype selection for the Queensland southern pine breeding, and clonal selection and deployment programs. Actual testing is expensive and time prohibitive for the large number of samples required, so cost-effective predictive methods are needed. It is important that assessment methods are accurate, economical, reliable and easily used on a large number of samples.

Recent technological advances have provided a range of non-destructive evaluation (NDE) tools and assessment methods options. These advances enable predictive wood quality assessments on standing trees but vary in sampling costs and their accuracy to rank genotypes consistently against specific product criteria. This study evaluated several standing tree predictive methods that were used to screen and select elite Series III clones and compares them with results from a sawing study of 3m butt logs of selected clones that provided sawn board assessments of modulus of elasticity (MoE) and rupture (MoR) as well as distortion.

MATERIALS and METHODS

All trees in the sawing study had previously been assessed as standing trees (ramets) as part of routine screening/selection activities when the trees were 4 and 5 years old. To establish the most cost-effective and reliable method/s for future wood quality screening and selection a range of available standing tree sampling and assessment approaches were used as indicated in Table 1.

Table 1 – Predictive wood quality assessment methods and wood traits assessed or predicted by non-destructive evaluation techniques.

Standing Tree Sampling Method[1]	Density	Spiral Grain	MfA	Acoustic Velocity	Predict MoE
12mm Cores (H&FS)	Yes	Yes			Yes (with ST 300)
Wood strip (Ensis) – "Paddlepop stick"	Yes			Yes	Yes
12mm Cores (Ensis SilviScan)	Yes		Yes		Yes
Director ST 300 (FPQ)				Yes	Yes (with density from 12mm core)

[1] H & FS = Horticulture and Forestry Science, Queensland Department of Primary Industries and Fisheries; FPQ = Forestry Plantations Queensland.

The 'Paddlepop stick' sampling and resonance testing methodology has been described by Ilic (2001, 2003). It requires the removal of a short block of wood from the outer wood of a standing tree and processing this to produce a small wood beam for testing that is approximately 5mm tangentially x 20mm radially x 120mm longitudinally. The use of SilviScan measurements of density and microfibril angle (MfA) to predict MoE has been described by Evans and Ilic (2001). The Director ST300 is described on the FibreGen web-site[1].

Increment cores removed for SilviScan analysis were sampled from the shortest diameter, perpendicular to any sweep or lean to avoid inclusion of compression wood. The Paddlepop samples were then removed closely adjacent to the point of increment core extraction.

A year after the standing tree assessments were carried out on them, the top thirty-two Series III clones were destructively sampled in two of the trial sites at Beerburrum and Maryborough. The trees were approximately 6.8 years old at the time of felling. Up to six ramets of each clone were sampled, three ramets from each of the two sites,

[1] www.fibre-gen.com (pdf format brochure available)

depending on availability. The ramets felled and sawn were the exact trees that were sampled using the NDE methods indicated in Table 1.

A three metre butt log was docked and de-branched and transported to Horticulture and Forestry Science's Salisbury experimental sawmill and research centre for processing.

SAWING METHODS

The butt logs were green sawn into a 75mm wide centre cant with recovery of 75×40mm boards where possible from log wing/s. Logs were oriented for sawing so that the centre cant orientation approximated the orientation of sample core and Paddlepop stick collection points – i.e. oriented along the same diametric plane to enable close to direct comparison between these various results. The outer boards of each centre cant were identified and the small clear samples were sawn from these boards. Log small end diameters ranged from about 100 to 180mm.

Before processing into sub-samples, all sticks were conventionally dried at 130˚C and planed to finished dry dimensions of 70×35mm. The boards were also assessed for twist, spring and bow to assess correlations with spiral grain assessments (twist) and impact of microfibril angle (spring and bow).

Small clear samples were recovered from the outer boards of each centre cant below the previous field sampling level (avoiding splitting and/or damage at this point). Engineering test samples, 1.5m long and with 70×35mm dried structural dimensions, were recovered from all boards above this field sampling point which approximated breast height (1.3 m).

The small clear-wood samples of 20mm × 20mm × 300mm were cut from as close to the bark surface as possible without including wane so that they would approximate the same wood sampled to produce the Ensis Paddlepop stick samples. These samples were tested for Modulus of Elasticity (MoE – stiffness), and Modulus of Rupture (MoR – strength) using an Amsler timber testing machine using 3-point bending.

The structural dimension boards of 1.5m × 35mm × 70mm were tested for MoE and MoR on a Shimadzu Universal testing machine using 4-point bending. The average results obtained from these samples were compared with the MoE predictions from the ST300 and the SilviScan analysis.

RESULTS and DISCUSSION

Sawing

Average MoE and MoR results for the top 12 clones compared to the other 20 superior clones studied are summarised in Table 2. The sample sizes vary from 6 to 30 sticks tested due to both the number of ramets available for sawing and tree size differences among the clones sampled. The top 12 clones were selected based on relative superiority of early age growth and form assessments (age 4 and 5 years) combined with above average wood density and low grain angle spirality.

Table 2. Average MoE and MoR of 70×35mm recovery from 32 Series III clones comparing the 'best 12' and twenty from original standing tree selections, with sample sizes indicated.

Clone Code	Average of MOE (Gpa)	Average of MOR (Mpa)	Sample size (No. of sticks)	Sample size (No. of ramets)
1	5.65	34.84	16	3
2	9.97	45.91	16	6
3	7.85	39.82	26	6
4	6.93	33.97	14	3
5	7.42	46.40	11	3
6	8.71	45.89	17	5
7	7.76	44.32	26	6
8	9.59	45.77	25	6
9	7.63	50.99	9	3
10	6.60	42.61	30	6
11	8.96	47.00	18	6
12	6.90	42.69	15	3
Mean (Top 12 clones)	**7.83**	**43.35**	**Total: 223**	**56**
13	7.23	38.30	16	3
14	5.93	38.82	19	3
15	6.69	42.05	13	3
16	7.50	39.84	12	3
17	6.52	39.58	14	3
18	7.70	43.88	27	6
19	8.14	45.81	6	3
20	8.04	49.54	8	3
21	6.83	43.64	21	6
22	7.52	46.77	11	3
23	6.88	39.45	16	6
24	6.74	41.52	12	3
25	8.83	46.95	23	6
26	5.37	40.96	11	3
27	5.16	35.47	28	6
28	6.43	44.31	24	5
29	6.91	40.93	16	3
30	6.29	44.44	17	3
31	5.97	39.99	15	3
32	5.32	35.20	26	6
Mean (Clones 13 to 32)	**6.69**	**41.37**	**Total: 335**	**80**

Some of the clones with low sample sizes were deliberately included in the study because of good wood property or form results. The performance of these clones is of interest to assist in guiding decisions on the relative emphasis to be placed on these traits for future selection.

Screening clonal tests

The initial plan was to assess one quarter of the approximately 1200 clones in the clonal test series for wood density and standing tree acoustics. However, when reviewing the early performance of all clones, only 175 clones met the superior volume, straightness and tree form criteria (low double leader and ramicorn branch incidence) making them realistic prospects for possible selection for propagation and deployment. Once the density and standing tree NDE assessments were completed, these 175 clones were culled to the best 34 based on volume superiority, stem straightness, tree form, branching, wood density and predicted wood stiffness. Core samples from these best 34 clones were then subjected to the more expensive spiral grain and SilviScan assessments.

The pleasing result in tree improvement terms is that the top 12 clones tested have averaged 17% higher average stiffness and 4.8% higher strength than the other 20 clones tested (Table 2). This confirms that the emphasis placed on wood quality in the selection process is reflected in improved quality of this initial pool of elite clones selected for propagation and deployment. At the same time it must be recognised that all current models developed by Forestry Plantations Queensland to compare the value of different genotypes still suggest that gains in stem productivity are the main driver of improved value (Dr Kerrie Catchpoole, pers. comm.). Therefore, it is important to identify highly productive parents with good wood properties if gains are to justify the expense of the clonal testing and selection program.

It is critical to future improvement to use this knowledge of parental wood quality to make strategic crosses that will increase the proportion of highly productive clones with superior wood quality for selection. This strategy is underpinned by knowledge of the inheritance patterns of these traits (Kain,2003). The results in Table 2 demonstrate that only four of the 12 top clones tested have produced average stiffness in this juvenile wood recovery exceeding 8.5 GPa, which should ensure that they would be part of a population of higher stress grade structural timber (MGP10 under the current Australian pine grading system). The goal of the breeding program is to improve the deployment population over time so that all deployed clones are of this quality as this should translate into a very significant improvement in the overall grade recovery, and therefore economic return, when sawn. Several clones, such as 18, 19, 20, 22 and 25

(Table 2) have superior wood stiffness to some of those selected in the top 12 indicating that their performance or values for other traits when initial selections for hedge production were made in 2004 (age 4 and 5 years) excluded them from the elite pool. However, in reviewing the results from this study at age 6.8 years, which was partly conducted to confirm the younger age selection rankings, some re-ranking of clones occurred. For example, clone 25 with an average stiffness of 8.83 GPa was initially excluded due to high spiral grain in growth rings 2 and 3 (-5.7˚ and -4.0˚ respectively) combined with above average incidence of ramicorn branches (29% of ramets) but in October 2006 it was included in the elite group due to its high stiffness combined with continuing well above average volume productivity. In contrast, clone 11 that had very good predicted stiffness from standing tree assessments in 2005, which was confirmed in this sawing study (mean MoE of recovered scantling = 8.96 GPa), has now been excluded from the deployment population as its volume advantage has dropped from above average at ages 3 and 4 years to below average at age 6 years. Such are the selection dilemmas associated with early age selection and balancing the emphasis placed on key traits of economic importance.

Relationships between standing tree NDE assessments

It is clear that strong linear relationships exist between ST300 velocity readings, SilviScan microfibril angle (MfA) assessments and predicted MoE and Paddlepop sample MoE predictions (Table 3). This is to be expected as these methods all rely on a fundamentally strong relationship between MfA and acoustic or stress wave velocity. Nevertheless, these results provide some confidence that all methods are assessing much the same trait/s and are of similar utility for screening.

Table 3. Correlation matrix for standing tree non-destructive evaluation traits with significance of each correlation coefficient indicated[2].

	ST300 Mean velocity	Silviscan Average MfA	Silviscan Average Predicted MOE	Spiral Grain Ring 2	Spiral Grain Ring 3	Spiral Grain Ring 4	Average Spiral Grain (Absolute values)	Paddlepop Average MoE
Silviscan Average MfA	-0.91 **	1						
Silviscan Average Predicted MoE	0.91 **	-0.92 **	1					
Spiral Grain Ring 2	0.33 NS	-0.3 NS	0.27 NS	1				
Spiral Grain Ring 3	0.40 *	-0.43 *	0.36 NS	0.85 **	1			
Spiral Grain Ring 4	0.42 *	-0.44 *	0.39 *	0.66 **	0.78 **	1		
Average Spiral Grain Absolute	-0.49 **	0.47 **	-0.41 *	-0.9 **	-0.92 **	-0.86 **	1	
Paddlepop Average MoE	0.84 **	-0.84 **	0.89 **	0.44 *	0.55 **	0.47 **	-0.56 **	1

The critical relationships are between these NDE results and the sawn board results. These are summarised in Tables 4 and 5. Some moderately strong (around r = 0.7) and significant (P=0.01) relationships between spiral grain angle (individual growth ring assessments at rings 2, 3 and 4, and the average of the absolute values of these angles) and the average twist measured in the scantling boards recovered from each ramet were found (Table 4). This provides encouragement to continue assessing this trait in screening assessments as twist can be an important source of downgrade. MfA has been associated with spring and bow but no significant correlations with spring were found in this study. Bow was moderately and significantly correlated (r = 0.64) with MfA (Table 4) but also with ST300 mean velocity (r=-0.51; Table 4), which provides a relatively inexpensive indirect method of screening for improvement in this trait given the strong correlations between ST300 velocity and MfA (r = -0.91; Table 3) and average MoE of all boards (r = 0.88; Table 4).

[2] NS = Not significant; * P = 0.05 ; ** P =0.01

Table 4. Correlation matrix for standing tree non-destructive evaluation traits versus sawn recovery averages for distortion, stiffness (MoE) and strength (MoR) with significance of each correlation coefficient indicated[3].

	ST300 Mean velocity	Silviscan Average MfA	Silviscan Average Predicted MOE	Spiral Grain Ring 2	Spiral Grain Ring 3	Spiral Grain Ring 4	Average Spiral Grain (Absolute values)	Paddlepop Average MoE
Average Twist	-0.23 NS	0.24 NS	-0.21 NS	-0.73 **	-0.68 **	-0.64 **	0.7 **	-0.23 NS
Average Spring	-0.31 NS	0.36 NS	-0.28 NS	-0.04 NS	-0.07 NS	-0.02 NS	0.08 NS	-0.29 NS
Average Bow	-0.51 **	0.64 **	-0.58 **	-0.15 NS	-0.23 NS	-0.23 NS	0.2 NS	-0.45 *
Average MoE All Boards	0.88 **	-0.81 **	0.89 **	0.26 NS	0.39 *	0.38 *	-0.42 *	0.89 **
Average MoR All Boards	0.43 *	-0.37 *	0.44 *	0.02 NS	0.14 NS	0.17 NS	-0.17 NS	0.56 **
Average MoE OUTER Boards	0.84 **	-0.75 **	0.84 **	0.18 NS	0.35 NS	0.36 NS	-0.38 *	0.86 **
Average MoR OUTER Boards	0.34 NS	-0.25 NS	0.31 NS	0.05 NS	0.17 NS	0.21 NS	-0.2 NS	0.43 *
Average MoE Small Clears	0.90 **	-0.86 **	0.89 **	0.18 NS	0.27 NS	0.24 NS	-0.33 NS	0.83 **
Average MoR Small Clears	0.50 **	-0.39 *	0.56 **	-0.21 NS	-0.05 NS	-0.04 NS	0.03 NS	0.52 **

Table 5. Correlation matrix for sawn recovery averages for bow, stiffness (MoE) and strength (MoR) and small clear sample results with significance of each correlation coefficient indicated[4].

	Average Bow	Average MoE All Boards	Average MoR All Boards	Average MoE OUTER Boards	Average MoR OUTER Boards	Average MoE Small Clears
Average MoE All Boards	-0.56 **	1				
Average MoR All Boards	-0.24 NS	0.66 **	1			
Average MoE OUTER Boards	-0.48 **	0.97 **	0.72 **	1		
Average MoR OUTER Boards	-0.21 NS	0.52 **	0.87 **	0.63 **	1	
Average MoE Small Clears	-0.48 **	0.81 **	0.47 **	0.81 **	0.4 *	1
Average MoR Small Clears	-0.27 NS	0.56 **	0.49 **	0.66 **	0.49 **	0.7 **

Overall the relationships found in Table 5 for the more focussed outer board and small clear samples do not vary markedly from those found for the average recovery of all boards. However, it should be recognised that these results will be affected by some bias due to low numbers of boards being recovered from small trees and differing sample sizes as indicated in Table 2.

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[3] NS = Not significant; * P = 0.05 ; ** P =0.01

[4] NS = Not significant; * P = 0.05 ; ** P =0.01

No results for wood density have been included in Tables 3, 4 and 5. This is because the only significant and/or strong relationships found for density were amongst the various test method results - gravimetric whole core extracted basic density, SilviScan air dry density and Paddlepop stick air dry density. This is a somewhat unusual finding for Queensland southern pine plantation material where usually some significant correlation between density and MoE and MoR would be found. However, this young (6.8-year-old) and quite fast grown material (>150mm diameter under bark at 1.3m; the largest tree was 233 mm DUB at 1.3m) with wide growth rings appears to have accentuated the impact of MfA on distortion and stiffness characteristics of the 70 x 35mm scantling recovered compared to current seed orchard stock routine plantation thinning (18-year-old) and clear fall (28- to 30-year-old) recoveries.

These findings emphasise the utility of several NDE approaches to screening genetic material for early juvenile wood properties. Given the potential productivity of some of these clones, the study has emphasised the importance of screening for wood quality to ensure that juvenile wood quality is improved in future plantings to meet our goal of significantly improving overall structural grade recovery. The future challenge is twofold: (i) to evaluate the potential to match clones to sites and also to manage stands with silviculture regimes designed to produce the optimised log size distribution sought by the processing industry and (ii) to factor in selection and monitoring of wood quality so that the trees produced are of maximum value and fit for purpose for processors.

Relative cost effectiveness of NDE methods

The question of how cost-effective and reliable the methods are for future wood quality screening of genetic stock will be the subject of more consideration and discussion than is possible in this paper. However, it is clear that the ST300 acoustic tool offers a relatively speedy and inexpensive screening technology but needs to be complemented by increment core extraction for spiral grain angle evaluation. ST300 readings, or those of similar acoustic technology systems, can be obtained quickly and relatively cheaply compared to obtaining increment cores for laboratory processing (gravimetric density) and/or SilviScan assessment (sample machining, conditioning and scanning) or 'Paddlepop' samples (slower in field, followed by lab preparation, machining and testing). Also these latter approaches require significant resources for result capture and compilation and processing compared to the standing tree acoustic technology.

Additionally, gravimetric density assessments in this study would appear to be of little value for this type and age of material and this will need to be considered for future screening activities. There is still an argument for taking increment core samples, or collecting destructive samples if the opportunity is available, to screen for spiral grain angle patterns to reduce the incidence of twist in sawn products.

CONCLUSION

Destructively sampling some of the best genotypes from two of the Series III clonal tests planted in Queensland in 1999 provided an opportunity to consider the reliability and utility of several NDE wood quality screening technologies. Although more extensive evaluation will be undertaken it seems clear from this study that the reliability of all methods is very comparable and therefore that ST300 combined with increment core sampling for spiral grain analysis provides a very cost-effective approach to clonal screening. As spiral grain analysis is significantly more expensive than collecting ST300 readings it would make sense to undertake a two stage screening based on ST300 sampling of large numbers of clones and ramets followed by a more restricted sampling for spiral grain evaluation.

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REFERENCES

Evans, R. and Ilic, J. (2001) Rapid prediction of wood stiffness from microfibril angle and density. Forest Products Journal 51(3): 53-57

Ilic, J. (2001) Paddlepop sticks – not just for licking. Paper in proceedings of 27th Forest Products Research Conference, CSIRO Forestry and Forest Products, Melbourne, Australia, Session 5, 45–46

Ilic, J. (2003) Dynamic MoE of 55 species using small wood beams. Holz als Roh- und Werkstoff 61:167-172.

Kain, D.P. (2003). Genetic parameters and improvement strategies for the *Pinus elliottii* var. *elliottii* × *Pinus caribaea* var. *hondurensis* hybrid in Queensland, Austrralia. Ph.D. thesis, Australian National University, ACT, Australia.